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HOW NON-TRADITIONAL MATHS STUDENTS FEEL ABOUT THE SUBJECT AND HOW THEY THINK IT'S BEING TAUGHT

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In England, a relatively new set of post-16 qualifications has been developed under the umbrella term 'Core Maths', with a focus on the application of mathematics in context, including the kinds of mathematics needed to support other subjects, to provide a sound basis for the mathematical demands of higher education and employment and to develop problem-solving skills for use in life. The UK government has an ambition that all post-16 students should be studying some mathematics, and Core Maths was designed in part with this aspiration in mind. In this paper, longitudinal questionnaire data from over 100 Core Maths students in 13 case study institutions are analysed to measure students' views of teaching as transmissionist, their mathematical dispositions and self-identification and how these change over a year of studying Core Maths. We find some evidence that pedagogy in lessons is perceived as being less transmissionist than it was in school mathematics pre-16. There is also some evidence of a negative change in students' mathematical dispositions over a year of Core Maths. We conclude that supporting teachers in embedding new pedagogical approaches remains a challenge and that this issue could inhibit the growth of new qualifications like Core Maths.

1. Introduction

1.1. Overview

A relatively new set of post-16 qualifications was introduced in England in 2014 ('Core Maths'), with the central aim of significantly increasing post-16 participation in mathematics. We begin this paper by outlining the motivations behind this important curriculum innovation in England and then detail the key issues that this paper is focused on: the extent to which student attitudes to mathematics, and their views on the teaching in their mathematics lessons, change over the course of a year of experiencing teaching of this new qualification.

1.2. Post-16 mathematics education policy and rhetoric in England England currently has one of the lowest rates in the developed world of students who study 'advanced' mathematics: around a fifth of students continue to study mathematics, after taking their compulsory General Certificate of Secondary Education (GCSE) qualifications at the age of 16, when mathematics ceases to be part of the compulsory curriculum. This makes England an outlier (Hodgen et al., 2010) in terms of participation in post-16 mathematics.

One of the main policy drivers for increasing participation in post-16 mathematics is an economic one (Her Majesty's Treasury, 2016; Noyes & Adkins, 2016; Smith, 2017): the shortage of mathematically literate school leavers is widely characterized in England as a disadvantage to the nation in

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economic terms (British Academy, 2015). There is also a strong argument that a good level of mathematical and statistical literacy is increasingly important for the social health of the country, as it enables citizens to understand the many aspects of the world around them and to participate fully in a modern, scientifically and technologically developed democratic society (British Academy, 2012; Gowers, 2014).

It has also long been argued by the higher education (HE) sector in the UK that many students lack the mathematical skills, knowledge and confidence necessary to benefit fully from university courses onto which they have enrolled (Advisory Committee on Mathematics Education, 2011; Hodgen et al., 2014; Glaister, 2017; Hodgen et al., 2018). Hodgen et al. (2014) demonstrate that only a relatively small number of students are well prepared by their schools and colleges to access HE courses in mathematically demanding subjects.

1.3. Core Maths:

a new post-16 qualification There is widespread political ambition in England that the vast majority, if not all, students should be studying mathematics in some form to the age of 18 (Smith, 2017). It is estimated that 330,000 entrants to university annually would benefit from having had recent experience of studying some advanced (post-GCSE) mathematics, including statistics, but that fewer than 125,000 actually do so each year (Advisory Committee on Mathematics Education, 2011). The desire to increase post-16 participation rates in mathematics was echoed in 2013 in the policy statement on the introduction of Core Maths, which states the ambition for ‘the overwhelming majority of young people in England to study mathematics at least to age 18 by 2020.’ (Department for Education, 2013, p. 3).

Core Maths’ refers to a suite of post-16, mathematical qualifications designed for students who have achieved at least a grade 4 in GCSE, a ‘standard pass’ achieved by approximately 71% of the cohort each year (Ofqual, 2017; Ofqual, 2018), and who do not enrol onto A-level Mathematics, the longstanding academic post-16 mathematics route. Designed to fit alongside a student’s main 16–18 programme (Department for Education, 2013), it can be taught over 1 or 2 years. Core Maths is therefore a key element of the government’s strategy to address the 16–18 ‘maths gap’ in England whereby a large proportion of students do not study any mathematics for 2 years immediately before going into employment or HE (Department for Education, 2013).

