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Mathematics teachers and learners as collective agents of change

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Abstract

In this article, we report on findings from the Primary Maths and Social Justice research project, a recent collaboration between the three authors and six teacher researchers from two culturally diverse primary schools in London, UK. The project aimed to develop strategies for addressing issues of social justice in the mathematics classroom, and operationalising the recently developed theoretical concept of socio-mathematical agency, defined as learners' capacity to apply mathematics in arguing collectively for social change. The teacher researchers' experiences, as captured through audio recordings of research team meetings and interviews, form the basis of our data analysis. Our findings highlight the processes that enabled teachers to reflect critically on existing practice, prompting them to adopt more collaborative, discursive and inclusive problem-solving approaches that resulted in significantly higher levels of

student engagement in mathematical activities. The teacher researchers found that cross-curricular projects provided more opportunities to apply mathematical knowledge in tackling social justice issues than the prescriptive and content-focused mastery-style mathematics schemes of work in place. They reported how students embraced opportunities to use mathematics in more meaningful contexts and in presenting arguments for change. We argue that a focus on developing socio-mathematical agency has the potential to enhance the role of teachers and learners as agents of change, an important element that is often underdeveloped in culturally responsive teaching.

Keywords teaching mathematics; social justice; socio-mathematical agency; primary education

Introduction

Bassey (2020) highlights how culturally responsive teaching is becoming increasingly popular, particularly in the US, as it is seen by educators as the most effective approach to meeting the learning needs of culturally diverse students and closing the achievement gaps between different groups of students. In the fields of science and mathematics education, its potential for enabling students to identify and make personal connections with subject content is becoming increasingly recognised. In this article, we highlight how culturally responsive mathematics teaching resonates with the concept of socio-mathematical agency (SMA) that we have recently developed. We provide a justification for focusing on SMA, and we consider how it might be conceptualised. We report on the Primary Maths and Social Justice (PMSJ) research project, which provided an opportunity to explore how SMA might be operationalised in practice. We discuss our findings, and how they might relate to teachers and learners of mathematics becoming agents of change in addressing the increasing challenges facing our global society.

Culturally responsive teaching

The concept of 'culturally responsive teaching' is defined by Gay (2010, cited in Bassey, 2020: 63) as 'using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for [students]'. Abdulrahim and Orosco (2020) outline how culturally responsive mathematics teaching builds on the three core aims of culturally relevant pedagogy proposed by Ladson-Billings (1995): (1) to provide positive learning experiences for all students that enable academic success; (2) to generate cultural competence through recognising and drawing on students' family and community knowledge as valuable learning resources; and (3) to develop critical consciousness or awareness of social inequities faced by students in school and society. Their synthesis of the research literature on culturally responsive mathematics teaching within the US demonstrates its potential for providing engaging and challenging learning environments that foster positive identities of students as mathematics learners, particularly among those from culturally and linguistically diverse backgrounds. Unfortunately, they also conclude that many teachers were poorly prepared to adopt such approaches. They highlight how students from diverse backgrounds tend to experience traditional mathematics teaching which treats mathematics as neutral and value-free, and which ignores the sociopolitical aspects of learning.

Hernandez et al.'s (2013) synthesis draws on a range of studies that focus on how teachers in the US attempt to meet the learning needs of all students, including those from diverse backgrounds. Their model of culturally responsive teaching also draws on Ladson-Billings's work, and it emphasises the importance of addressing social justice through encouraging students to question and challenge existing structures and develop critical consciousness. However, they found that most of the science and mathematics student teachers they worked with, while successfully implementing other aspects of the model, neglected the social justice aspect, and were deterred from acting as agents of change by the environment in which they were training. They describe how most schools follow traditional science and mathematics curricula that fail to recognise the social or political nature of education.

Bassey (2020) also emphasises the importance of social justice as an essential component of culturally responsive teaching that is often marginalised by researchers. While most studies recognise the cultural diversity of learners, and seek to establish conditions in which a wider range of students can contribute and succeed, she claims that many overlook the need to develop students' sociopolitical consciousness. Bassey (2020) argues that culturally responsive teachers should act as agents of change by encouraging their students to critically examine the conditions, cultural norms, policies and practices that produce and maintain inequities within their communities and wider society. In her view, culturally responsive teaching necessitates students thinking critically about social issues and how to engage in meaningful activism to bring about positive social change.

Socio-mathematical agency

We concur with those who argue that developing critical consciousness is an essential aspect of culturally responsive teaching. We advocate for SMA, which we define as the ability to use mathematics effectively in arguing collectively for social change (Wright et al., 2023b). Our conceptualisation of SMA is comprised of three elements: (1) powerful mathematical knowledge; (2) critical understanding of mathematics; and (3) collective mathematical agency. Below, we seek to explain and justify how we arrived at each of these three elements, and to expand on what we mean by them.

Powerful mathematical knowledge

Abdulrahim and Orosco (2020) and Hernandez et al. (2013) highlight the difficulty of implementing culturally responsive mathematics teaching in an environment in which the sociocultural nature of mathematics is commonly denied. We are concerned about the resurgence in recent years of teacher-centred pedagogies, based on introducing a series of abstract mathematical concepts in a highly structured and unambiguous way (Wright et al., 2022b). These include direct (or explicit) instruction in the US (Doabler and Fien, 2013; Rosenshine, 2012) and mathematics mastery approaches in England (Drury, 2018).

