

# A research agenda for computer-aided assessment of university mathematics

**EAMS**

21 June 2021

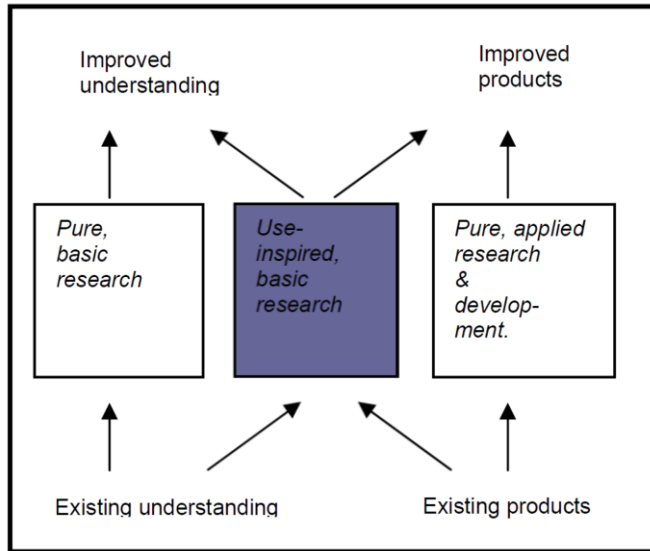
**Ian Jones**  
Loughborough University

**George Kinnear**  
University of Edinburgh

**Chris Sangwin**  
University of Edinburgh

# Aims

develop a shared research agenda for  
computer-aided assessment of university  
mathematics



Lester, F. K. (2005). On the theoretical, conceptual, and philosophical foundations for research in mathematics education. *ZDM - International Journal on Mathematics Education*, 37(6), 457–467. <https://doi.org/10.1007/BF02655854>

# Collaborative agenda-setting

- A collaborative process
- Modelled on previous exercises (Alcock et al., 2016; Sutherland et al., 2011)

Alcock, L., Ansari, D., Batchelor, S., Bisson, M.-J., De Smedt, B., Gilmore, C., ... Weber, K. (2016). Challenges in mathematical cognition: A collaboratively-derived research agenda. *Journal of Numerical Cognition*, 2(1), 20–41.

<https://doi.org/10.5964/jnc.v2i1.10>

Sutherland, W. J., Fleishman, E., Mascia, M. B., Pretty, J., & Rudd, M. A. (2011, June 1). Methods for collaboratively identifying research priorities and emerging issues in science and policy. *Methods in Ecology and Evolution*. John Wiley & Sons, Ltd.

<https://doi.org/10.1111/j.2041-210X.2010.00083.x>

## Theoretical Contributions

### Challenges in Mathematical Cognition

#### A Collaboratively-Derived Research Agenda

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### Abstract


This paper reports on a collaborative exercise designed to generate a coherent agenda for research on mathematical cognition. Following an established method, the exercise brought together 16 mathematical cognition researchers from across the fields of mathematics education, psychology and neuroscience. These participants engaged in a process in which they generated an initial list of research questions with the potential to significantly advance understanding of mathematical cognition, winnowed this list to a smaller set of priority questions, and refined the eventual questions to meet criteria related to clarity, specificity and practicability. The resulting list comprises 26 questions divided into six broad topic areas: elucidating the nature of mathematical thinking, mapping predictors and processes of competence development, charting developmental trajectories and their interactions, fostering conceptual understanding and procedural skill, designing effective interventions, and developing valid and reliable measures. In presenting these questions in this paper, we intend to support greater coherence in both investigation and reporting, to build a stronger base of information for consideration by policymakers, and to encourage researchers to take a consistent approach to addressing important challenges in mathematical cognition.

Keywords: mathematical cognition, numerical cognition, research agenda, mathematics education

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## Introduction

Research on mathematical cognition has made substantial advances in recent years, in areas that span diverse theoretical frameworks both within and across disciplines. For instance, neuroscience research has revealed potential mechanisms contributing to the representation of number and related concepts in the brain (De Smedt, Noël, Gilmore, & Ansari, 2013). Behavioural research has identified distinctive characteristics in the mathematical thinking of young children with atypical development (Dennis, Berch, & Mazzocco, 2009; Geary, 2010; Kaufmann

