

## **Cambridge Mathematics Education Project: developing a framework for students ‘deep’ understanding in Key Stage 5 mathematics**

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This paper outlines the focus and activities of the Cambridge Mathematics Education Project’s (CMEP) evaluation process. In particular, it summarises the essential features of the case study research currently underway in Key Stage 5 classrooms across England. The case study research aims to evaluate the implementation of CMEP resources in classrooms, as well as investigate the types of learning environments and experiences the resources help to promote.

**Key words: CMEP; Key Stage 5 mathematics; evaluation; case study research**

### **Introduction**

The Cambridge Mathematics Education Project (CMEP), a five-year project launched in October 2012, develops online resources to support the teaching and learning of Key Stage 5 (KS5) mathematics. CMEP is a Department for Education (DfE) funded project, which aims to provide creative resources that help to make KS5 mathematics a richer, more coherent and more stimulating experience for students and teachers alike. CMEP seeks to:

- Provide a coherent and synoptic view of KS5 mathematics
- Make visible connections between ideas which pervade mathematics
- Encourage ambitious thought-provoking teaching and learning in every classroom
- Support teachers in the effective use of CMEP resources

Developed as a teacher resource for classroom use, CMEP aims to provide opportunities for students to engage with a rich body of mathematical knowledge. Primarily, this is achieved by designing tasks that encourage students to think mathematically when solving problems. It is hoped that such opportunities will support students to achieve a deeper understanding of mathematics.

### **CMEP Evaluation - Phases of research**

CMEP Evaluation (Evaluation) aims to support the Project by collecting and reporting data to support team decision-making, as well as ensuring teacher voice remains a central feature of CMEP iterative processes. The Evaluation sees the initial five years of the Project as divided into three phases, each with distinct research needs to facilitate smooth transitions across phases.

The first phase occurred between Project inception (September 2012) and August 2014 and served to develop an initial design for CMEP. The Project recruited 45 Partner Schools to ensure teacher feedback was systematically collected (see Feng and Kimber, 2014). Resource development was prioritised and feedback sought from

teachers at CMEP Partner Schools to iterate on the design processes and strengthen the definition of quality for CMEP tasks. Participating schools and teachers were provided with a log-in to the CMEP website/web resource, which is currently a closed site. The Project also worked closely with leaders in the mathematics education field. The Evaluation employed questionnaires, interviews, and focus groups with a wide range of stakeholders in KS5 mathematics, including Partner School teachers, representatives from Higher Education mathematics departments, and University of Cambridge Faculty of Mathematics academics and lecturers. The aims of data collection included seeking suggestions on possible innovations necessary for KS5 mathematics and the emerging A-Level qualification (scheduled to be first taught in 2017), and gathering direct feedback on original CMEP tasks. The large majority of the data was collected at seven residential teacher workshops attended by Partner Schools and hosted by CMEP at the University of Cambridge.

The second phase took place during the academic year, 2014-2015, and served as a proof of concept. During this time, CMEP residential workshops expanded their focus to support teachers in implementing CMEP tasks in their classrooms. Additional Continuing Professional Development (CPD) was offered by a CMEP partner, Mathematics in Education and Industry (MEI), to 12 cohorts of teachers across England. During this period, schools registering with CMEP as Affiliate School status – obtaining log-in access to the CMEP closed site – increased from around 100 to over 500. To reflect the increased use of CMEP resources in classrooms, the Evaluation engaged further with teachers within the Partner School network reporting as frequent users. This was to investigate how teachers engage with CMEP resources and how teachers self-report outcomes and impacts on teaching and learning. Data was primarily collected at two residential teacher workshops at the University of Cambridge as well as through surveys administered to the MEI CMEP CPD cohort.

The third phase of the Project is set to begin in the spring term of 2016 with the launch of the CMEP public site (without log-in requirements). As CMEP becomes better known and more widely used among KS5 providers, the Evaluation shifts focus towards how CMEP is implemented in different classroom settings. Data will be collected through case studies focusing on classrooms informed by CMEP. Case studies have been underway since September 2015 in identified Partner Schools. Schools from the MEI CMEP CPD network will also be invited to take part from January 2016.

### **Literature review and research questions**

The research questions for the Evaluation case study research are:

1. How is CMEP being implemented in KS5 classrooms?
2. What kind of environments and experiences promote mathematical thinking in classrooms informed by CMEP?

A review of the literature was integral to the research process to ensure the research was in line with current knowledge in the field of mathematics.

Influential to the development of the research are social constructivist views of learning, which emphasise the importance of society, culture, language and social interaction in the construction of new knowledge (Vygotsky, 1978). By adopting a social constructivist view, the Evaluation acknowledges the collaborative nature of classrooms in the construction of knowledge and draws attention to students as active agents in their cognitive development.