The qualifications aim to develop students’ mathematical understanding and application of mathematics in ways that are valuable for further study and employment across a range of areas and to use mathematics to solve real-life problems (Department for Education, 2018). They allow students to build on the mathematics they learned at GCSE up to age 16, to develop valuable numerical and quantitative skills for life and work, but the course has less focus on introducing new content and more on the deeper understanding and applying of existing mathematical knowledge in a range of real-world contexts and applications.

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Research has shown repeatedly that students do not generally see how traditional school mathematics (i.e. GCSE or A-level) is either useful or relevant to them (Brown et al., 2008; Sealey & Noyes, 2010; Hodgen et al., 2017). Core Maths is intended, therefore, to have broader relevance than other mathematics courses (mainly GCSE) which students in England might previously have experienced (Department for Education, 2018).

Since first teaching in 2014, with first examinations in 2016, there has been steady growth in the numbers of students taking Core Maths qualifications. There were approximately 3,000 examination entries in the first cohort (2016), 5,300 entries in 2017, 6,800 in 2018 and 9,000 in 2019 (MEI, 2019). However, there remains considerable scope for growth in the numbers of students taking this qualification, and the uptake has yet to reach anywhere near the level matching policy aspirations around post-16 participation in mathematics in England.

More details about the policy background, and the technical details of the full set of Core Maths qualifications, can be found in an earlier paper (Homer et al., 2018) and government publications (Department for Education, 2018).

1.4. Pedagogical approaches to the teaching of mathematics

Since the 1970s, starting with Freudenthal and colleagues, who argued for mathematics teaching that connects with the life experiences of the learners, there has been extensive research in mathematics education on the use of context in mathematics, sometimes including realistic contexts or real-life experiences and models, but, crucially, recognizing the necessity of making the mathematics 'real' in the students' mind (Freudenthal, 1983; Van Den Heuvel-Panhuizen, 2003; Dickinson et al., 2014). Across the world, the extent to which 'real-world' contexts, or perhaps more accurately, non-mathematical contexts and approaches, are emphasized in mathematics curricula and content varies, and the extent to which practice reflects policy rhetoric is sometimes weak (Smith & Morgan, 2016). In the compulsory phase in England, evidence suggests that such contextualized approaches do not sit well with the assessment system employed (Dickinson & Hough, 2012), which, in turn, implies that many teachers and students in England have limited experiences of such teaching and learning in mathematics classrooms up to the age of 16. Yet the use of such appropriate mathematical and non-mathematical contexts and models in mathematics has been shown to yield positive outcomes for both students and teachers. Various studies in different countries such as Turkey, Greece and the UK (Dickinson & Eade, 2005; Searle & Barmby, 2012; Hough et al., 2017; Papadakis et al., 2017) have found positive outcomes in terms of students' attitudes, interest and engagement in mathematics, improved problem-solving skills and also greater positivity from teachers about use of context in mathematics (Cambridge Mathematics, 2019).

For Core Maths, with a greater stated emphasis on non-mathematical contexts and applications in the policy documentation

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(Department for Education, 2013), pedagogical approaches are likely to require, for example, the use of more tasks of an open-ended nature, more connections made between different mathematical topics and more activities where students take the lead in their learning (Dickinson & Eade, 2005; Hough et al., 2017). Elements of such approaches to teaching are sometimes referred to in the literature as connectionist pedagogy, where the word 'connectionist' is deliberately employed in reference to effective mathematics teaching with two different meanings: firstly, teaching connected to students' mathematical understanding and products (so typically student centred, with dialogue, discussion and mathematical communication) and secondly, teaching that makes connections between different mathematical areas and between mathematical and non-mathematical knowledge (Askew et al., 1997; Swan, 2006; Pampaka & Williams, 2016).

Connectionist approaches to the teaching of mathematics are known to be related to developing more positive student attitudes with regard to mathematics, which can then in turn improve mathematical attainment, and students' propensity to continue studying the subject (Pampaka et al., 2012; Pampaka & Williams, 2016). In contrast, more transmissionist teaching approaches are those that are typically more teacher centred, where mathematics teaching is broadly conceived as a set of rules that are to be passed on to students (Swan, 2006). The evidence suggests that transmissionist approaches to mathematics teaching are commonly practised in English compulsory schooling, both pre- and post-16 (Pampaka et al., 2012; Smith, 2017; Golding et al., 2018).

