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# Implementing research in the practice of curriculum designers: Barriers and an example approach

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*Barriers to educational designers' engagement with research, including barriers to access, interpretation of implications, implementation, and interpretation of outcomes, can limit the translation of research into practice through educational design. Our aim in this paper is to define four challenges to implementing research through the processes and products of curriculum design and to explore theoretically-grounded principles for addressing these challenges through an example of a design tool, the Cambridge Mathematics Framework. To illustrate the principles underlying this tool, we give a brief concrete example of its use in a curriculum design implementation.*

*Keywords: Curriculum, concept mapping, design, evaluation*

## Introduction

The benefits of engaging with research in educational design have long been recognised in a range of approaches which place value on developing explicit, well-supported reasoning to inform design decisions, and on iterative refinement using data from implementation in authentic contexts (McKenney & Reeves, 2012). Lowering barriers to implementing research through educational design may allow these benefits to be realised more often and more fully. In this paper, we aim to characterise four challenges to implementing research through the processes and products of design and explore the question of how these challenges might be addressed. Using the example of a design tool, the Cambridge Mathematics Framework (CMF), we present principles and underlying theoretical influences for addressing these challenges with respect to research implementation and evaluation methods, and briefly illustrate its use in a curriculum design implementation. In the following section, we begin by describing research implementation challenges.

## Challenges to research implementation through processes and products of design

In our examination of factors which might potentially affect educational designers' ability or opportunity to implement research in design, we have identified four challenges.

*1. There are factors which limit engagement with research.* The resource-intensive nature of research implementation presents a challenge to engagement with educational research (van Schaik et al., 2018). Even in national-level curriculum design, time and resource constraints have been noted which can limit the amount and depth of engagement with research (Jameson et al., 2021). Smaller-scale design efforts may be more narrowly focused but may bring proportionally fewer resources to bear on research integration, or on evaluating the influences of research-informed features when designs are implemented.

*2. Design is an intermediary construct.* We hold that any designed resource or experience is an artifact which serves as an intermediary between the theories and intentions of the designer and those of teachers and students, because designers typically do not enter classrooms to directly implement and

explain the resources they have created. The distance in time, space and perspectives between researchers, designers, teachers and students often leads to differences between what is stated by researchers, intended by designers, enacted by teachers and experienced by students (Barab, 2014). Koichu and Pinto (2019) call implementation a “multiparty enterprise” and the CERME11 TWG23 adapted a definition of implementation to include the notion of distance between communities of resource proponents and communities of resource adapters (Artigue, 2021). With respect to curriculum design, Remillard and Heck (2014) describe this distance within their curriculum model, an update to Stein et al.’s (2007) model of curriculum phases, which the participants of TWG23 in CERME11 adapted in a model of research implementation (Aguilar et al., 2019). The new research implementation model highlights the transformations that research implications undergo as they are first used to structure objectives (intended implications), are translated into classroom experiences (enacted implications), and result finally in particular outcomes (attained implications).

*3. Research is one influence among many on outcomes.* There is a dilution of research implications which is not made explicit in the CERME11 model (Aguilar et al., 2019). Design itself (the “attributes of the innovation”) is only one of many factors which may contribute to the final impact of innovations on learning (Century & Cassata, 2016, p. 186). That is, the further down the chain from published research, the more room there is for other factors to influence what happens and the less research influences may be contributing to observed outcomes, even taking differences in intentions, background and interpretation between researchers, teachers and students out of the picture. Therefore, the enacted and attained implications may be impossible to separate from the individual instances of enactment and subsequent learning outcomes as a whole, which may take their specific forms for a variety of reasons. A third challenge, then, is one for implementation research: How can we analyse the contributions of research influences, particularly when research is being translated into practices which occur at some distance from the classroom (as with some forms of educational design practice including curriculum design)?

