CAMBRIDGE Mathematics

Methodology

Glossary App

Others in this series

- Building the research base
- Formative evaluation

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Methodology: Glossary app

Background and Methodology Report

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Overview

With improvements in technology over the last few decades, the availability and use of educational apps has increased. The Cambridge Mathematics team has identified the need for an accurate, holistic and accessible glossary of mathematical vocabulary. To help in collating this, the team are developing a glossary survey app to investigate perceptions of current mathematical definitions within the mathematics education community. The app will be piloted, evaluated and adjusted before a full launch and the project will follow best practice guidelines for data collection and product development.

Introduction

The use and sophistication of technology has increased drastically in the last few decades, including in the education sector. The Cambridge Mathematics team are enthusiastic about leveraging technology, where it impacts on the learning of mathematics or more generally aids our organisational structures and communication. This report describes the initial planning and development of one example of technology use – the *CM Define It* app. A small-scale **pilot study** will be trialled within the maths education community and we predict that feedback may change certain elements to make the app more user-friendly and accessible.

Aims for glossary research

There is currently no single widely-agreed source for the key terms in mathematics; hence a need for an accurate, holistic and accessible glossary of mathematical vocabulary. The app will act as a crowdsourcing tool, collecting information about how individuals in the maths education community interpret and use mathematical definitions. The aim of the project is not to devise new mathematical definitions, but to investigate how the community perceives existing definitions of mathematical key words. As a result, the research will inform the mathematics glossary that will be embedded in the Framework.

This research project is important for several reasons. It will allow researchers to explore and develop subject-specific terminology that accurately explains key mathematical vocabulary in order to expose misunderstandings or misconceptions around the use of a word or term, and identify inconsistencies in, or preferences for, definitions between particular populations, for instance by geographical region. In addition, most glossaries attempt to meet the need of a single audience (primary children, beginning

teachers, researchers, etc) so one holistic glossary of mathematical terms that could address different levels of learning and knowledge would offer readers a choice of several possibilities. Digital technology will provide an efficient method for creating wordlists for teachers, curriculum developers, assessment designers and textbook writers – providing a reference list of important words in a given academic area (Fahim, Fat'hi, & Nourzadeh, 2011). Lastly, when learners search for definitions, they often find themselves spending time navigating irrelevant websites or losing information (McPherson, 2005 as cited in Park & Kim, 2017). A single place for mathematical definitions could help to overcome this issue.

How research informs our design

Mathematics and language

Riccomini, Smith, Hughes and Fries (2015) suggest that developing the language of mathematics is a crucial element of teaching maths to young children and that this process continues throughout an individual's mathematics education, as the ability to use words to explain, justify and communicate mathematically is important to the development of mathematical proficiency. Research suggests that language is an important component of mathematics success (Seethaler, Fuchs, Star, & Bryant, 2011 as cited in Riccomini et al., 2015) and that a student's general knowledge of mathematics vocabulary can predict mathematical attainment (van der Walt, 2009). Rubenstein and Thompson (2002) as cited in Riccomini et al. (2015) suggest at least 11 categories of difficulty that students could face when learning mathematical vocabulary. These include:

a. meanings being content-dependent (e.g. the possibility that foot could mean 12 inches or the bottom of the bed)

b. mathematical meanings being more precise (e.g. product meaning the solution to a multiplication problem or the product of a company)

c. terms being specific to mathematical contexts (e.g. polygon, parallelogram, imaginary number)

d. terms having multiple meanings (e.g. side of a triangle or side of a cube)

e. technical meanings that are discipline-specific (e.g. cone as in the shape or food)

f. everyday homonyms (e.g. pi and pie)

g. related yet different words (e.g. circumference and perimeter)

h. challenges with translated words (e.g. mesa vs table)

i. irregularities in spellings (e.g. obelus vs obeli)

j. concepts being verbalised in different ways (e.g. 15 minutes past or quarter past)

k. students and teachers using informal vocabulary instead of mathematical terms (e.g. diamond vs rhombus) (Rubenstein & Thompson, 2002 as cited in Riccomini et al., 2015, p. 238)

Monroe and Orme (2002) recognise that an important step in overcoming such issues is for teachers to understand the many difficulties that students can face. Riccomini et al. (2015) state that for students to use mathematical language effectively and with purpose, teachers need to facilitate students' basic understanding and fluent use of academic vocabulary.