In contrast with other post-16 mathematics qualifications, within Core Maths specifications, a minimum of 20% of the course is required to be new mathematical content (Department for Education, 2018). Alongside the focus on real-world application of mathematics, this implies that there is scope, or perhaps the necessity, for the development of different teaching approaches in comparison with pre-existing, more traditional, mathematics courses such as A-level where the emphasis is more on developing knowledge of new content and of more advanced mathematical techniques (Glaister, 2017).

1.5. Student attitudes to mathematics:

self-identification and disposition There is a long-running literature regarding the measurement of 'attitudes to mathematics' such as beliefs, values, self-efficacy and motivation (Fennema & Sherman, 1977). Recent work revisits a range of the issues and definitions of particular constructs (Lim & Chapman, 2013). In this paper, in terms of particular attitudes being measured, we focus on two constructs that were developed specifically for measuring Core Maths students' attitudes to mathematics and how these might change over the course of studying Core Maths:

(1) Mathematical self-identification (Pampaka & Williams, 2018), which is the extent to which students feel that they self-identify with mathematics in the present.

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This can be measured quantitatively using strength of agreement with items such as

I have a mathematical mind.

There are people in my close family who like maths.

(2) Mathematical dispositions (Pampaka & Williams, 2018), which measures the extent to which students feel mathematics will be important to them in the future, in terms of their mathematical intentions and aspirations. This can be measured using items such as

Maths is useful for making decisions in daily life.

Maths is important for my future career

The instruments we employ, of which we give full details in the Methods section, were originally developed largely for use with Core Maths students during its early pilot phase in a cross-sectional validation study (Pampaka & Williams, 2018). In the current study, we use these instruments longitudinally to measure change in self-identification and dispositions.

These constructs can be considered as important learning outcomes of mathematics courses. There is evidence in England that school mathematics is often lacking in relevance to students and is focused on preparing for and passing examinations rather than on developing genuine mathematical understanding (Smith, 2004; Lewis, 2016). In such contexts, where prior mathematical preparation and experiences in mathematics classrooms are perceived as negative, there is clear scope for a new and different post16 qualification that impacts positively on student self-identification and dispositions. Furthermore, evidence also suggests that, for a wide ability range, developing more positive attitudes to mathematics can be the difference between those who succeed in the subject and those who do not (The Royal Society, 2008; Pampaka et al., 2011). Pampaka et al. (2011) also stress that any study which sets out to examine the effectiveness of mathematics education in terms of attainment alone, and does not consider student attitudes to mathematics, will be of little use in understanding what is going on in the mathematics classroom and in helping in the efforts to increase participation in mathematics and numerate disciplines more broadly.

1.6. The aims of the current paper

Given the policy imperative of increasing post-16 mathematics participation in England, and the development of Core Maths as a potential contribution towards this goal, there is obvious research interest in understanding how students perceive and experience this new course. The overall aim of this paper, then, is to investigate quantitatively students' experiences of Core Maths in the wider context of a compulsory pre-16 mathematics curriculum that has generally been regarded as quite alienating to a large proportion of students (Brown et al., 2008). The findings of this research will contribute to the growing evidence base (Homer et al., 2018; Golding et al., 2018; Mathieson et al., 2020) focused on whether Core Maths is likely to provide a successful post-16 pathway in mathematics—in terms

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of uptake, attainment, mathematical capability and so on—for the large number of potential students for whom it was designed. It also adds to the international evidence on the impact new mathematics curricula can have on student experiences and attitudes to mathematics.

This paper considers the following two research questions:

RQ1 What are students' perceptions of pedagogical experiences of Core Maths, and how do these compare with those of their pre-16 (GCSE) mathematics classes?

RQ2 Is there any evidence of changes in Mathematical self-identification and Mathematical Dispositions over the course of a year of Core Maths?

To answer these questions, we use quantitative questionnaire data as detailed in the next section of this paper.

2. Methods

2.1. Questionnaires to Core Maths students in case study institutions

Our questionnaire data derive from a study investigating the successes of and challenges faced by Core Maths in its first few years of implementation (Homer et al., 2018). The study explores the views and experiences of Core Maths students, mathematics teachers and managers within 13 English schools and colleges where the Core Maths course forms part of the post-16 curriculum (Homer et al., 2018). The set of 13 institutions was chosen to cover a range of post-16 institutions by geographical region and institution type. Appendix A.1 presents a table of these institutions (pseudo-anonymized) with details of their key characteristics, including the range of Core Maths specifications that they cover.