*4. Research implications are not always straightforward.* The final challenge we will highlight here is that research in mathematics education does not inherently add up to a coherent whole. It is a heterogeneous body of work reflecting a wide range of perspectives, assumptions, goals and practices, serving numerous wider agendas shaped by research communities rather than by the requests of teachers or administrators (Burkhardt & Schoenfeld, 2003). Knowledge from research likewise differs in nature and focus from pedagogical knowledge (McIntyre, 2005). Implications for teaching and design are therefore seldom straightforward. Moreover, while there are strong reasons for researchers and educators alike to consider implications from very different sources together as a coherent set, the diversity of the field can make this a complex undertaking involving detailed understanding of a wide range of relevant theories and experimental designs (Prediger et al., 2008). Despite this, it is important for designers to be able to access research influences at this level of detail, to navigate a variety of theoretical frames appropriate to different aspects of design problems, and to use available data accordingly (Kieran et al., 2015).

There is no one-size-fits-all solution; however, next we present one approach developed to help designers overcome these challenges when developing mathematics curricula.

## **An approach to addressing challenges of implementing research through design**

In this section we provide as much detail of the components, use, and theoretical basis of the CMF as space permits. The CMF is a conceptual mapping tool which designers can use to explore, analyse and accommodate research implications for the interdependence of mathematical ideas when discussing and justifying the writing and ordering of curriculum content. It consists of the following key components: (1) a dynamic network of selected mathematical ideas in the domain of school mathematics and connections between them, which we have developed based on thematic review, synthesis and interpretation of the mathematics education research literature, along with connections to research sources; (2) tools for exploring, analysing and visualising the network and the research base; (3) Research Summary documents which explain the research justification for specific groups of mathematical ideas and relationships and which undergo external review; (4) descriptions of how students engage with these ideas in practice, in a form designed for teachers and designers to relate to their own experience; and (5) external content such as curriculum statements or mathematical tasks which can be mapped on to the network of mathematical ideas and analysed in terms of content and ordering. Ideas in the network are not ordered in an absolute sense, by year or age, but by how ideas contribute to one another. This ordering is not linear but allows for many paths from one idea to another which a designer may find useful to consider. Importantly, it is a conceptual ordering and not meant to imply teaching order or student trajectories, as students often need to go back and forth as they develop experiences working with a set of ideas. Finally, (6) the CMF can be used to produce concrete artifacts for analysis and discussion in the form of maps in which designers have gathered relevant collections of waypoints and linked them to their own content.

In a typical curriculum development scenario, a designer using the CMF might start by searching for mathematical ideas relevant to the section of the curriculum they're working with and display them in the order they depend on one another, from left to right, together with curriculum content on the screen as a map. Then curriculum content can be linked, or "mapped onto" to the mathematical ideas, which helps designers to explore possibilities within the map as a whole for reordering, adding, subtracting or changing curriculum content. When changes are made to the curriculum content on the basis of the CMF, the research justification provided in the CMF for the mathematical ideas and connections can serve as a reference for designers in documenting and communicating their justifications to stakeholders.

We structure the theoretical underpinnings of the CMF around several key design assumptions; in this paper we describe three which are most relevant to research implementation. We have drawn on literature in multiple areas: domain coherence in mathematics, conceptual mapping, and shared representations as boundary objects. Our first design assumption is that support for research-informed perspectives on domain coherence in the design of curricula or resources can contribute to their value for teaching and learning by allowing designers to consider a wider range of implications and develop curricula and resources with greater domain coherence as a result. This assumption is related to challenges 1 and 4, since it involves providing support (i.e. making it more straightforward, thorough or feasible) for using research perspectives in design decisions and provides aid to designers in synthesizing research from multiple sources and perspectives. It is based on strands of research involving the conceptual structure of mathematics learning and notions of coherence. Thurston (1990)