Crowdsourcing

More and/or more useful knowledge can be collated with the involvement of multiple contributors (Llorente & Morant, 2015). Crowdsourcing refers to distributing a task among a group of people. With the evolution of the Internet, crowdsourcing has enabled communities to collaborate and exchange information (Isman, Bennet, Judah, & Glenzer, 2012, as cited in Llorente & Morant, 2015). A key scenario in crowdsourcing is gathering ideas about a given topic and voting on the most popular option (Llorente & Morant, 2015). As an information-gathering method, crowdsourcing has been used to develop mobile applications in recent years and can be used to create useful software applications (Zheng & Dawson, 2016). It has been used to collect student feedback in higher education (Schmidt, 2013 in Zheng & Dawson, 2016) and could offer an improved education environment if used appropriately (Zheng & Dawson, 2016). Surowiecki (2004) as cited in Zheng & Dawson (2016) suggests that a group of people can develop more ideas as a collective if the following key elements are present:

a. diversity of opinion – where each person has independent knowledge

b. independence – where opinions are not controlled by others' opinions

c. decentralisation – where individuals can draw on concentrated knowledge

d. aggregation – where a mechanism can help turn private opinions into collective decisions (Surowiecki, 2004 in Zheng & Dawson, 2016, p. 210)

This suggests that crowdsourcing may be a useful method to adopt when designing a glossary of mathematical terms that could be used by the mathematics education community worldwide. It would

allow individuals to express their opinions about definitions, combine their expertise and knowledge and work together as a collective. In this context, crowdsourcing refers to collecting responses about mathematical definitions from an audience of teachers, academics, resource and assessment developers, students and other members of the mathematics education community.

Technology and apps

An app is a software application that works on mobile technology devices such as smartphones and tablets (Pilgrim, Bledsoe, & Riley, 2012 in Bouck, Satsangi, & Flanagan, 2016). It is estimated that there were 197 billion mobile app downloads in 2017 and that by 2021 there may be 352 billion (Dogtiev, 2019). The availability of education-based apps has drastically increased in the last decade (Douglas, Wojcik, & Thompson, 2011 as cited in Bouck et al., 2016). In the education sector, apps are being used to monitor behaviour (e.g. Class Dojo), communicate with parents (e.g. Remind), to serve as a social media-style learning tool (e.g. Edmodo) and engage students in different academic areas (e.g. Splash Math) (Bouck et al., 2016). An app therefore is currently a popular way to collect information.

The remainder of this report will explore the development of the app and the process of designing, testing, evaluating and improving it over the next eight months.

