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Changing images of mathematics in the transition from school to vocational education

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Abstract

Public perceptions of mathematics in England are often of a remote inaccessible academic discipline, and disaffection with the subject is a widespread problem. Results from a multi-method study of post-16 students in vocational education in England show however how students' experiences of mathematics after their transition from school to vocational education can lead to changes in their beliefs, emotional responses and attitudes to mathematics. The construct of a personal image of mathematics provides a model to capture these changes and leads to an examination of the features of students' learning experiences that allow positive images of mathematics to develop. Negative images are often grounded in prior experiences of failure and disaffection at school but exposure to a mathematics curriculum with a focus on application rather than knowledge, in a different educational setting, helps students develop an alternative view of the subject to the common image in society. Experiences of a different teaching approach also contribute to these new images, whilst shifts in students' values make their new encounters with a more applied form of mathematics particularly relevant.

Key words: Mathematics, images, affect, vocational education.

Introduction

An extensive review of post-16 mathematics education in England (Smith, 2017) highlighted the prevalence of poor attitudes to mathematics in society and the need to gain better understanding of this problem. Negative views of mathematics have been reported for some time in England (e.g. Buxton, 1981; Cockcroft, 1982) without evidence of any improvement or how this might be achieved. Although dominant attitudes in some countries differ, England is not alone in identifying negative attitudes to mathematics permeating society (Basic Skills Agency, 1997) and public images that commonly capture the subject as being remote and inaccessible (Ernest, 2008; Leder & Forgasz, 2010). Mathematics has historically been considered in many countries as the domain of a select minority with special ability (Buxton, 1981; Picker & Berry, 2000; Volmink, 1994) leading to contrasts between the views of mathematicians and the general public (Furinghetti, 1993). Impressions of secrecy, exclusivity and a 'gate-keeping' role have created a controlling but divisive function for the discipline (Volmink, 1994), which is often associated with polarised self-beliefs, of either having the capacity to understand the subject or being unable to comprehend it at all (Furinghetti, 1993). Such beliefs have led to opposing opinions, in which mathematics is claimed to be either loved or hated.

In contrast to these responses, ethnomathematics (d'Ambrosio, 1985) presents an alternative view of the subject as an intrinsic part of local cultures across the world, naturally embedded into the life experience of an individual. This suggests an accessible type of mathematics of a more applied nature that is used widely, although this frequently remains invisible in everyday life and work (Coben, 2002; Wedege, 2010). This view of mathematics does not feature strongly within an academically orientated education system such as exists in England and may be largely unrecognised by the public but is nevertheless woven into the fabric of daily life.

A dichotomy between a public image of mathematics as a remote academic discipline and experiences of mathematics in applied forms surfaces in English post-16 vocational education when students encounter alternative curricula such as functional mathematics. Functional skills mathematics focusses on applications in a range of contexts, in contrast to the more knowledge-based General Certificate in Secondary Education (GCSE) taken at age 16 years in school. Students' experiences of GCSE mathematics in school and functional skills in post-16 vocational education are the main focus of this paper and how exposure to two contrasting mathematics curricula in different educational settings affect their responses.

The construct of an *image of mathematics* (Belbase, 2013; Ernest, 2008; Furinghetti, 1993) is used to explore changes in students' perceptions of mathematics as they make this transition from school to vocational education and begin studying for a functional skills qualification. Research findings from a study of students (aged 16-19 years old) learning mathematics in vocational education (Dalby & Noyes, 2016) are re-examined to understand how changes in classroom experiences and curriculum affect students' images of mathematics, particularly focusing on those with lower than average attainment in the subject at age 16. Although the data is not recent, the findings are particularly relevant to current issues with post-16 mathematics that remain unresolved. The paper seeks to address two questions:

- What changes in students' images of mathematics take place in the transition from school to vocational education?
- How are students' images of mathematics shaped by new learning experiences and social values?

The context for the study will first be described before presenting a conceptual framework and discussing the notion of an image of mathematics. A summary of the main findings follows and key points are then discussed in the light of current policy before reaching some conclusions about the implications.

