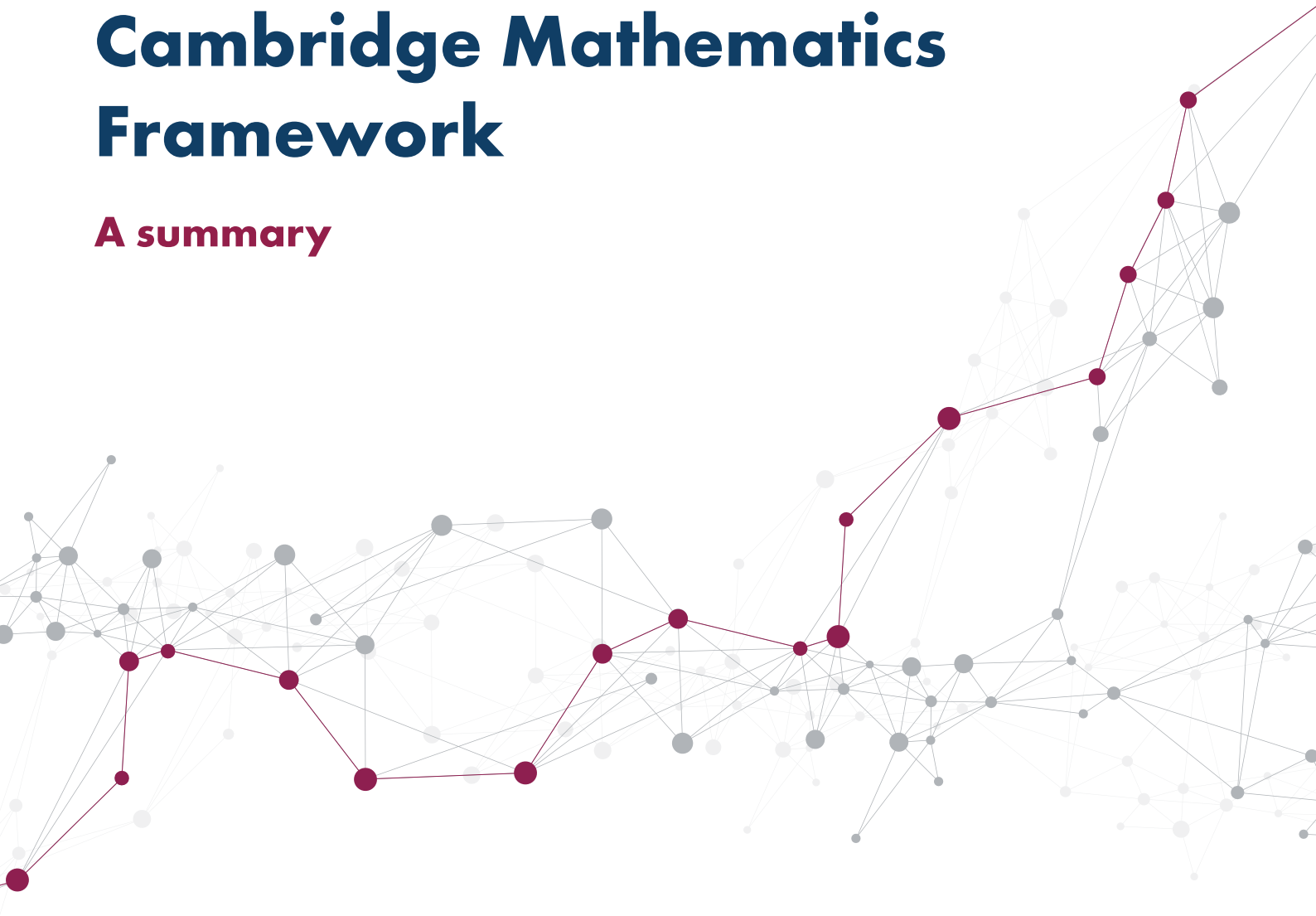
CAMBRIDGE Mathematics

Evaluating the Cambridge Mathematics Framework

A summary



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Researchers often adopt an evaluation framework to judge the impact and influence of their research. This can help to communicate whether the study/intervention met the aims and goals of the research within the given context. In turn, this can make implications of such studies more transparent and useful for different stakeholders. This paper summarises the CMF Evaluation Framework developed to guide the assessment of impact of the Cambridge Mathematics Framework (CMF) in different contexts, including curriculum development support. Because there are many factors behind curriculum outcomes, it is important to consider both qualitative and quantitative data when evaluating the impact and influence of the CMF, and so this summary explains why it is crucial to collect different data when working in the context of the classroom. A case study is also presented, in which the CMF was used to inform the re-design of the Statistics and Probability strand of the Australian Curriculum by the Australian Curriculum, Assessment and Reporting Authority (ACARA) and Cambridge Mathematics (CM).

Introduction: Why evaluate?

This document presents a summary of the full paper describing the design tool used to guide evaluation of the CMF – which itself is a tool for educational design in mathematics. Evaluation must involve multiple, tailored approaches which consider the interplay of many contexts and factors. An evaluation framework for assessing impact can help to justify research objectives so individual studies can capture and communicate the complexity of situations in which a design tool is used. In turn, this can make the implications of studies more transparent and useful for stakeholders.