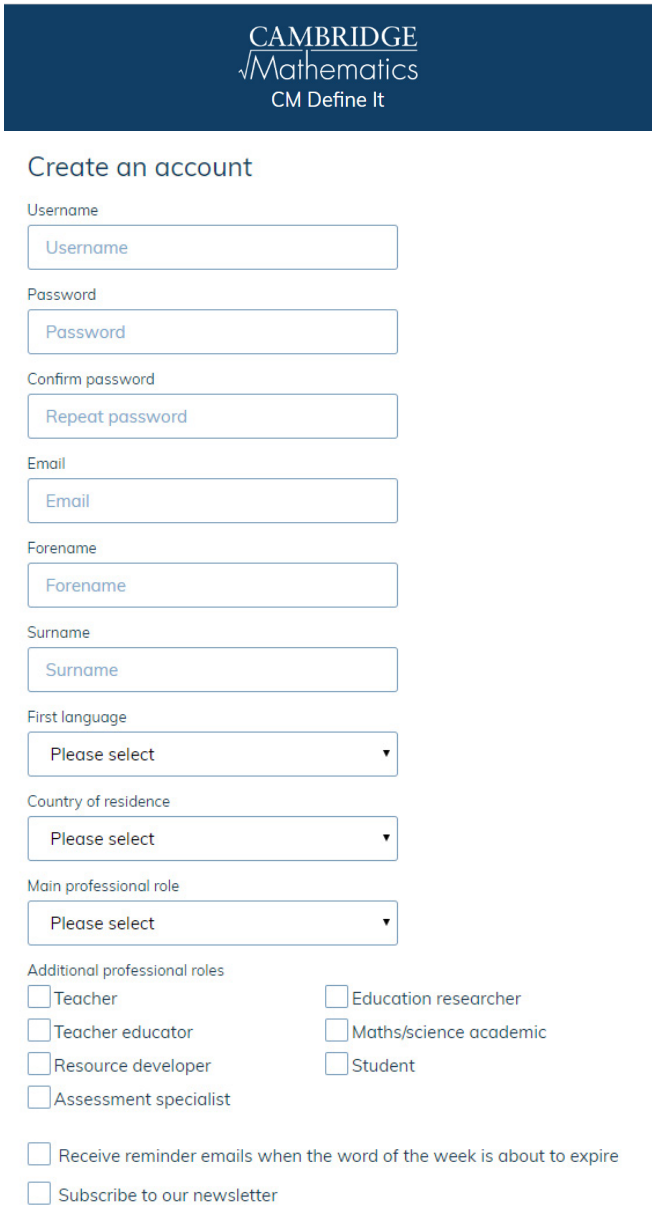
Design and survey methods

The *CM Define It* app is a research tool which uses crowdsourcing and survey methods to collect information about key mathematical definitions from members of the mathematics education community. It pushes out several existing definitions for participants to rate. Based on this data, the Cambridge Mathematics team will be able to make more informed choices about which definitions would be most useful to adopt or adapt for the Framework glossary. The aim is to collect information about a range of issues with key existing definitions, such as how accurate and useful they are, how easy or difficult to understand they are, whether they emphasise key points enough and whether they enhance understanding of given words.

The mathematics education community comprises a variety of roles. Research participants may include: teachers of mathematics, teacher educators, education researchers, academics, resource developers and assessment specialists. Different participants may be exposed to or use definitions at different levels of complexity in their day-to-day role (for instance, a primary school teacher may not use the same

definition as a university lecturer), and so the definitions presented in the app will come from sources that cater for diverse levels of mathematical knowledge.

The data collected will include demographic information and users' opinions about the definitions. This will help the team to decide what constitutes an appropriate definition and whether this varies for different audiences

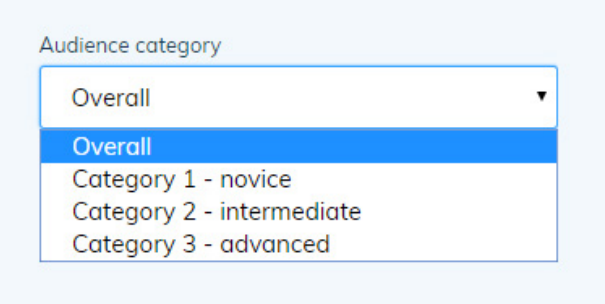


Participants will register on the screen above. The app will then provide participants with one mathematical key word prompt per week, consisting of up to 5 definitions of that word taken from different sources and identified by the Cambridge Maths team, through their research, as key vocabulary.

Ball and Bass (2002) claim that a mathematical definition does not have a use, no matter how refined or elegant, if it includes terms that are not in line with the prospective user's knowledge. Therefore, definitions must be mathematically appropriate and useful to learners who are at different levels (Ball & Bass, 2002).

It is highly likely the users of the app, and the prospective users of the Framework glossary, will include those who use definitions with learners who have different levels of mathematical knowledge. During the design phase, the Cambridge Mathematics team conducted semi-structured interviews with professionals working in education who offered advice regarding the app and its features. One interviewed professional developed a highly successful educational survey app for teachers whilst another develops mathematics resources. Both interviews informed the design of the *CM Define It* app. The team also interviewed a specialist working in statistics communications who agreed that including definitions which address different levels of mathematical knowledge is important. The selection of definitions will include those that are appropriate for professionals working with different groups of learners. Participants will be asked to select a group of learners with whom they would use mathematical definitions. The groups of learners defined in the pilot study are:

- Novice learners – learners who are developing their early knowledge of core mathematical concepts, e.g. young children,
- Intermediate learners – learners who are building on previous knowledge and refining their understanding, e.g. younger teenagers, and
- Advanced learners – learners who are comfortable with many core mathematical concepts and are studying or starting to study more advanced or specialised topics, e.g. older teenagers or trainee teachers



Since the initial audience will be English speakers, some definitions will be taken from international sources to acknowledge that some words or terms vary across national boundaries. Appropriate steps to credit the sources will be taken.