To gather views at the start of the academic year, the first round of fieldwork took place in September 2017 and consisted of questionnaires and interviews with students and teachers. Follow-up visits took place in May 2018. A sister paper reports in more detail on the qualitative data from these visits (Mathieson et al., 2020)

2.2. Transmissionist teaching scale

The questionnaire, administered to all Core Maths students, began with a brief demographic introduction (gender, year group, year of completion of pre-16 schooling and attainment in mathematics at 16, i.e. GCSE Mathematics).

In the first administration of the questionnaire (September 2017), it included a set of 11 scale items entitled 'Your experiences of mathematics lessons' which referred to students' pre-16 (i.e. GCSE) experiences. In May 2018, the same set of questions were asked but referred to views on the Core Maths lessons which had taken place over that academic year.

This section measured the extent to which mathematical classroom practices were perceived as transmissionist (Schuh, 2004; Pampaka & Williams, 2016; Pampaka & Williams, 2018). This measure (which we refer to as transmissionist teaching scale) is based directly on Pampaka & Williams's (2018) work with Core Maths students. It allows us to see if there is any evidence that

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perceptions of pedagogical approaches in mathematics lessons were different—perhaps less transmissionist—in Core Maths lessons (post-16) in comparison with GCSE (pre-16). Items measure student perception of the frequency of particular activities in class. Example items are

• We discussed our ideas.

• We compared different methods for doing questions.

• The teacher drew links between topics.

According to the UK Department for Education (2013), Core Maths is intended to

'develop students' mathematical understanding and application of maths in ways that are valuable for further study and employment across a range of areas... and will build skills in applying maths to new problems and issues'.

This is in contrast to the pre-16 mathematics curriculum (e.g. GCSE Mathematics) which has been characterized as disaffecting and demotivating, in part due to pedagogical practices and broader systemic issues (Smith, 2004; Lewis, 2016, Chapters 1 and 14).

Appendix A.2 lists all these items and details the response format employed.

2.3. Mathematical self-identity and dispositions scales

The final section of the questionnaire consisted of a set of 18 scale items headed 'Your feelings about mathematics', based again on Pampaka & Williams's (2018) work which developed measures of Mathematical self-identification (nine items) and mathematical dispositions (nine items).

Appendix A.3 presents full details of these two sub-scales. Example items are

I can get good results in maths Mathematical self-identification item I look forward to studying more mathematics when I leave school Mathematical dispositions item

There were a few very minor word changes to the questionnaire between the two administrations (September 2017 and May 2018) to reflect the different experiences being captured at the two time points. In essence, in the study, we are looking for evidence of any change in student perceptions of teaching approach (compared to GCSE) and mathematical self-identification/dispositions over the course of a year of Core Maths, perhaps as a result of different classroom experiences of what mathematics learning can be like when comparing pre-16 (GCSE) mathematics and post-16 Core Maths.

2.4. The achieved longitudinal sample

It was not possible to collect questionnaires from all Core Maths students in all institutions at either visit. A range of factors, such as student absence at one data collection time point or the other, reflect the sometimes challenging reality of empirical data collection in institutions. In September 2017, 203 students completed the first questionnaire (median sample size within 13 schools/colleges = 7), 106 of whom also completed the second questionnaire in May 2018 (see Appendix A.1). The analysis reported on in this paper focuses entirely on

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the 100 students across 11 institutions (median size in each institution = 8) for whom we have complete data at both time points and who stated that they were in their first year of Core Maths study. In terms of the representativeness of this sub-group of 100 students, we find that there is no difference between them and the wider group of 203 case study students in terms of gender balance, GCSE attainment, views on teaching of mathematics and attitudes to mathematics measures (from the first questionnaire administration in September 2017). It was impossible to investigate student and institutional factors which might show variation across our three measures, given the relatively small sample size achieved.

2.5. Reliability of scales

We use the standard measure of reliability, Cronbach's alpha (Field, 2013, p. 706), to assess the internal consistency of each of the scales. Values of alpha typically above 0.7 indicate that the individual items in the scale are measuring well a single overarching construct, although these standard cut-off values are somewhat arbitrary. We also investigate whether individual items detract from the reliability and where they do we use the standard practice of removing such problematic items (Field, 2013, p. 715). This maximizes the scale reliability, which is important, particularly when alpha values are initially below 0.7.