The research also draws on the work of scholars in mathematics education such as Boaler (2010), Mason, Burton, and Stacey (2010) and Swan (2006), as it aims to frame the outcome of deeper understanding in terms of the development of students' mathematical thinking. It is also cognisant of the role of classroom dialogue in the development of students' thinking and reasoning in mathematics (see Howe and Abedin, 2013).

### **Methodology and methods**

To investigate the types of environments and experiences that promote mathematical thinking in classrooms informed by CMEP, the Evaluation has chosen to conduct case study research. Case study methods are appropriate for an in depth investigation of the types of interactions and phenomena present in classrooms. More specifically, the approach seeks to respond to the complexity of classroom environments and the lack of control over behavioural events (Yin, 2014). Each case is defined as a single KS5 mathematics classroom.

The case study research design is exploratory: rather than seeking to provide insights on causation or correlation, it strives to “develop pertinent hypotheses and propositions for further enquiry” (Yin, 2014, p.10). These hypotheses and propositions will address issues such as resource design and the type of learning environments and experiences needed to support deep understanding in mathematics. Findings from the case studies will serve to inform future discussions with the DfE, provide feedback to the Project and learning for the wider mathematics community.

CMEP aims to engage in two types of case study. The first type, referred to as SOW (scheme of work) case studies, explores how Partner Schools who have self-selected to integrate CMEP tasks into departmental schemes of work engage with the resources. SOW case studies will involve data collection from September 2015 to July 2016. The second type, described as New User case studies, investigates how KS5 providers who are relatively new to CMEP engage with the content and begin implementing resources in their classrooms. New User case study data collection will take place from January to July 2016.

### ***Case study sample***

The sample of classrooms selected for the case studies is meant to be informative for CMEP. As a result, the schools/classrooms are not representative of CMEP users as a whole nor of KS5 providers in England, more generally. The sample was derived mostly from convenience sampling, with some focus on the types of schools with which the Project wanted deeper engagement for the purposes of Project learning.

SOW case studies were self-selecting from three schools (four teachers/classrooms) that informed the Project of their intention to integrate CMEP tasks into their schemes of work for 2015-2016. The Evaluation conducted initial visits to these schools in the summer term of 2015 and began data collection in the autumn term of 2015. All teachers participating in these case studies had previously attended CMEP teacher workshops in Cambridge.

New User case studies were selected from schools, which had signed up to the MEI CMEP CPD course in autumn 2015 and attended a first day (out of two days) training session before 1 December 2015. From these participants, a shortlist of teachers, who had agreed to be contacted for research engagement, was recruited. Schools were selected on key characteristics using data from the DfE public database: average point entry to KS5 mathematics for 2014 and Free School Meal (FSM)

status<sup>1</sup>. Cohort size was also considered to ensure that at least some schools have large cohorts (over 20 students enrolled in A level mathematics).

Identified schools were allocated to FSM bands and randomly sampled. Six were selected: two from the low FSM band, two from the middle FSM band and one from the high FSM band<sup>2</sup>. One provider without available data (due to the unavailability of 2014 data) was also selected. This enabled a new establishment, such as a studio school, to potentially appear in the sample. Although the chosen schools will not be representative of their FSM band, due to the sample size, exploration of potentially different classroom settings will inform the Project on possible future questions. It is hoped that at least four schools from the New User case study type will participate.

### ***Data collection***

Case study schools/classrooms are visited two or three times per term. The data collection methods are represented in Figure 1.

Figure 1 Data collection methods

<b>Data type</b>	<b>Detail</b>
Classroom observations	Notes recorded on an observation template developed by the Evaluation; informed by the literature and advice from relevant academics.
Video and audio transcripts	Classroom sessions video recorded (whole class) and audio recorded (individual groups of 2-6 students, with 6-12 groups per class).
Interview and focus group transcripts	Teacher interviews and student focus groups (3-4 students per group) conducted once per term.
Examples of students' work	Video recordings of groups or pairs working; images of students' work.
Quantitative survey data	Teachers complete a pre-task survey at the planning stage of using a CMEP task and a post-task survey following use of the same task in a lesson. Students complete a post-task survey. Teachers and students are encouraged to complete surveys whenever a CMEP task is used even when it is not an observed lesson.
Teacher diary	Teachers keep a diary of their reflections on using individual CMEP tasks. This activity is encouraged rather than prescribed and uses an online facility.

### **Case study framework**

To support data collection and analysis, the Evaluation has developed a case study framework (see Figure 2). Data will be collected and analysed through the lenses of

<sup>1</sup> DfE definitions of FSM bands were used: schools with low FSM have 20.0% or less of their pupils eligible for FSM; schools with medium FSM have between 20.1% to 35.0% of pupils eligible; schools with high FSM have greater than or equal to 35.1% of pupils eligible. Pupils' entitlement to FSM is often used as an indicator of deprivation. Schools with similar proportions of pupils eligible for FSM can be considered to be similar. (Retrieved from [http://www.education.gov.uk/schools/performance/2013/secondary\\_13/s10.html](http://www.education.gov.uk/schools/performance/2013/secondary_13/s10.html))

<sup>2</sup> Only one school fell into the high FSM band from MEI training attendees willing to engage in further research activity

classroom ‘environments’ and ‘experiences’ (see research question 2 above). This reflects the Project’s understanding that student learning will be enhanced as a result of exposure to certain classroom experiences and environments. The Evaluation does not aim to delineate all possible experiences and environments (as many might be relevant), but rather to concern itself with those of particular interest to the Project.