Context

The English education system is characterised by a historically grounded division of academic and vocational pathways. Students take the General Certificate in Secondary Education (GCSE) examinations in a range of subjects, including mathematics, at the end of lower secondary education (age 16 years) and these largely determine whether they subsequently follow an academic or vocational pathway. Most vocational education in England takes place in large further education (FE) colleges, whilst schools are the main providers of post-16 academic courses. Students who follow a vocational pathway would therefore normally experience changes in both curriculum and educational institution as they move into post-16 education. Such transitions are often associated with adjustments to social cultures and a re-shaping of personal identities (Ball, Macrae, & Maguire, 2000; Hernandez-Martinez et al., 2011) but, for students who undertake vocational study programmes, this is a significant step in a journey towards employment that influences their values (Turner, Harkin, & Dawn, 2000). Students' trajectories towards employment are often complex and fragmented (Cohen & Ainley, 2000) but vocational education involves a process of 'becoming' (Colley, James, Diment, & Tedder, 2003) in which new identities are constructed within an institutional culture where work-related values are dominant. In this transitional period, the reshaping of personal identities in a different educational setting provides an opportunity for new experiences of mathematics.

Since 2014, government policy in England has required post-16 students who have failed to achieve a satisfactory GCSE Mathematics grade (Grade 4) to continue studying mathematics and re-sit the examination. This may involve taking an interim qualification such as functional skills mathematics, which focuses on application and problem solving in 'real life' scenarios before retaking GCSE. Some students therefore experience a different type of mathematics in this period with an emphasis on application rather than an academic knowledge-based curriculum.

In schools, disaffection with mathematics is a significant problem (Brown, Brown, & Bibby, 2008; Nardi & Steward, 2003) and is often accompanied by a disinterest in continuing to study the subject. It is therefore not surprising that many low-attaining post-16 students initially exhibit negative attitudes when mathematics becomes a compulsory part of their vocational programme (Dalby & Noyes, 2016; Higton et al., 2017). A better understanding of these students' images of mathematics and the factors that encourage more positive dispositions, seems fundamental to developing strategies to re-engage them with mathematics.

Images and affect

In general, an image is considered to be a mental representation, idea or conception which can offer rich information and capture a holistic view of inter-related concepts. These mental representations may be expressed verbally or visually in, for example, drawings and metaphors (Picker & Berry, 2000; Sterenberg, 2008). These expressions may capture some elements of the mental image but not necessarily the full meaning or the origins of the views and dispositions they represent.

Presmeg (1997) refers to a distinct form of visual imagery based on memory that is created from personal experiences. Similarly, Ernest (2008) suggests that personal images of mathematics originate in past experiences but adds that these are influenced by social talk and therefore affected by dominant images encountered by the individual in society. Within students' images of mathematics we might then expect to find evidence of influence from common social images, alongside elements based on personal memories of previous encounters with the subject. This may well include the *separated* image of a difficult, cold, abstract and inaccessible subject which is prevalent in Western society (Ernest, 2008) and dispositions that are legacies of students' personal experiences of learning mathematics.

In a study of the dominant perceptions of mathematics amongst the members of the public, Sam and Ernest (2000) utilise a conceptualisation of image with a number of key elements, suggesting that these mental images may provide some important indicators of behaviour. The elements listed include a range of beliefs, attitudes and feelings (emotive descriptions) with statements about the nature of mathematics and the learning of the subject (Sam & Ernest, 2000). This conceptual view identifies fundamental constructs of mathematical affect such as beliefs, attitudes and emotions (McLeod, 1992) as constituent parts of personal images of mathematics, although the concept of values (DeBellis & Goldin, 2006) which is widely recognised as an important addition, is not included. Debates about the meaning of these terms have been on-going (Di Martino & Zan, 2010; Zan, Brown, Evans, & Hannula, 2006) but there are some key points of relevance to this study concerning the affective elements of an image of mathematics and cognitive development.

First, the distinction made between stable traits and transient states (McLeod, 1992) for these affective constructs suggests that changes in personal images may occur over short or long time periods. The possibility of short-term changes is particularly relevant to the transition of young people into vocational education where they may only be studying mathematics for less than a year before taking a further qualification.

Secondly, the claim that emotions and attitudes can influence cognitive functions (Zan et al., 2006) suggest that personal images of mathematics can have an important influence on the learning process. The exact nature of interaction between affective and cognitive functions remains unclear and the variety of models that incorporate different beliefs, attitudes, emotions and behaviour into one framework indicates the complexity of capturing such interactions (Di Martino & Zan, 2011; Goldin, Epstein, Schorr, & Warner, 2011).

