

Evaluating the Cambridge Mathematics Education Project

Wai Yi Feng and Elizabeth Kimber

University of Cambridge

The Cambridge Mathematics Education Project (CMEP) aims to support and enhance A-level mathematics education. Funded by a grant from the UK Department for Education, the project began in October 2012 and is run by members of the University of Cambridge Faculty of Mathematics and of NRICH. The project is developing resources for teachers and students. Partner schools from across England have been recruited to work closely with the project team, trialing resources and giving feedback, and taking part in the internal evaluation of the project. We describe the CMEP pilot site and discuss some of the thinking behind the research and evaluation of the project, including the development of the evaluation questionnaire.

Keywords: evaluation, A level, post-16, teaching resources, problem-solving, mathematical thinking

A level mathematics and the context of the Cambridge Mathematics Education Project

This paper assumes some familiarity with the qualifications and education system in England, Wales and Northern Ireland. Advanced level Mathematics or 'A level Mathematics' refers to the post-compulsory (post-16), two-year course comprising Advanced Subsidiary (AS) level Mathematics and A2 Mathematics. This course includes topics such as coordinate geometry, functions, and elementary calculus. There is a choice of mechanics, statistics or decision mathematics for the applications units, which make up one third of the content of each qualification. Some students also take AS or A level Further Mathematics and cover topics such as complex numbers, matrices, differential equations, polar coordinates as well as more advanced applied mathematics. We use the term 'A level students' to refer to students studying AS or A level Mathematics or Further Mathematics.

There has been much discussion of the content and structure of A level mathematics qualifications, the nature of the assessment and the preparation of students for further study or use of mathematics in degree courses (Ofqual, 2012, pp. 58-59; Institute of Physics, 2011, p.2). The structure and content of A level Mathematics and Further Mathematics are currently being revised and the new specification is scheduled to be ready for teaching from September 2016, with the assessment of the one-year AS level being 'decoupled' from that of the two-year A level. Examinations for each qualification will be taken at the end of the course.

The Cambridge Mathematics Education Project

The Cambridge Mathematics Education Project (CMEP) is funded by the UK Department for Education and has funding for an initial period until March 2016. CMEP is a project within the University of Cambridge Faculty of Mathematics

involving both members of the Faculty and of NRIC (www.nrich.maths.org). The project is currently in the development phase and resources are being developed for teaching A level mathematics with the goal of “help[ing] make A-level mathematics a rich, coherent and stimulating experience for students and teachers” (CMEP, 2014). The project aims to support all A level mathematics students and not just those who intend to study mathematics at university. The following project aims are stated on the CMEP website (CMEP, 2014):

- (1) Identify the main themes and big ideas that permeate pre-university mathematics and lead into further study and industry.
- (2) Consider how [A level] mathematics can inspire and benefit students moving from school into university and the work-place beyond.
- (3) Create innovative and carefully constructed materials around the themes and big ideas.
- (4) Consider the most effective ways of helping students to understand the mathematics.
- (5) Ensure that the materials are engaging and accessible to a wide range of students and teachers.
- (6) Provide support to mathematics teachers to help them to use the materials effectively.

The CMEP resources will be housed on a purpose-built site, which will be freely available. The pilot version of the site has been available for use in teaching since September 2013 and is currently password protected. The site and resources are being designed to support an approach to A level mathematics which promotes mathematical thinking (Mason, Burton, & Stacey, 2010), emphasises connections within the subject and builds awareness or appreciation of mathematics beyond the A level specification. We describe the structure of the site in more detail in the next section. During this development phase, the project is working closely with a number of ‘partner schools’ from across England and is actively seeking feedback from teachers about the resources, especially feedback based on experiences of using the resources with students.

The CMEP site

The CMEP site houses the resources and teacher support materials. It is designed to work on smartphones and tablets as well as on interactive whiteboards and classroom computers. Site development is continuing in the light of teacher feedback.

On the CMEP site, A level mathematics content has been organised by theme along a system of ‘tube lines’ and this is intended to convey the themes and connectedness of the mathematics. Resources are housed at stations along the tube lines. Resource types include introductory investigations, problems to encourage multiple approaches, and review questions, many of which are from past A level papers or from the United Kingdom Mathematics Trust (<http://www.ukmt.org.uk/>). Most resources, including many of the review questions, are accompanied by hints and detailed solutions.

¹The thematic organisation of content is complemented by a section of the site devoted to the many important mathematical ideas that cut across themes and do not fit naturally at a single station. These ‘pervasive ideas’ have been grouped into three

¹ This final paragraph has been adapted from the text on the CMEP pilot site.

families: concepts, contexts and processes. The ‘concepts’ are mathematical ideas, such as linearity and symmetry, that occur across content strands. The ‘contexts’ family is about how mathematical ideas fit together in a bigger picture and includes historical background, applications of mathematical ideas to the real world and indications of how mathematical ideas come together in more advanced mathematical topics. The ‘processes’, for example, conjecturing, modelling and dimensional analysis, are about the ways in which mathematics is done. Each pervasive idea has its own page describing the idea together with some resources which have been specifically written to support the teaching of these ideas. Occurrences of pervasive ideas are also highlighted at stations because the project team believes that it is important and useful for students to be aware of these pervasive ideas as they study mathematics.