describes this structure as being “like a scaffolding, with many interconnected supports”; he conceives of it as tall, because concepts build on one another, broad because of the multitude of interconnections necessary to provide foundations for building, and connected, with the connections helping students and mathematicians to compress sets of ideas to make use of them more efficiently (Thurston, 1990, p. 2). Tall (2013) suggests that this structure is built through categorization (the “recognition of essential properties”), encapsulation (“repeating actions” that “can be manipulated as mental objects”) and definition, using “language to formulate specific concepts as a basis for reasoning and proof” (Tall, 2013, p. 51). Research on learning in different topic areas of mathematics often has implications for the particular mathematical ideas and connections of importance, and we have applied Tall’s principles for learners to our expression of conceptual structures implied by research for designers. On this basis we view designs with high domain coherence as those which aim to leverage conceptual dependencies that are well-aligned with those reported in research. This definition is in agreement with the idea of “learner-centered curricular coherence as...an organizational means to promote a high likelihood that each learner traverses one of many possible paths to understand target disciplinary ideas [...] by building on and continuously broadening and modifying their ideas and experiences.” (Confrey et al., 2017, p. 719) and has also been informed by perspectives emphasizing the logic underlying sequences of ideas (Schmidt et al., 2005; Stark, 1986).

The second design assumption is that our goals from the first assumption can be aided by a mapping approach. This assumption is related to challenges 1 and 2, as mapping can make detailed relationships explicit and easier both to work with and to discuss. The affordances of conceptual mapping for analysing and communicating relationships between mathematical ideas have been demonstrated in research on learning trajectories and related constructs (Confrey, 2019). These affordances are also well characterised more generally in studies of knowledge management (Eppler, 2004).

The third design assumption is that the maps and mediating documents of the CMF can serve as shared artifacts which may facilitate discussions about design both within and between communities of practice, and that doing so may help design intents to be realised more fully by teachers or adapted for them more effectively by eliciting feedback. This assumption is again related to the need for communication in challenge 2. For this we draw on Remillard and Heck’s (2014) characterization of curriculum and resource implementation as taking place in a system of communities between which designs are translated and possibly transformed as they are documented by designers, enacted by teachers and received by students. This has led us to shape aspects of the CMF according to the properties of shared knowledge representations, especially boundary objects as proposed by Star & Griesemer (1989); in particular the qualities of being adaptable yet structurally consistent and of allowing members of different communities to recognise information from their own perspectives and connect this to others’ through a common space or artifact.

Taken together, these design assumptions are intended to address challenges 1, 2 and 4 by helping designers to deal with issues of coherence and the complexity of the research base and by providing a shared frame of reference for design discussions and support within and between communities. Challenge 3, however, is the issue of how research influences in design contribute to design process and teaching and learning outcomes. Much of this challenge involves implementation research rather

than the design of the CMF itself.

The CMF is currently being implemented in a number of different curriculum and resource design contexts at different scales. In all cases so far, the CMF as a design tool is being implemented with designers, whose designs are subsequently implemented in learning contexts. The contributions of the CMF are therefore directly related to design outcomes and somewhat indirectly related to teaching and learning outcomes, as any design influences would be. We are developing a preliminary evaluation framework to help us to analyse the direct and indirect contributions of our research interpretations in the CMF across a variety of authentic implementation contexts. Such contexts can be expected to have uncontrolled external factors (Barab, 2014) and multiple influences determining outcomes (Stern et al., 2012), making contribution analysis a useful approach for evaluating impact and gaining insight into specifically how our approach might be improved.

This framework helps us to characterise implementations according to several factors. First, we have identified four categories into which our evaluation goals might fall (adapted from Stern et al., 2012): Attribution: how much influence did the CMF have on the outcomes?; Contribution: Did the desired outcomes occur?; Mechanism: By what means did the CMF contribute?; and Translation: What circumstances are conducive to achieving intended outcomes using the CMF? The first two categories involve the value and relevance of the CMF; the last two may help us to learn about broader contexts in which use of the CMF is more likely to be successful. In addition to goals, this framework will help us to position an implementation according to meaningful duration, conceptual range, systemic scope, and distance of the CMF from measured outcomes, and will help us to frame outcome indicators and measures accordingly. Below, we briefly discuss some design outcomes from a recent implementation of the CMF which further illustrate this approach.