Methodology

The data that informs this paper is part of a larger multi-method study of post-16 students in three large English further education colleges. Although the study was reported earlier (Dalby, 2014; Dalby & Noyes, 2016) the findings have been re-examined and provide evidence relevant to current issues.

Students from three vocational areas participated in the study: Hairdressing, Public Services and Construction. These areas were selected to ensure a balance of:

- Vocational areas with different gender biases;
- Vocational areas with strong and weak links to mathematics;
- Vocational areas with a practical or theoretical focus.

Case studies of 17 student groups in these areas and their mathematics teachers were carried out. The majority of the students were on a similar level of vocational programme (Level 2) and were all learning functional mathematics as an additional subject, taught in weekly lessons over the course of one academic year. All the teachers were considered as subject specialists (i.e. they taught mathematics as their main subject). Data were obtained from semi-structured interviews with teachers, teacher questionnaires, observations of classes and termly meetings with a focus group from each class. A total of 14 teachers were involved and 103 students took part in the focus groups.

In the first term, members of the focus groups completed an individual card-sorting activity and participated in discussions to explore:

- why they had come to college;
- what college is like compared to school;
- what functional mathematics is like compared to school mathematics;
- what learning mathematics in college is like compared to learning mathematics in school.

The card-sorting activity was designed to capture the views of individual students through an accessible ‘hands on’ task. Each student was provided with a Likert scale on a long strip of card and a set of statements on small separate cards. The researcher asked a question verbally and the students placed the cards, one by one, under the most appropriate heading on the Likert scale to indicate their view. For example, students were provided with the statements shown in Table 1 with a Likert scale for frequency (hardly ever/sometimes/about half the time/often/almost all the time) and asked to place the cards to describe their experience of mathematics lessons in school. They were then asked to repeat the exercise to describe their experience of mathematics lessons now in college, emphasizing that this may be exactly the same, or it could be different. Students were asked to complete the activity without discussion so it reflected their personal views.

After placing the cards, which were numbered on the back, students wrote their card numbers under the appropriate heading on a pre-prepared record sheet to show their arrangement against the Likert scale. These records were later transferred into a spreadsheet by the researcher and used to carry out the analysis. During the activity, the researcher observed the students, answering any queries about the meaning of the statements and checking that they were taking sufficient time to read and place the cards thoughtfully. Assistance was given where needed to transfer the card numbers to the record sheet.

The statements on the cards were derived from discussions with student focus groups in other colleges about their experiences and what they felt were the important issues. This led to a draft set of statements which were piloted with other students and revised following their feedback on the readability, intended meaning and accessibility of the language.

In the second term students discussed their responses to a selection of contextualised mathematics tasks. These included tasks in contexts from their own vocational areas that may be familiar and some contexts that would be unfamiliar. Students were not expected to work through these tasks but to give their views of the relevance, including how realistic, authentic the context appeared to be. In their final meetings they repeated some of the earlier card-sorting activities about their experiences of mathematics in college and discussed their overall experiences of mathematics in college.

The research was both exploratory and explanatory, based on a grounded theory approach with concurrent data collection and analysis from which case studies of each class and their teacher were developed. This multi-method design allowed triangulation of both sources and methods to be incorporated into the study. Students' experiences of learning mathematics in school and college were explored using the card-sorting activities and group discussions. Data from the card-sorting activity was numerically coded and analysed using simple quantitative methods, whilst qualitative data were analysed using coding and constant comparison methods to identify key themes. These themes were then further explored through within-case and cross-case comparisons, with particular attention to comparisons between cases with contrasting student attitudes.

Within this paper, a detailed analysis of data concerning students' attitudes to mathematics will be presented. Further details of other parts of the study are reported elsewhere (Dalby, 2014).

Findings

There are four data sources that are examined in this paper:

- the individual card-sorting activities about students' beliefs and attitudes towards mathematics in school and college;
- focus group discussions about students' experiences of mathematics in school and college;
- individual card-sorting about students' beliefs about functional mathematics;
- focus group discussions about functional mathematics.