Transmissionist teaching scale

With three items appropriately reverse coded (Appendix A.2), Cronbach's alpha is 0.67 for all 11 items during the first questionnaire administration in September 2017. One item (The teacher encouraged us to work more quickly) seriously detracts from the reliability, which means that the scale reliability is higher and reaches the standard threshold for acceptability of 0.7, if this item is excluded. It is worth noting that this is a reverse coded item, which might in part explain its poor psychometric performance compared to the other items in the scale. Removing this item results in a 10-item scale with alpha = 0.72 for which we calculate a mean score. This is our measure of perceptions of transmissionist teaching at GCSE (September 2017) and then Core Maths (May 2018). Higher scores correspond to stronger perceptions of transmissionist teaching, and values of this measure can be interpreted on the same scale as the individual items.

Mathematical self-identification scale

For the nine-item self-identification sub-scale (Appendix A.3), alpha is low (0.56) in the first administration, and removing I like using maths I am familiar with, rather than new maths topics and I often need help with maths (both reverse-coded items) improved alpha to 0.62. The mean of the seven remaining items is our measure for this construct; higher scores correspond to stronger mathematical self-identification.

2.5.1. Mathematical dispositions scale. The nine-item dispositions sub-scale (Appendix A.3) has alpha = 0.83. One item, Maths is useful for making decisions in daily life, slightly detracts in the first administration (alpha deleted = 0.84). We have decided to keep to the nine items and form a mean score as the measure of mathematical

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dispositions. Higher scores correspond to more favourable dispositions towards mathematics.

2.5.2. Relationship between these two measures. In the first administration, the two sub-scales, mathematical self-identification and mathematical dispositions, are positively correlated ($r = 0.58$, $n = 100$, $p < 0.01$; disattenuated correlation, accounting for measurement error, $r = 0.81$). This is evidence that they are indeed measuring distinct, but related, traits and gives us confidence that they are best treated separately in the remaining analysis.

2.6. Statistical methods of analysis

We use a range of relatively simple descriptive, summary and inferential approaches (e.g. paired sample ttests) to analyse the outcomes of the three scales in question and to assess any degree of changes in these. In discussion of findings, we focus on effect sizes rather than on p-values, since the correct interpretation of the latter has a long and problematic history (Wasserstein et al., 2019). In addition, for completeness, we account for the multi-level structure of the data (students nested in schools) in separate analyses, in order to complement the statistical t-test analyses (Goldstein, 1995). In these multi-level models, we use a variance components, random intercept model for the change in scores (with no co-variates), to assess whether the intercept (i.e. the estimate of the overall change) is significantly different from zero.

3. Results

3.1. Demographics and prior attainment at 16

The sample of respondents was quite equally balanced by gender (52% male, 48% female), while, in terms of attainment in mathematics at 16, the mean GCSE grade in the sample was 5.41 (standard deviation (SD) = 0.95). A grade 5 (or above) is commonly perceived as a ‘strong’ pass grade and approximately 50% of students are typically awarded at least a grade 5 at GCSE (Ofqual, 2017; Ofqual, 2018.

3.2. Transmissionist teaching approach (RQ1)

The mean value of this ten-item scale in the first administration in September 2017 was 2.48 (SD = 0.43) indicating that the activities in Appendix A.2 (e.g. We chose which questions/problems to tackle) are perceived to have taken place in GCSE classes between rarely (=3) and sometimes (=2) on average. In the second administration in May 2018, when the same questions were asked, but about Core Maths lessons, the mean had decreased to 2.38 (SD = 0.38) (paired t-test, $t = 2.20$, $df = 99$, $p = 0.03$, Cohen’s $d = 0.27$; the p-value for the corresponding multi-level model is $p = 0.018$).

This indicates that students reported that teaching in Core Maths classes was a little less transmissionist than teaching at GCSE ha

3.3. Mathematical self-identification (RQ2)

In the first administration, the seven-item scale had a mean and SD of 3.54 and 0.48, respectively. For the items in Appendix A.3 (e.g. I have a mathematical mind), this indicates that students typically responded between unsure (=3) and agree (=4).