# Contributors

Pat Barmby	No More Marking Ltd.
Sam Fearn	Durham University
Thomas Wong	Heriot-Watt University
Ian Jones	Loughborough University
Paola Iannone	Loughborough University
Colin Foster	Loughborough University
Ann O'Shea	Maynooth University
Peter Rowlett	Sheffield Hallam University
Tim Hunt	The Open University
Tim Lowe	The Open University
Igor' Kontorovich	The University of Auckland

Niclas Larson	University of Agder
Morten Brekke	University of Agder
André Heck	University of Amsterdam
George Kinnear	University of Edinburgh
Chris Sangwin	University of Edinburgh
Maryam Alarfaj	University of Edinburgh
Karen Henderson	University of the West of England
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Rhys Gwynllyw	University of the West of England
Ben Davies	UCL
Ruth Reynolds	UCL

# Timeline

E-A×M+S



British Society for  
Research into  
Learning Mathematics

NE RUME

## Online form

- Participants submit their questions

## Conference discussions

- GK/IJ presented at conferences
- Gathered comments from attendees
- Also suggestions for new questions

## Manuscript writeup

- Draft written by GK/IJ/CS
- Shared with WG for comments

## WG meeting (May 2020)

- Discuss questions in small groups
- Refine wording

## WG meeting (Jan 2021)

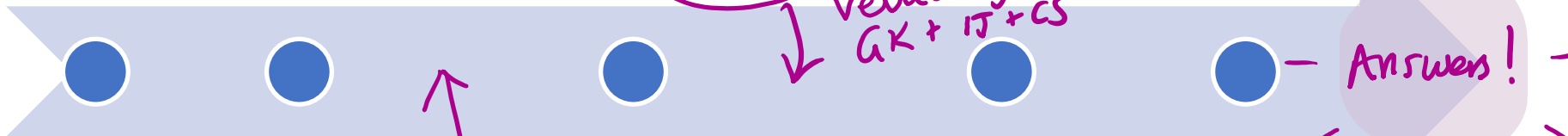
- Update on progress
- In small groups:
  - discussing questions of interest
  - starting to edit website content

Answers!

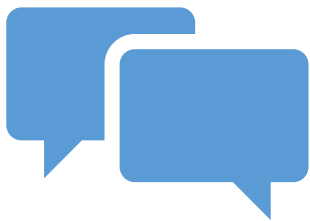
Loose categories formed

vetted by GK + IJ + CS

supplement to manuscript



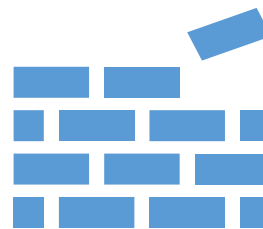
# Themes



**Errors and  
feedback**



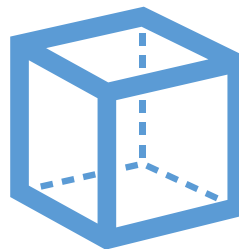
**Students**



**Design and  
implementation**



**Affordances**



**Mathematical  
skills**



# Errors and feedback

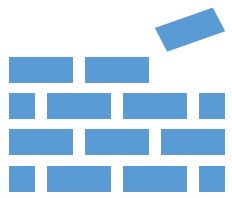
- What errors do students make?
- How to optimise feedback design?
- Can automated feedback be improved by emulating teachers?



# Students

- How do students:
  - interact with e-assessment systems?
  - engage with feedback?
  - work together?
- What are students' views about e-assessment?





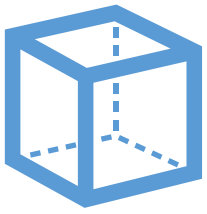
# Design and implementation

- Principles for task design – what exists, and what should be used?
- What guidance for lecturers exists, and how effective is it?
- What are the effects of randomisation?



# Affordances

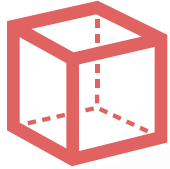
- What learning can we assess with current e-assessment tools?
- How can free-form student input be dealt with?
- What capabilities are on the horizon?