Summaries of these results are presented briefly before highlighting the main points that emerged from a more extensive synthesis. The beliefs and attitudes of students about mathematics are self-reported in this study and therefore have limited reliability as actual measures of these constructs, especially since the sample size is fairly small. However, this is a study that is largely exploratory and the use of these data is to gain insight into students' images of mathematics. For this purpose the way they present their beliefs in discourse is of particular interest.

In the first card-sorting activity students placed cards on a 5-point Likert scale to indicate how strongly they agreed or disagreed with given statements about mathematics in school and in college. After summarising students' ratings in a spreadsheet, the Likert scale was converted to an ordinal scale so further analysis could be carried out. The ordinal data was used to calculate differences in student ratings for the same statement for school and college and these were then tested for significance using the sign test. *Table 1* shows the number of students with a negative change, no change and a positive change in their ratings of each statement for school and college with the level of significance.

Statement	Negative change	No change	Positive change	Z value	Significance
I liked maths	23	39	41	-2.13	5%
I liked the teacher	17	22	64	-5.11	1%
I understood it	14	37	52	-4.55	1%
I felt confident	13	47	43	-3.88	1%
It was interesting	17	33	53	-4.18	1%
I was bored	50	26	27	-2.51	5%
It was confusing	42	41	20	-2.67	1%
I could have done better	51	28	24	-3.00	1%
It was difficult	55	28	20	-3.93	1%
I felt stressed	55	33	15	-4.66	1%

Table 1. Differences between students' perceptions of mathematics in school and college

There is evidence of several (self-reported) changes in students' beliefs, emotional responses and attitudes to mathematics in their transition from school to college. Overall, students found mathematics in college easier than mathematics in school and more interesting. They were less stressed in college, more confident, less confused, liked their teachers more and understood the mathematics better. There was also some evidence, although less significant, that students liked mathematics more and were less bored.

Changes in students' beliefs, attitudes and emotions were explored further through discussions in the focus groups and some common themes emerged that supported the above results. Students with negative responses to mathematics frequently linked these to poor learning experiences in the past. Descriptions of disaffection, disengagement and failure were common features of their discussions about school, often accompanied by expressions of strong negative emotions. Students' provided examples of previous experiences that showed how negative attitudes and emotions had often led to deliberate avoidance behaviour, or frustration about being unable to make progress. These students typically approached mathematics in college with a fear of on-going failure, a general anxiety about mathematics and low self-efficacy.

Qualitative data from the focus groups also suggested a shift towards more positive attitudes, beliefs and emotional responses to mathematics in college for some students. Oliver, a student on a Forensic Science course explained the change as follows:

> I was terrified because I knew I was weak at it. I couldn't do percentages, I couldn't do ratios, I couldn't do fractions, I couldn't do formulas. I certainly hadn't got a clue about algebra. I can do it all now. (Oliver, Forensics course)

Oliver's journey from a fear of mathematics to a position of confidence was echoed by other students from his group who had struggled in school but was also evidenced in other groups:

> Oh yeah, I'm a lot more confident now than I was at the start. (Damien, Public Services)

> I understand things more, better now. Everything seems a lot more clearer. (Ellie, Hairdressing)

These increases in confidence and understanding of mathematics were often attributed to the approaches used by their teacher and the particular course that they were taking, which was functional skills mathematics.

Students also placed cards on a 5-point Likert scale to indicate how strongly they agreed or disagreed with given statements about functional mathematics in college. The results showed strong agreement with the following statements:

- maths is a subject you need to get on in life;
- I will need to use maths in a job one day;
- the skills are useful;
- I need the qualification to progress.

Functional mathematics in college was viewed by many students as a subject with value in relation to life and work, either because they could see how the mathematics itself was useful, or because the qualification was necessary for their progression to a higher level course or the workplace.

Ben (Construction), for example, explains the difference between mathematics in college and school as follows:

> In this one they relate it to real life so you can understand it better. The one in school used to be from a text book and the teachers just used to make us copy out of the textbook for an hour. That's it. (Ben, Construction)

Ben identified that the mathematics in college was different because he could see links to his life outside the mathematics classroom. In contrast, he connected mathematics in school closely to a text book and repetitive activity that had little personal meaning.