Partner schools

The project team is working with 45 partner schools recruited from across England. These include: 14 Further Education or Sixth Form Colleges; 25 Academies or Community Schools, of which 18 are comprehensives (i.e. not academically selective); one Voluntary Aided School; two Independent Schools; and three Free Schools. The approximate proportion of students who take A level mathematics in our partner schools ranges from less than 5% to more than 75%. Engagement with partner schools is via attendance at CMEP teacher workshops and visits to the schools by the project team. Feedback on the project is also collected via paper and online questionnaires, and focus group interviews.

The first wave of 27 partner schools were recruited in 2013 and include five ‘inner circle’ schools within easy reach of Cambridge with which the project had been working closely from its beginning. The remaining 22 schools in the first wave were identified by the project using data published by the Department for Education in fulfilment of project deliverables to engage broadly with providers of post-16 mathematics from across the sector. In order to ensure that the selected partner schools have sustainable A level mathematics cohorts such as to make engagement with the project at this stage worthwhile for the schools, one criterion for becoming a partner school was that the school must have entered at least 20 students in A level Mathematics in 2012. Collectively, the partner schools represented all geographical regions in England, included different types of schools and colleges, and had different profiles for A level mathematics results.

To supplement the first wave of partner schools identified by the project and to provide opportunities for engagement to interested schools, a call for expression of interest was published online and advertised at mathematics education conferences (e.g. the British Congress of Mathematics Education 8). A further 18 schools were recruited as partner schools in this second wave in 2014. All other schools which expressed interest in the project have been given ‘affiliate school’ status and access to the CMEP pilot site. So far, 61 schools are enrolled as affiliate schools.

CMEP teacher workshops

The workshops in Cambridge provide an opportunity for partner school teachers and the CMEP team to work together over three or four consecutive days. The teachers give detailed feedback on the resources and site, share their experiences of using CMEP resources and engage with wider aspects of the project. Active efforts have

been made to encourage workshop attendance amongst all partner schools. Teachers from 21 partner schools attended workshops in 2013, and a further 23 partner schools have been represented at workshops in 2014. Two more workshops are planned for 2015. Teacher feedback at workshops has been gathered through discussion, an open writing task, focus group interviews and an end-of-workshop questionnaire.

Evaluating CMEP

The initial funding period for the project runs from October 2012 to March 2016. This period spans changes in the content and structure of AS and A level Mathematics and Further Mathematics, the introduction of new Core Maths qualifications and changes in funding for post-16 students. Given that this is a period of considerable change in post-16 mathematics, it would be difficult to look at the impact of the project purely in terms of participation rates or A level grades. The evaluation will look at the depth and breadth of impact on teachers and students and whether any impact on teaching or learning can be attributed to the resources and site or to teachers' involvement in the project. Information for the evaluation has so far been gathered through the CMEP workshops, visits to schools, a departmental monitoring questionnaire and an evaluation questionnaire.

Evaluation questionnaire

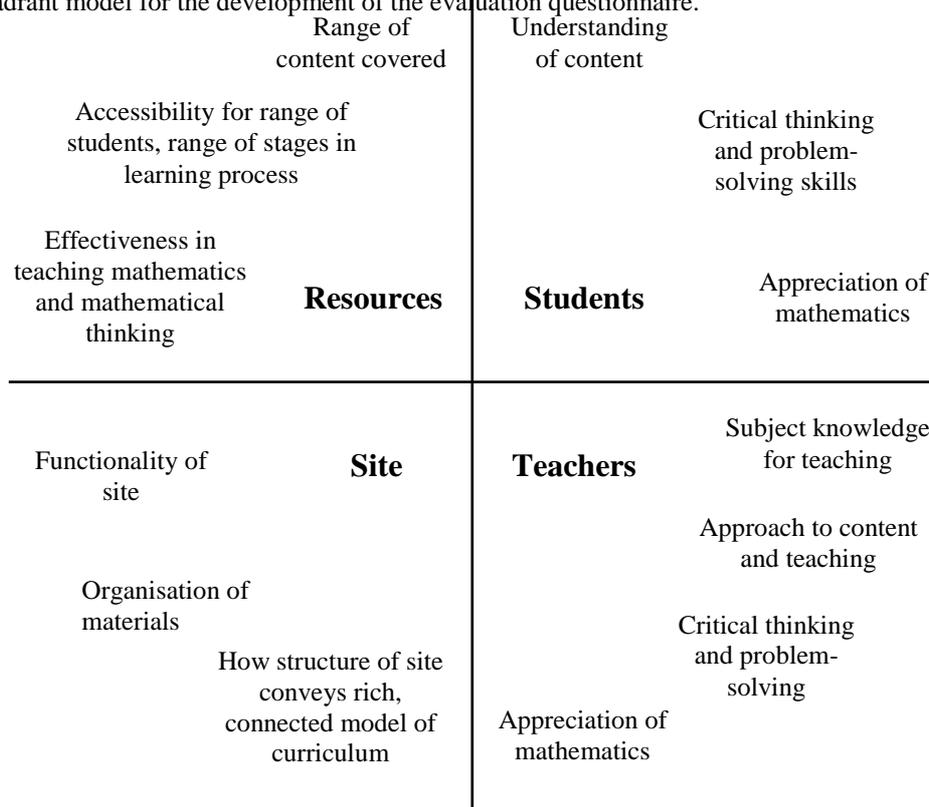
An online evaluation questionnaire for teachers has been developed and at the time of writing data is still being collected. Questionnaire items have been designed to capture a baseline for the project's summative evaluation and to gather teachers' views to feed into the development of the project. The questionnaire contains Likert scale items and open questions intended to probe teachers' attitude to the resources and site, and to gather views about their A level teaching. A number of items were developed from the Teacher Attitude Survey at the Kaput Center for Research and Innovation in STEM Education (2014). This instrument looks at how respondents view themselves as teachers, their preparedness to teach, and the emphasis given to various student objectives.