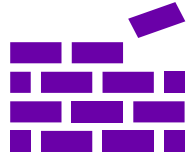
# Mathematical skills

- How can e-assessment support learning and assessment of mathematical skills?
  - Problem solving
  - Proof
  - Example generation

# Themes and connections



**Mathematical  
skills**



**Design and  
implementation**



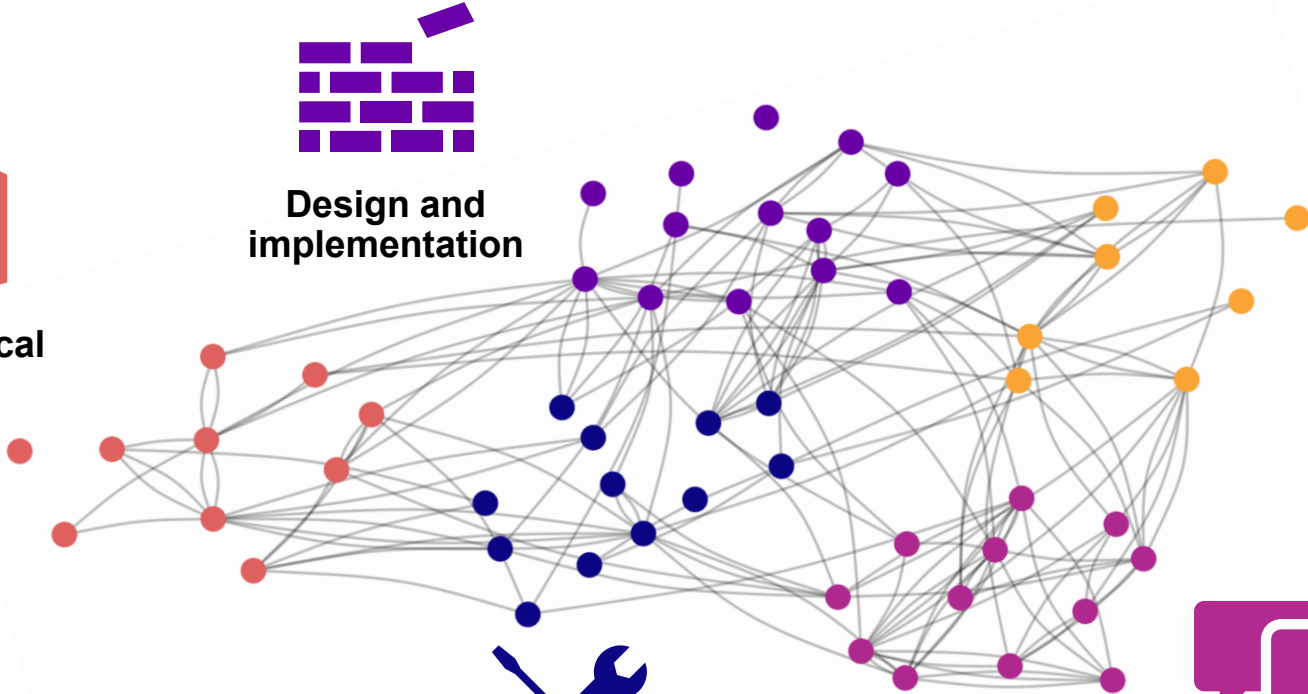
**Students**



**Affordances**



**Errors and  
feedback**



# Find out more

## Manuscript (in preparation)

- Presents themes, with short description of each sub-theme

## Website

- Full details for each question

Maths CAA Research Agenda About the project Contributors Questions

### Q44: How can e-assessments be designed to expand and enrich students' example spaces?

- [George Kinneer](#)
- [Colin Foster](#)

Learning about concepts by developing a rich example space has been suggested as educationally valuable (e.g., Watson & Mason, 2006), with e-assessment proposed as a particularly suitable mechanism for gathering and checking examples. However, there are currently few examples of this being done in practice, and little in the way of guidance about designing effective tasks.

#### What motivates this question?

Watson and Mason (2006) build on Michener's notion of 'example spaces' and highlight students' mathematical development in terms of (i) expanding the range of examples students are aware of within a particular space.

#### What might an answer look like?

The core of the question here is about how to design tasks to achieve a particular effect, so the answer could take the form of 'designing tasks to achieve a particular effect'.

#### Related questions

- The design of example-generation questions is one aspect of [Q43: What principles should inform the design of mathematics e-assessment tasks?](#)
- Implementation will depend on the capabilities of the e-assessment tool; see [Q45: To what extent can current e-assessments meaningfully judge student responses to example generation tasks?](#)
- Investigation of this question could proceed in parallel with [Q46: How does the use of e-assessment impact students' example generation strategies and success, relative to the same tasks on paper or orally?](#)

#### References

Sangwin, C. J. (2004). On building polynomials. *The Mathematical Gazette*, 89(516), 441–450.  
<https://doi.org/10.1017/S002557200178205>

**Thank you!**

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