Differences between school mathematics and functional mathematics were also identified by other students in the focus groups, for example:

> Because at school you was doing maths to get grades where you'd do certain types of maths just to get you better grades but here you do maths that's going to help you with future life and stuff that you're always going to need. (Connor, Construction)

Connor perceived school mathematics to be about passing an examination but functional mathematics was useful in daily life. The differences were however not just in the mathematics but also in the way it was taught, as a group of Hairdressing students explain:

> Ellie: Yeah, he always puts it into a problem where he would say if you was in a hairdressing salon how would you do this? How would you solve this? What ratios would you need on that?
> Leanne: Or a supermarket, how do you figure out like you know…
> Ellie: He does it to everyday life problems.
> Leanne: If you give money in do you know how much change you're giving back and all like that? He does it with us with stuff like that.

In the experiences of these students, functional skills mathematics was taught with frequent references to familiar scenarios outside college in their personal lives and it was this that made it appear different.

The usefulness of functional mathematics contrasted strongly with the dominant themes in focus group discussions about school mathematics, which was viewed as remote and inaccessible.

Some students with strong beliefs that functional mathematics was useful to their lives and vocational aspirations also acknowledged that GCSE mathematics had higher value in society though.

> It's more useful than GCSE. It's not more useful CV-wise, like qualification-wise. (Lee, Public Services)

A tension between the wide acceptance of GCSE mathematics in society and the usefulness of functional mathematics was evident in several focus group discussions. Although students had experiences of an alternative form of mathematics they were still subject to influences from society that prioritised the academic knowledge-based GCSE qualification and found these two views difficult to reconcile.

A synthesis of the findings shows evidence of five areas in students' images of mathematics:

- beliefs about the nature of mathematics;
- beliefs about the process of learning mathematics;
- beliefs about the purpose of learning mathematics;
- emotional responses to mathematics;
- attitude to learning mathematics.

This is less extensive than the range of categories identified by Sam and Ernest (2000) but it includes some similar elements.

Further analysis of these changes was carried out in cross-case comparisons between groups with strong positive images (5) and those with strong negative images (5). This led to the identification of some common features within the groups with the most pronounced changes in students' images of mathematics. One of these, evidenced through observation and student feedback, was the presentation of mathematics to students as relevant and useful 'tool for life'. This image was promoted through a teaching approach that focused on the use of meaningful real-life contexts or examples to make connections to students' personal lives or vocational interests. Students in these classes often commented that their experiences of learning mathematics were different from school.

The functional mathematics curriculum made this easier to achieve due to the emphasis on using and applying mathematics in a range of contexts. In the cases where there was little or no evidence of improved attitudes though, observations and student feedback indicated that contexts were less meaningful for students and there were less connections to their lives or vocational aspirations. Furthermore, students in these groups often found the teaching approaches similar to those they had experienced before in school.

Finally, the timescale for these changes in students' images of mathematics is worth noting. There was evidence from the card-sorting activities and discussions in the first focus group meetings (December) of changes in beliefs, attitudes and emotional responses. Evidence from the final focus group of the college year (June) then showed very little change from the first meetings. This suggests that most of the changes in students' images occurred within three months of entering college but that the new images formed by this point were then sustained through the year. It was expected that there would be some changes but these were more rapid than anticipated, with students' early experiences of mathematics in college being particularly influential. Positive attitudes were evidenced more extensively than expected in the student groups. After the early changes, the way in which attitudes stabilised was also surprising, indicating that there were consistent features of their experiences of mathematics in college that affected these.

Discussion

The images of mathematics evidenced in the study included a range of elements not dissimilar to those identified by Sam and Ernest (2000) and reflected many of the common features identified in public images of mathematics by other scholars (Furinghetti, 1993; Leder & Forgasz, 2003; Volmink, 1994). Students' images were built on memories of their prior learning of mathematics but were affected by both early and more recent experiences. The way in which contrasting experiences in college (compared to school) were capable of re-shaping existing images, even over a period of only a few months, suggests that students' images were capable of changing, with the acquisition of new memories continually reinforcing or replacing existing elements. As Presmeg (1997) and Ernest (2008) suggest, new experiences in a different social setting allowed images to be re-shaped and even transformed. There appears to be great potential to change students' images following their transition from school to vocational education in college but this is dependent on several factors that were highlighted in the study.