Each week, app users will be notified of a new word. Participants will rate each definition on a scale of 1-5 stars, with 1 star holding the lowest rating and 5 stars holding the highest. Participants will then be asked to give reasons for their ratings. They will be provided with five criteria assessing positive and negative aspects of definitions. The criteria will include:

a. whether the definition was technically accurate,

b. whether the definition emphasised the key points,

c. whether the definition was accessible for the intended audience,

d. whether the definition was sufficient for the intended audience, and

e. whether the definition added to or clarified participants' own understanding.

The feedback will allow the Cambridge Mathematics team to understand why participants awarded different ratings to different definitions. Free response boxes will also be available so participants can offer additional comments that may not be captured by the pre-defined criteria. Rohrer (2014) suggests that quantitative and qualitative data is important when collecting feedback, especially in **field studies** and **usability studies**. To meet this good practice recommendation, the app will collect both **quantitative data** (ratings) and **qualitative data** (free response option). Interviews with education professionals confirmed the importance of collecting quantitative and qualitative data. One of the specialists agreed that it is useful to provide participants with pre-defined criteria and a free response option.

Users will be asked for full consent in order to participate. To comply with General Data Protection Regulation (GDPR) regarding the collection and storage of personal information, participants will be informed of what the research project involves, what data will be collected and for what purposes, how their data will be used and stored and how they can request for their data to be deleted.

The current design of the glossary app may change as feedback is received from the pilot study and other testing prior to its launch.

Taking user experience and respondent fatigue into consideration

In order to retain and motivate participants in the study, the app should be a good experience for them. User experience (UX) has been defined as: "the degree of positive or negative emotions that can be experienced by a specific user in a specific context during and after product use and that motivates for further usage" (Schulze & Krömker, 2010, p. 262). It encapsulates three main components: emotion, motivation and reflection, which interact with each other to create the phenomenon of user experience (Schulze & Krömker, 2010). Product developers should always consider the user experience of the product they are developing to ensure that the experience is a positive one.

Pals, Steen, Langley and Kort (2008) discuss different approaches used to study the involvement of users, including participatory design and evaluating user experience. Participatory design refers to the attempt to narrow the gap between the researchers, designers and users by increasing their co-operation (Muller, 2002). Ideally, users of the product are engaged in the process from the start and during its iterations; therefore, they contribute actively to the development of the product (ISO, 1999, as cited in Pals et al., 2008). This means that participatory design is a design approach which does not aim to evaluate a finished product, but which aims to support the design of the product (Pals et al., 2008). The Cambridge Mathematics team will adopt this method as participants will be involved in the first iteration of the *CM Define It* app development – the pilot phase – which will inform the launch phase. Evaluating user experience refers to examining different elements of an individual's experience of a product, including satisfaction, entertainment and enjoyment (Pals et al., 2008). User experience will be evaluated after the pilot scheme, as participants will be asked to complete a survey which will investigate the usability of, and their experiences of, the app.

Respondent fatigue is a factor which must be considered when developing a product that requires responses. This phenomenon often occurs when survey participants experience tiredness and boredom, which can result in deterioration of the quality of data provided (Ben-Nun, 2008). This is often the case when participants are presented with lengthy questionnaires. When respondents experience fatigue effects, they may choose answers such as "not applicable" or engage in response set (ticking responses in a straight line), which poses a threat to the validity of their responses (Ben-Nun, 2008). To address this issue, the glossary app will ask focused, relevant questions and will keep the number of questions to a minimum. The free response box will also be optional; therefore, users will be able to provide qualitative responses only if they wish to do so.

Evaluation

The app will be pilot-tested with a small group of participants within the mathematics education community over a short time period (around 4-5 weeks). Participants will also complete a survey which will investigate the usability of the app and the user experience of the participants. The collected feedback will allow the Cambridge Mathematics team to make appropriate changes to the app.

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