In the context of the CMEP case study research, ‘environments’ refers to two key areas. First, the physical environment in the mathematics classrooms observed, for example, the arrangement of tables, where students sit, students’ gender and ethnicity, and the type of equipment used during lessons. It also refers to the teaching and learning atmosphere, for example, a supportive (or unsupportive) atmosphere and classroom language (e.g. discursive versus didactic). ‘Experiences’ can be defined as those learning experiences, which help students to develop their mathematical thinking.

The Evaluation is aware of the potential overlap between the above definitions. For example, Mason et al. (2010) refer to questions as part of the “Mathinking atmosphere” of classrooms (p.139). Given the use of the word ‘atmosphere’, this could be construed as part of the classroom environment. Equally, questions – students being exposed to a range of questions in their mathematical learning – could be viewed as an experience.

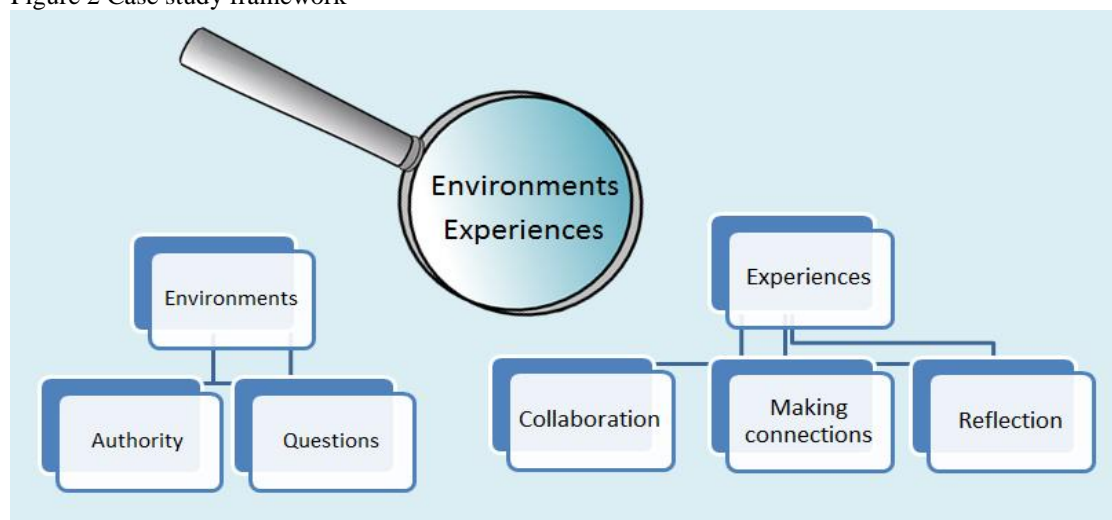
In considering which themes to include under each lens, the Evaluation considered areas of value to the Project. The following were identified as significant:

- Authority – Where does the authority lie in the observed lessons? Does it lie with the teacher, the students, the mathematics, or with the examination?
- Questions – the types of mathematical questions used during CMEP lessons
- Collaboration – students collaborating with each other to solve problems
- Making connections – students making connections across mathematics
- Reflection – opportunities for students to reflect on their learning (or students becoming more aware of the process of reflection whilst solving problems)

These themes have been categorised under one of the two lenses (see Figure 2) while recognising possible overlaps. Research design, data collection, and analysis will be carried out with a view to investigating these themes.

A coding tree for the analysis of qualitative data will be employed for each theme, providing the possibility of an in depth focus on selected themes as the research progresses, as well as general learning across themes. This learning will be triangulated with learning from survey data (also designed to capture data on the themes) and the classroom observation template, which serves to capture many of the physical aspects of the classroom environment.

Figure 2 Case study framework



### Research limitations

Findings from the SOW case studies are subject to bias in that they are self-selecting. However, the study does not seek to infer findings to a wider population. Rather, the research takes the approach of offering possibilities of what could be achieved with CMEP while discussing influencing factors. Similarly, the MEI CMEP CPD is a small sample of participating schools to date. The Evaluation does not perceive this as an issue given the case study, exploratory, non-experimental nature of the research.

### Conclusion

The case study research provides an opportunity to explore the innovation in mathematics education proposed by CMEP at KS5. It recognises the potential of learning – the result of research findings – for the mathematics community, as well as for task designers. Findings from the case studies will be used to inform future evaluation and research activities in the academic year 2016-2017.

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