The transition to college provided an opportunity for positive changes in students' images of mathematics through exposure to an alternative, more applied mathematics curriculum. In classes where teachers embraced this curriculum and made use of the opportunities to present mathematics as a relevant and useful subject, students encountered contrasting learning experiences to those they had experienced in school. These contributed to the development of images of mathematics that were more positive. There are three aspects of their experiences in college that were particularly important in the development of these new images of mathematics: the curriculum, the teaching approach and the setting.

The mathematics curriculum that they encountered in college, functional skills mathematics, focused on the application of mathematics and the development of skills rather than knowledge acquisition. This gave teachers the opportunity to present mathematics as a subject that was connected to real life and work. In England, the history of qualifications with an emphasis on application has been fragmented and, although successive attempts have been made to develop skills-based qualifications suitable for students in vocational education, these have been relatively short-lived compared to the GCSE qualification (Dalby & Noyes, 2020). If views of mathematics are going to change in society, then widespread use of a mathematics qualification that focuses on application would appear to be one way in which entrenched negative attitudes in society might be influenced during students' journeys through education.

In student groups where positive images of mathematics were evidenced, teachers used the opportunity afforded by the functional mathematics curriculum to emphasise the relevance and usefulness of mathematics. This typically involved the use of familiar contexts and scenarios to demonstrate how mathematics was *connected* to students' personal lives and vocational studies. These were used in two ways. Contextualised problems were sometimes used to model the mathematics, or students were presented with examples of familiar situations in which mathematics was used, simply as illustrations.

The use of contextualised tasks has been problematic for various reasons (Beswick, 2011) but when used for the purpose of understanding the mathematics, its success relies on accurate representation of the mathematical structure in the given scenario. In Realistic Mathematics Education (RME) for example, the context used is described as needing to be 'meaningful' to students, i.e. a situation that they can imagine (Van den Heuvel-Panhuizen & Drijvers, 2001) but this may not necessarily be strongly connected to their lives and interests. Although this approach is effective in terms of understanding the mathematics (Dickinson & Hough, 2012; Laurens, Batlolona, Batlolona, & Leasa, 2017), the emphasis is on cognition rather than affect. If students' images are to become positive then affective elements also need to be addressed.

The use of mathematics in contexts relevant to students' lives, either as examples or in contextualised tasks, fulfil a different function by demonstrating the relevance and uncovering the hidden mathematics (Coben, 2002; Wedege, 2010) that they may have already encountered in their everyday lives or vocational practices. The identification of authentic contexts (Wiliam, 1997) is however a challenge, especially in England's FE colleges where student groups are not necessarily taught in vocational groups and common interests are therefore limited to their personal lives. Nevertheless, the use of relevant contexts addressed some of the negative aspects of students' views of mathematics and remains an important device to develop a different image of the subject.

As a result of their experiences of functional mathematics in college, rather than retaining a negative *separated* image of mathematics, some students developed *connected* images of mathematics with clear links to their lives and values. Differences in the mathematics curriculum and teaching approach between school and college were instrumental in facilitating these changes but students were also influenced by participation in new social situations and learning environments. This exposed them to new social images that affected their personal beliefs, attitudes and emotions, and allowed space for different connections to mathematics to develop. Independence and orientation to the workplace were becoming increasingly important for these students (Brannen & Nilsen, 2002; Côté & Bynner, 2008) and connections to practical workplace applications of mathematics resonated more strongly than in school. A different educational environment, in which students developed new values and identities, provided opportunities to create new images of mathematics that were connected to their aspirations. Furthermore, where connections were made between emerging work-related values and mathematics, students also reported an increased engagement with mathematics learning and gains in understanding.

There are two important implications here for teachers in colleges. Students' images of mathematics were not only affected by a different curriculum in college but also by the use of a different teaching approach by their mathematics teachers. Continuing with the same teaching approaches used in school was unhelpful to students with negative images since this reinforced existing beliefs and attitudes. To cultivate positive images, mathematics teachers needed to embrace the alternative curriculum and teach this in ways that emphasised the connections to students' lives and aspirations. Vocational teachers also have a part to play in the development of these connected images. As they help students prepare for the workplace, emphasising the importance of mathematics skills and highlighting where mathematics is used in work routines strengthens the connections.