Outcomes of some curriculum intervention studies can be straightforward, or they may be less direct and therefore more difficult to attribute to any one factor (Middleton et al., 2006; Stern, 2015). Often, many real-world situations (such as classroom interventions) involve a mix of forces that may affect the outcomes of such interventions. Measuring a combination of direct and indirect outcomes can help to characterise the contributions of these different forces. If effects cannot be measured directly, proxy indicators (and their distance from the effect) may be chosen to help assess the effects of an intervention.

An evaluation framework can help to organise what is being evaluated, the evaluation questions, indicators, success criteria and standards, study context and methods, so that studies can be designed to yield meaningful results and conclusions.

Assessing the strength of evidence in an evaluation

As we design intervention studies for evaluation purposes, we consider different sources of guidance for evaluating evidence, including the Weight of Evidence Framework from the Evidence for Policy and Practice Information and Coordinating Centre in the UK (EPPI-Centre) and the What Works Clearinghouse (WWC) developed by the US Department of Education's Institute for Education Studies (IES). The WWC is a system for reviewing and reporting research on "programs, products, practices, and policies" (IES, 2021).[1] At the moment, we mostly engage in single case studies and case study comparisons. As opportunities develop, we may undertake additional types of studies, such as case-control studies, quasi-experimental design (QED), randomised controlled trials (RCTs) and possibly longitudinal studies. Each type of study could contribute in a useful way to our evaluation of the CMF.

Using the CMF as an educational design tool

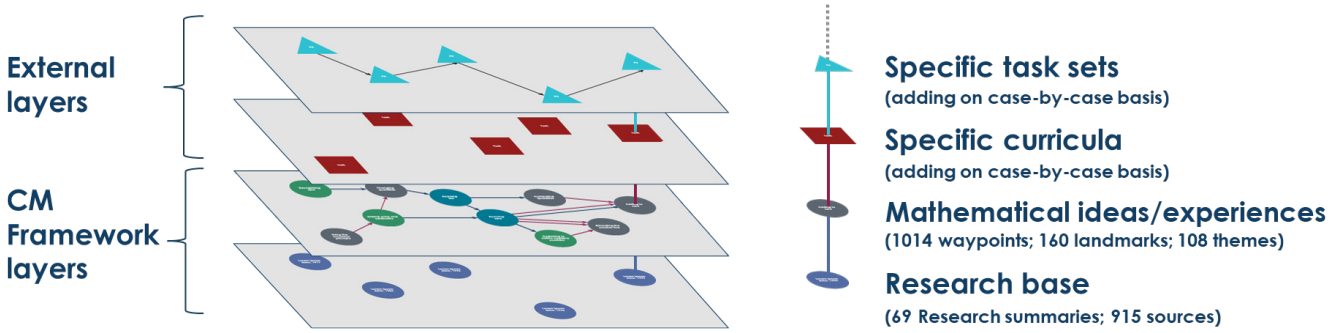
For the purposes of this paper, *educational design* refers to anything developed with the intention to contribute to positive teaching and learning outcomes, and the processes/systems in designers' professional activities that result in a completed or refined design. *Educational designers* are individuals involved in educational design from various professional communities, and an *educational design tool* offers support for design processes, such as making decisions about educational content or its presentation.