The evaluation team is not surveying students at this stage, but the evaluation questionnaire asks teachers about actions and behaviours of their students when they are learning mathematics. The project aims to support all A level mathematics students and therefore certain items are asked separately for students who are likely to achieve different ranges of grades at A level (A*-B, C-D, and E-U). Grades are grouped in this way in order to gather more information about the mathematical attitudes and needs of lower attaining students.

As part of the development of the evaluation questionnaire, a *quadrant model* based on four components of the project (Resources, Site, Teachers, and Students) was developed and the areas that we wanted to address for each component were identified, as shown in Figure 1. Questionnaire items were drafted for each of these areas. It should be noted that by 'Appreciation of mathematics' we mean seeing the study of mathematics as useful and worthwhile and believing in one's ability to learn new mathematics, as well as the enjoyment of mathematics. Within 'Approach to content and teaching' we include the belief that the essential themes and big ideas of A level mathematics can be conveyed to or uncovered by all students.

The evaluation questionnaire has been administered in two waves in the spring and summer of 2014. The first was for CMEP partner schools which had been involved with the project since summer 2013. The second wave was for partner

Figure 1: Quadrant model for the development of the evaluation questionnaire.



schools that were recruited in 2014 and is still being completed. At the time of writing, the questionnaire has been completed by teachers at 37 of the 45 CMEP partner schools.

In addition to the evaluation questionnaire, the evaluation team has developed a departmental questionnaire for the CMEP partner schools. This will be administered annually and captures information about the organisation of A level teaching at a departmental level, the mechanisms for additional support for students and how decisions are made about choice of teaching resources. Information gathered through this questionnaire will help to put feedback in context and it may also enable clustering of schools as the number of schools accessing the site increases.

The challenge of looking at impact on students - the use of CMEP resources in the classroom

In analysing the draft questionnaire items in relation to the stated aims and philosophy of the project, five student attributes emerged:

1. Ability to perform standard mathematical procedures.
2. Wider interest, engagement and enjoyment. Interest in the use of mathematics.
3. Awareness of connections within mathematics and using these to develop understanding of concepts. Taking different approaches.
4. Persistence and resilience, articulating ideas, reflection and learning from errors.
5. Problem-solving, recognising the affordances and limitations of existing mathematical toolkit.

Part of our research involves trying to identify how using the resources and site may help to develop these attributes but looking at the interaction between teachers, students and resources is not straightforward. Some teachers are choosing to develop their own versions of the resources and it is recognised that these adaptations may or may not be faithful to the original design principles. The project team is addressing the need for the site to communicate the philosophy of the project and there are plans to develop exemplar lesson plans for a few resources in order to support the flexible use of resources in line with the project philosophy. However, the way resources are shared within departments may limit the extent to which the site is able to support the use of resources: teachers at partner schools are sharing individual resources electronically or preparing folders of printouts. Although useful in terms of uptake of resources, this does not give the opportunity for mediation by the CMEP site.

Summary

The Cambridge Mathematics Education Project is seeking to support students and teachers of A level mathematics by developing resources that promote mathematical thinking and convey the connectedness of mathematics. A particular challenge is how teachers and students can be supported in using the resources in ways that reflect the philosophy of the project.

The evaluation team has conducted an extensive survey of teachers at partner schools to gather feedback on the resources and obtain information about teaching approaches and student behaviours when doing mathematics. The responses are being used in the development of the resources and will help to gauge the depth and breadth of impact of the project.

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