Some of the key elements of students' images evidenced in the study show a close alignment to research findings concerning affect and these are worth considering in view of ongoing concerns about post-16 students' affective responses to mathematics (Noyes & Dalby, 2020). There was evidence of changes in attitudes, emotions and beliefs (McLeod, 1992) and, as highlighted by Zan et al (2006), anxiety about mathematics was common. A key finding, however, concerned how these attitudes, beliefs and emotional responses to learning mathematics changed over time. Rather than beliefs remaining fairly stable whilst attitudes and emotions were more transient (Wedege & Evans, 2006; McLeod, 1992), there was evidence of concurrent changes in beliefs, attitudes and emotions over a short period of time, suggesting the presence of fast-changing aspects of each element (Goldin, 2003; Hannula & Laakso, 2011). Importantly, if students' images of mathematics had become more positive by the end of their first term in college, a time period of less than three months, it was likely that this change would remain stable, at least until the end of the college year.

Comparisons to existing models suggest compatibility but also some differences. For example, the emotional responses of students were closely connected to prior experiences of learning mathematics (Hannula, 2002) but their attitudes and beliefs were also grounded in previous encounters with the subject. There was evidence of attitude being linked to engagement (Goldin et al., 2011) but emotions and beliefs were also entwined into student behaviour. In Goldin's 'engagement structure' students' beliefs are intertwined within cognitive and affective structures and explain "in-the-moment mathematical behaviour" (Goldin et al., 2011, p.558) but not a more sustained response, as shown with the vocational students in this study.

Evidence that it is possible to change students' images in college is a key finding of this study but the question of how to change the dominant image in society remains, especially in an education system where academic qualifications are the priority and vocational skills are a secondary consideration. Even students who understood the usefulness of functional mathematics were sometimes uncertain about the value of the qualification in comparison to GCSE because of the wider acceptance in society and 'gate-keeping' function of the qualification. The prioritisation of GCSE mathematics in current post-16 mathematics policy in England and a decline in the use of functional mathematics (Dalby & Noyes, 2020; Noyes, Dalby, & Smith, 2020) therefore present challenges to the development of positive images of mathematics in vocational education. Students are now more likely to experience the same mathematics that they studied at school, with limited opportunities for teachers to emphasis the relevance and usefulness than they did at the time of this study. Although a renewed commitment to the development of skills is welcome (DfE, 2021), students are still influenced by common images in society and these are likely to reflect the high value of academic qualifications for some time. Meanwhile, the emphasis in post-16 vocational education remains firmly on a mathematics qualification associated with a remote and abstract academic image of the subject.

Conclusions

This study of students' images of mathematics is largely exploratory. The approach used has limitations due to the reliance on self-reported beliefs and attitudes, and the relatively small sample size. These conclusions therefore focus on the images constructed by students in their discourse and the implications of these. A more detailed analysis of student attitudes using recognised measures of, for example, attitude and self-efficacy would be useful to build on the findings reported here. This could provide more detailed and robust quantitative data to examine the type and extent of attitude change. A longitudinal study, spanning the transition from school to college, could also provide more insight into how images are shaped and developed.

From this study, it can be concluded that the construct of a personal mental image provides a useful way to represent the set of beliefs, attitudes and emotions described by students in connection with their responses to mathematics in school and college. Although these images are grounded in memories of prior experiences, exposure to an alternative mathematics curriculum and different approach can have a significant and positive effect. There appear to be benefits, therefore, in providing contrasting learning experiences for students who have been disaffected with mathematics in school, to enable the construction of more positive images.

The potential of an alternative curriculum to have a positive impact on students' images and engagement has implications for the type of mathematics taught to students in vocational education and the teaching approaches used. Mathematics teachers are in an influential position to facilitate the development of positive images of mathematics but are constrained in England by a policy that focuses on achievement of the same GCSE qualification that students have taken and 'failed' in school.

In the transition from school to workplace, understanding how students' images of mathematics are formed may well provide a better understanding of how learning mathematics in vocational education can be instrumental in shifting long-standing negative images in society. However, widespread change is likely to be dependent on a change in the value attributed to skills-based qualifications by policy-makers and those within education, in order to create the conditions in which new images can develop.

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