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In the second administration, the mean had barely changed (mean 3.52, SD = 0.51) (paired t-test, t = 0.53, df = 99, p = 0.60, Cohen's d = 0.05; p = 0.42 for corresponding multi-level model).

In summary, there was no evidence of an overall change in mathematical self-identification between the two time points.

3.4. Mathematical dispositions (RQ2)

In the first administration, the nine-item scale had a mean and SD of 3.41 and 0.56, respectively. Again, this indicates that students typically responded between unsure (=3) and agree (=4) to items like Maths is useful for making decisions in daily life (Appendix A.3).

In the second administration, this had significantly decreased to 3.19 (SD = 0.60) (paired t-test, t = 4.03, df = 99, p < 0.01, Cohen's d = 0.37; p = 0.001 for corresponding multi-level model).

• This indicates that students' mathematical dispositions had declined overall between September 2017 and May 2018.

4. Discussion and conclusion

4.1. Pedagogical experiences of a new mathematics course

We have found some evidence that experiences in Core Maths classes are perceived by students as less transmissionist than their experiences at GCSE (Cohen's d = 0.27), although this effect is not particularly strong. This study did not include formal lesson observation, but we did informally observe classes in all our case study institutions. We found a wide variety of overall lesson styles, ranging from traditional (i.e. transmissionist) approaches, to those that were arguably more in the spirit of Core Maths as more connectionist and less transmissionist (Pampaka et al., 2012; Pampaka & Williams, 2016). Given the relatively innovative nature of Core Maths in England, with a focus on mathematics as a problemsolving process (Department for Education, 2013), it might not be easy for teachers used to working in accountability-driven and performative environments to change their practice to make the mathematics sufficiently 'real' for students (Ball, 2003; Van Den Heuvel-Panhuizen, 2003; Golding, 2017). Hough et al. (2017) also point out the likely need for specific pedagogical training for teachers of Core Maths, and the need to develop the pedagogy of Core Maths teachers is one recognized by the government and other stakeholders (Department for Education, 2013, p. 4; Smith, 2017; Advanced Mathematics Support Programme, 2019). Further research is required to investigate how successful the professional development of Core Maths teachers might be in changing both teacher beliefs and practices (Askew et al., 1997; Swan, 2006), and whether any such changes might spread beyond Core Maths into other mathematics classrooms (Golding, 2017; Golding et al., 2018).

4.2. Changes in mathematical self-identification and dispositions

We have found that Core Maths students are not particularly well disposed towards mathematics, at both the beginning and end

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of a year of Core Maths teaching. Beyond this, when we look at our data longitudinally, we have evidence of little change in mathematical self-identification, and a decline in mathematical dispositions, in our student respondents over this year (Cohen's d = 0.05, 0.37, respectively). This indicates that students have not really changed the extent to which they collectively perceive mathematics as useful to them now (self-identification). However, they are also less inclined to think that mathematics will be useful to them in the future than they were on finishing their compulsory schooling (dispositions) (Pampaka & Williams, 2018).

One might have hypothesized that a more application-focused mathematics course, intended to be more relevant to students, would engender more favourable opinions towards the studying of mathematics (Pampaka & Williams, 2016). However, while we do not yet have sufficient data to comment more extensively on our findings that this is not the case, one possibility is that what students are doing in Core Maths is not typically thought of by them as 'real' mathematics, in comparison with their experiences of school (GCSE) mathematics (Mathieson et al., 2020). There are parallels here with debates in the science education literature, and students' views on definitions of 'science' versus 'school science' (Tytler & Osborne, 2012; Roberts & Bybee, 2014). An important area for further research could investigate in detail Core Maths students' views on what mathematics is, what it is for, and whether these perceptions change over the time they study Core Maths.

One final comment here is that there is a lot of variation in practice at the institutional level in terms of how CM students are enrolled onto the course, whether by choice or by being directed onto it by their institution (Mathieson et al., 2020). In terms of self-identity/dispositions on entry to post-16 programmes, we do not have data on how those studying Core Maths compare to students not studying the subject. Our evidence suggests that the former group do not score particularly highly on either of our scales, but more research could investigate how typical the Core Maths group is of the broader cohort in this regard.