The CMF is an educational design tool offering support for design processes and decisions relating to curriculum design, resource design and teacher professional development, among other applications. It allows users to explore and search through a network of interdependent ideas in mathematics, which have been informed by research and evidence (see Figure 1).

Figure 1 on next page

[1] For more detail about these two systems for guiding the evaluation of quality of evidence, please see the full report (Jameson, 2021).

Figure 1: Diagram showing the connected layers of the CMF



The network in the CMF

- stems from summarising research in mathematics education,
- links to the underlying research base and specific libraries (for tasks or curricula), and
- includes supporting documents that are accessible to users with different backgrounds and levels of classroom experience.

Many of these aspects can be considered for evaluation. The CMF can be thought of as

a. a decision aid,

b. a conceptual model of mathematics learning,

c. an information system serving dynamic knowledge maps, and

d. a shared frame of reference for research implications in design (Jameson, 2021, p. 11).

Each of these different perspectives can offer particular ways in which we might evaluate outcomes from the use of the CMF.

Evaluating the CMF as an educational design tool

a. A decision aid should support users in making appropriate choices while minimising irrelevant information. It should include practical considerations and consider the values of possible outcomes. As an immediate goal, we hope the CMF helps its users to keep aware of important connections and dependencies between mathematical ideas when making decisions about what to include, how to organise, what to align and how to communicate their educational design to stakeholders. This awareness of connectivity in design and communication could make students' and teachers' experiences with mathematics more productive and positive (Cambridge Mathematics, 2018; Jameson et al., 2018).

b. The CMF could also be evaluated as a conceptual model of mathematics learning. The CMF enables users to filter and visualise areas of the model as maps of interconnected ideas, with more detail available for specific aspects of the map. We have been evaluating the CMF as a conceptual model through the external review process, during which experts in the mathematics education field review the ideas and research justifying these ideas, and provide feedback, which is then incorporated back into the CMF (Jameson, 2021).

c. We could also evaluate the CMF as an information system for dynamic knowledge maps. As the outputs from the CMF can be expressed as interactive knowledge maps and visual representations of key ideas in maths learning, the Framework could be evaluated using this approach by checking if users of these maps are able to productively answer questions such as "where am I in the landscape?" "where can I get to from here?" or "how do I find relevant knowledge, how can I judge its quality, how can I make sense of its structure, and how do I go about applying or developing it myself?" (Eppler, 2004, pp. 191-192).

d. Finally, the CMF can also be evaluated as a shared frame of reference for conceptual connections and research implications. This is important when members of various education communities use the tool for their own aims and purposes, facilitating collaboration and an exchange of perspectives. (Lee, 2007; Star & Griesemer, 1989). The CMF could be evaluated in terms of its usefulness as a shared frame of reference, by investigating, for instance, what is useful for an educational designer who is designing a resource addressing a specific activity for teachers.

It is important to highlight that the CMF is not a curriculum, and this has implications for evaluation. Quite often student performance data (classroom outcomes) is used to evaluate a curriculum (though this approach can be controversial). The CMF, as a design tool, is one step removed from a curriculum and therefore at least two steps away from what happens in the classroom. It is used to inform the context-specific decisions about curricula, but it does not specify what those decisions should be in each context, nor does it specify what activities/lessons teachers will use to translate the curriculum into the classroom. Because student data can be influenced by many factors, results need to be interrogated with this understanding and care taken in attribution.