### **A brief description of some illustrative implementation outcomes**

Our most recent case study took place as we were beginning to develop the evaluation framework. In the summer of 2020, the CMF was used in work on Statistics and Probability strands of the Australian Curriculum as part of the review currently being carried out by the Australian Curriculum, Assessment and Reporting Authority (ACARA). The ACARA team worked with the CMF and the Cambridge Mathematics (CM) team and described design outcomes from this work through face-to-face meetings and semi-structured diaries. Below we give a very brief description of the context and summarise the outcomes we have synthesized from meetings and diaries with respect to the four research implementation challenges; this synthesis contributed to identifying these challenges.

*1. There are factors which limit engagement with research; 4. Research implications are not always straightforward.* The ACARA team reported that while they spent just as much time thinking about research, using the CMF they were able to use this time to bring much more research from sources which were new to them into their discussions. They felt in some ways that there would always be some research that they would not have time to fully engage with, but that the way it was presented in particular topic areas in the CMF helped them to address specific questions and introduce new ones. They made use of a variety of CMF features in order to access research; they began with Research Summaries and CMF content curated for them according to their existing curriculum statements, and branched out by using search features and following connections to look for other

aspects of topics to consider. In the course of this, they reported being unable to find some things; we realised that while some of what they were looking for was implicit in some CMF content, it was not explicit enough for the ACARA designers to recognise, and they had to spend more time looking for it than we intended. This helped us to revise not only the presentation of that content but to examine other areas of the CMF for similar issues.

The ACARA team also reported engaging with research implications in a mix of forms. They looked back and forth from research summary text to maps to descriptions of map elements. They were able to find some useful ideas through their own queries. The flexibility of the multi-representational approach in the CMF meant that to the extent required the ACARA team was able to develop and follow their own lines of inquiry beyond the starting points curated by CMF writers, with a few exceptions mentioned in 1. Moreover, the Research Summary starting points contributed substantively to several of the discussions we observed.

*2. Design is an intermediary construct.* We observed the ACARA team using CMF maps and Research Summaries in discussions with us, and they felt the information they found helped them to provide useful research justifications for their decisions to ACARA colleagues and teachers, who reviewed initial changes in reference groups, by illustrating (in a different form) some of the connections highlighted in the CMF. These justifications were positively received and the ACARA team felt they had been effective. The ACARA team also was able to highlight specific changes to the wording of curriculum statements which they made to bring in influences they found in the CMF and make them more explicit for teachers. See 3. for examples.

*3. Research is one influence among many on outcomes.* The ACARA team was able to clearly identify specific changes in their internal discussions due to use of the CMF, some of which led to curriculum changes. Two examples are provided below:

- In one set of statements about data, they changed language to explicitly reference the shape of distributions. Distribution and shape were major themes in the research they engaged with through the CMF, and they wanted teachers and students to be aware of the shape of distributions when interpreting data. Across Years 4 and 5, for example, the words describe and interpret have been expanded to acquiring, validating and representing types of data.
- They referred to research encountered in the CMF to develop a progression in statistical investigation through Years 3–10. This progression moves from guided statistical investigation involving categorical or discrete data to planning and carrying out statistical investigations, analysing data, communicating findings, developing questions, incorporating summary statistics, sampling, and working with multiple data sets and with bivariate data.

## **Conclusions**

In our illustration, when using the CMF designers were able to engage productively with a larger number of research implications than they had before in a similar amount of time, and encountered ideas that led to specific adjustments in their approach, as well as ideas which validated many of the directions they had been going in the review. However, while they felt this enhanced their work, it did not save them time as there is always more research available than time to engage with it; the CMF simply created a higher limit to engagement. They were able to build and communicate research

justifications including themes from the CMF, and they were able to directly attribute some of their design decisions to the CMF. In many cases the research synthesis aided the ACARA designers as the CM writers intended, but some cases in which this did not take place were identified for further work. These outcomes from our work in progress on evaluation suggest that the CMF might be a reasonable example of one approach to addressing the research implementation challenges we have described.

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