4.3. The impact of local enactment of Core Maths

We have found that many institutions are teaching Core Maths in a year (Appendix A.1), rather than in 2 years as originally intended (Department for Education, 2013). This might affect the student experience, in terms of the pedagogy employed, and/or the impact on changes on mathematical selfidentification/disposition. However, we do not have enough data to explore this effect fully from a quantitative point of view in the current study. What we know from this and other work is that the implementation of Core Maths is varied, in terms of length of course, how students are recruited onto Core Maths, and how the subject is aligned with the main programme of study (Mathieson et al., 2020). There are also important variations in the 'positioning' of Core Maths across institutions in the sense of where Core Maths fits in the mathematics course/qualification 'hierarchy', something we have investigated

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in other work (Mathieson et al., 2020) and which remains of keen interest to policy makers (Smith, 2017). These factors, alongside the extent to which teachers have access to sustained professional development opportunities, are likely to influence pedagogies and associated changes in student selfidentity/dispositions over the period of studying Core Maths.

4.4. Methodological reflections and study limitations

There are some important limitations to this study. Perhaps the most obvious is that the achieved longitudinal sample size is relatively small (n = 100) and there is significant attrition from the first administration of the questionnaire (sample size = 203). Our data comes from students who both stayed on the course and in the study, and we do not know what the perceptions of the wider original group might be. In addition, the small sample size means that meaningful quantitative analysis of institutional variation is not possible. We know from our qualitative work that different modes of implementation across institutions are important in influencing student experiences and perceptions of Core Maths (Mathieson et al., 2020).

From a psychometric point of view, the mathematical self-identification scale is not particularly reliable (alpha = 0.62 for seven items), suggesting that perhaps this scale needs more development, or perhaps that the construct needs further theoretical consideration and development (Wilson, 2004). This might be important when applying the scale to students doing a course like Core Maths, which is quite different in purpose to more traditional, content-focused, mathematics courses. When looking at longitudinal change for this scale, it might be that some items are unlikely to exhibit change in response. For example, this might especially be true of those items that refer to parents/family/carers (e.g. My parents/carers like maths).

Finally, it is worth stating that both items that were removed from the original self-identification scale were reverse coded (Appendix A.3), perhaps indicating that students did not always pick up on this when responding. The mathematical dispositions scale certainly performed better from a technical point of view (e.g. alpha = 0.83 on nine items).

4.5. Conclusion

In this paper, we have presented evidence that students perceive teaching in Core Maths lessons to be a little less transmissionist than during GCSE. However, in our data, self-identification and disposition with regard to mathematics do not show any positive development between the beginning and end of an academic year studying Core Maths. Clearly, if the UK government’s policy ambition of (many) more students studying post-16 mathematics is to be realized, in part through much higher participation in Core Maths, we need more quantitative and qualitative research to improve our understanding of Core Maths enactment in the diverse post-16 landscape in England. This will provide evidence to inform all stakeholders of how best to ensure wider participation in post-16 mathematics in England.

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5. Ethics

This project was subject to ethical review and received a favourable opinion by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee at the University of Leeds (reference: AREA 16-066) on 18 January 2017.

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Appendices

A.1. Case study institutions

Case study institution	Institution type	Region of England	Core Maths specification[1]	Length of course (years)	Number of respondents	
					September 2017	September 2017 and May 2018
Ball Comprehensive School	11–18 school	North East	AQA	2	2	0
Bismut Academy	11–18 school	East Midlands	OCR	1	17	0
Donaldson High School	11–18 school	West Midlands	AQA	2	16	8
Lions Academy	11–18 school	East Midlands	OCR	1	31	15
Mumford High School	11–18 school	Yorkshire and Humberside	OCR	2	25	8
Palis High School	11–18 school	London and the South East	Edexcel	2	5	2
Coates Studio	14–19 studio school	North West	AQA	1	6	4
Rousseau UTC	14–19 UTC	West Midlands	AQA	2	6	5
Arnold College	General FE college	West Midlands	AQA	1	14	9
Jones College	General FE college	North West	AQA	1 and 2	9	3
Dickenstein SFC	Sixth Form College (16–19)	Yorkshire and Humberside	OCR	1	51	29
Mori SFC	Sixth Form College (16–19)	North East	Edexcel	1	9	8
Viana SFC	Sixth Form College (16–19)	North West	AQA	2	12	9
Total					203	100

[1] AQA, Edexcel and OCR are the main awarding organizations in England that set examinations and award qualifications