CMF Evaluation Framework

We have developed the Evaluation Framework design tool to guide research design which serves our goals for evaluation. This framework lays out the roles and considerations for necessary elements of evaluation studies, with a focus on understanding the contributions of the CMF to intervention outcomes: evaluation goals, research questions, ranges of direct and indirect application of the CMF, settings, participants, stakeholders, and outcome measures or indicators.

Our main goals for evaluation are:

- to provide information that users and stakeholders need to know regarding how trustworthy, meaningful and useful the CMF as a tool is for their context, and
- to refine aspects of the CMF and our impact models and to contribute to theory-building if possible.

As there are a number of contexts in which the CMF could be used, it will interact with a wide range of other factors. We aim to keep adding to our pool of evaluation data to improve our understanding of the uses and impacts of the CMF.

Table A: Example research questions to guide evaluation

Example CMF contribution claim	Example research questions
Contributions to classroom outcomes	What evidence shows that the CMF had a substantial influence on resources or teaching sequences underlying observed outcomes? Are there indications that teachers' comprehension of mathematical ideas have changed? Is this reflected in their teaching?
Contributions to domain coherence	Is the CMF presenting a coherent picture to users depending on their queries? Does it improve their use of important connections? Are the curricula/materials used in this study more coherent as a result of influence by the CMF?
Contributions to system coherence	Does the CMF make it feasible/easier to analyse and improve the alignment of curricula, resources, PD support and assessments with the corresponding curriculum?
Contributions to professional decision-making	Do direct users of the CMF feel they have made more informed decisions? Do they feel this has improved the quality, efficiency or defensibility of their outputs?
Contributions from a map-based information system	Is useful information available? Can users access it easily? Is it expressed meaningfully and clearly for target audiences?

The impact can be evaluated with various ranges from direct to indirect use of the CMF in mind, including the *temporal range*, *conceptual range*, *systemic range* and *distance range*. The temporal range refers to the amount of time that a study must take place in order for relevant data be to available. The conceptual range of a CMF intervention study refers to the number of mathematical ideas and links in the CMF, with which educational designers may engage. Systemic range is crucial when studying our system coherence. It is important to consider factors that can affect the characteristics of an intervention, such as how many elements of the system are involved in alignment of materials (curriculum, assessments, resources, teacher professional development, etc.) using the CMF. The distance

range refers to the steps that the CMF is removed from the indicators. The more the tool is removed from direct experiences, the more likely that other factors influence the teaching and learning outcomes.

Table B: Examples of levels of distance from direct use of the CMF (adapted from Ruiz-Primo et al., 2002)

	Immediate	Close	Proximal	Distal	Remote
Distance from CMF	Develop or use artifacts created directly from use of the CMF	Develop or use processes, outputs closely aligned with the immediate artifacts, content of CMF	Work with relevant knowledge, insights in CMF but not our pre-curated groupings of ideas	Design a resource or assessment based on a CMF-influenced curriculum	Demonstrate performance on general measures on equivalent topics
Distance from a specific use of the CMF	SoW itself + artifacts students and teachers produce in/for a single lesson	Activities related to but not mentioned by the SoW, teacher judgment	Ideas applied flexibly between specific topics in which students were first taught	Regional/state performance measures	National or international standardised assessments

Important factors for consideration

It is also important to consider the setting, participants and stakeholders, and outcome indicators (measures). With regards to the setting, direct outcomes occur when designers are working directly with the CMF; for instance, when developing curricula in publishing houses or schools. Indirect outcomes happen in classroom teaching environments and policy discussions. Participants in an intervention may be educational designers, teachers, policy makers, students and/or teacher educators. Stakeholder groups may include those who directly use the CMF and those who spend time and resources on designing and evaluating the CMF; for instance our collaborators, the University of Cambridge and external reviewers.

Depending on what goals and aims designers and stakeholders have, there may be indicators of direct and indirect outcomes of using the CMF tool. Indicators of direct outcomes may include:

- specific characteristics and elements of the design (what content is included, its order and how connected content is);

- changes in the professional knowledge of the designers (whether self-reported or observed); and
- the observed effectiveness of conversations about the design (Jameson, 2021, p. 24).

Indictors of indirect outcomes could include:

- pre- and post-assessments of student performance (relative to a comparison group);
- how teachers deliver their lessons (video recordings and interviews); and
- comparing teachers' planning and use of resources after using the CMF tool (Jameson, 2021, p. 24).

Applying the CMF Evaluation Framework

In order to investigate and comment on the outcomes of using the CMF in curriculum and resource design, we have adapted the process from an example by Klaver et al. (2016), with further detail taken from Delahais and Toulemonde (2012), and Mayne (2012) (as cited in Jameson, 2021):

1. Work with stakeholders to determine what impact looks like for the specific goals of the study
2. Work with stakeholders to find and prioritise outcomes of interest
3. Find and select intervention opportunities following points 1 and 2
4. For each prioritised intervention:
    a. Develop research questions and identify potential sources of data relevant to causal pathways (e.g. data on how/how much the CMF contributed to a design, etc.)
    b. Collect data
    c. Analyse data and report quality of data relative to research questions
    d. Consider alternative explanations for outcomes and gather additional data to address these (if needed)
    e. Explain observed outcomes: How do they compare to our implementation goals?
    f. Determine the contribution that the CMF had on the outcomes
    g. Ensure that the stakeholder reviews the contribution story and the evidence
    h. Respond to stakeholder review and refine the contribution story
5. Intermittently review data from many intervention studies; cluster data from different studies which apply to the same causal link in the impact models as appropriate

6. Collaborate with stakeholders to review the strength of available evidence
7. Develop the larger contribution story and present the types and strength of evidence
8. Present collected information and evidence to stakeholders (Jameson, 2021, pp. 24–25)

Employing this transparent process can support us in collecting information about the outcomes and impact of using the CMF in specific contexts and gives different stakeholders the foundations for judging whether the CMF can be used in their context while considering their goals and priorities.

Example of using the CMF in a curriculum design case study

Recently, ACARA used the CMF to revise the Statistics and Probability strand of the Australian Curriculum.

Table C: A practical example of how the CMF Evaluation Framework was used to evaluate the impact of using the CMF to revise the Australian Curriculum Statistics and Probability strand[2]

Evaluation framework dimensions	Example: ACARA Statistics and Probability revision
Goals: Evaluation questions	1. Was the ACARA team happy with the results of the curriculum revision? 2. To what degree can changes made to the Statistics and Probability strand be attributed to use of the CMF? 3. How was the CMF used and how did this contribute to the revisions made? 4. Are there additional contexts we would expect these processes and outcomes to apply to? 5. Are particular refinements to the CMF content or interface warranted based on feedback about these processes or outcomes?
Temporal range	Foundation – Year 10; in practice mainly secondary, small but important relevance to primary
Conceptual range	Statistics and probability
Systemic range	Designed curriculum, national level
Distance range	Immediate and proximal: focus on direct measures and design outcomes
Contexts/settings	National curriculum review: curriculum design team and reviewers

[2] For more detail, please see the full report (Jameson, 2021).

Evaluation framework dimensions	Example: ACARA Statistics and Probability revision
Participants, stakeholders & beneficiaries	Participants: ACARA review team: expert mathematics curriculum designers Stakeholders: ACARA curriculum review leaders, teachers, consultants Beneficiaries: teachers, students
Outcome indicators & measures	Single case study: design implementation Interview and diary data; revised curriculum; reviewer feedback; no student performance data

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