Direct instruction is justified by those advocating for equity and social justice, who argue that lower attaining students are disadvantaged by less-structured teaching approaches. It is characterised by the teacher carefully explaining a worked example, often chosen with minimal conceptual steps to avoid cognitive overload, followed by students tackling several similar closed exercises. The emphasis is on maintaining pace and using regular testing to expose and correct any misunderstandings. However, such a teacher-led approach is often associated with the disengagement, alienation and disempowerment of learners (Ewing, 2011).

Mathematics mastery approaches draw on some widely accepted theories of learning, including variation theory (Watson and Mason, 2006). The National Centre for Excellence in the Teaching of Mathematics (NCETM, 2022), which is funded by the UK government to promote mastery approaches, includes the development of students' enjoyment of mathematics, reasoning skills and ability to make connections in its underpinning principles of mathematics teaching for mastery. However, the limited mathematics subject knowledge of primary school teachers (most of whom are generalists who teach all subjects) and the over-reliance on commercially produced schemes of work mean that these principles are often not translated into classroom practice (see below).

We consider the knowledge-centred curricula associated with these teacher-centred pedagogies to be based on a narrow interpretation of powerful knowledge. Muller and Young (2019) argue that certain types of knowledge, particularly those which are abstract, formal and specialised (Bernstein, 2000), are inherently powerful. However, they also contend that powerful knowledge is more than merely a collection of isolated propositions and must include an awareness of disciplinary meaning, by which they mean how new knowledge is generated within the discipline. Shalem and Allais (2019) highlight how a curriculum based on principles of social justice must allow students to engage with debates around how knowledge becomes accepted as legitimate, and the relationship between abstract disciplinary knowledge and real-world problems. Within school mathematics, this implies that students should develop an appreciation of how new mathematical knowledge is validated through a process of argumentation and refutation among peers (Ernest, 1991). They should be given the opportunity to experience processes that mathematicians go through in generating new knowledge, including working

collaboratively, conjecturing, posing questions, following their own lines of enquiry, considering multiple solutions to problems, and constructing mathematical arguments in which they explain and justify their solutions to others (Mason et al., 1985).

Teacher-centred approaches and knowledge-centred curricula also fail to address the need for students to develop agency. Suggesting that learners can be empowered simply by acquiring knowledge ignores how the power of knowledge is dependent on the agency of the knower (Alderson, 2020; Manyukhina and Wyse, 2019). Focusing too narrowly on acquiring knowledge that is abstract, seemingly apolitical and disconnected from human experience can divert attention away from addressing the multitude of real problems and injustices facing society (Alderson, 2020). As mentioned above, mastery approaches to teaching mathematics are becoming increasingly popular in primary schools (with students aged 5 to 11) in England. However, the lessons are often prescriptive in nature, neglect the development of learner agency, and tend to reinforce inequitable teaching practices by limiting access to genuine problem-solving opportunities to only the highest attaining students (Alderton and Pratt, 2023).

Much curriculum time in primary schools in England is devoted to project-based learning, providing opportunities for students to explore issues of social justice such as human rights, respect, fairness or the environment. However, there is evidence to suggest that, when tackling these issues, students tend to draw on their own personal experiences and accounts from social media, family and friends, and are reluctant to apply the disciplinary knowledge that they learn in school, including the knowledge acquired through designated mathematics lessons (Jerome et al., 2021).

SMA should therefore involve students developing powerful mathematical knowledge, which includes an appreciation of disciplinary meaning in mathematics, as well as developing the capacity to apply abstract mathematical concepts in solving meaningful problems relating to their real-life experiences.

Critical understanding of mathematics

The third aim of culturally responsive mathematics teaching (to develop critical consciousness) (Abdulrahim and Orosco, 2020) is an essential element of socially just mathematics teaching, and one that critical mathematics educators consider of utmost importance. There is a danger that addressing the first two aims (academic success and cultural competence), while neglecting the third, will fail to address the disempowerment of marginalised students. Skovsmose (2011) warns that mathematics can be empowering in a pragmatic sense (academic success in mathematics can provide greater opportunities for future employment and further study) while being disempowering in a sociopolitical sense (prescriptive teaching approaches can be seen as preparing learners for work processes that involve compliance and following routine instructions). Skovsmose (2011) highlights how focusing exclusively on cultural competence, by making mathematics more relevant to students' backgrounds, risks closing down opportunities for students to learn about contexts beyond those they have already experienced. Instead, he proposes considering students' foregrounds, by developing students' awareness of their own sociopolitical situations, thus enabling them to widen their perspectives and broaden their future life opportunities.

Critical mathematics education builds on Freire's (1974) notion of 'education for critical consciousness', in which he argues that genuine understanding must be accompanied by learners developing a greater awareness of their own sociopolitical situation. In applying Freire's theories to mathematics education, Gutstein (2006) refers to reading and writing the world with mathematics, which involves students using mathematics to develop an understanding of issues of power, discrimination and inequity, and how these relate to their own lives and to wider society. This requires that teachers recognise the sociopolitical nature of mathematics, and that both teachers and students become agents of change. Teachers should facilitate mathematical enquiries that generate students' agency, enabling them to realise their foregrounds and preparing them to engage in future action to bring about positive social change (Wright, 2016).

SMA should therefore involve students generating a critical understanding of mathematics through developing a readiness to use the subject to explore and develop their awareness of social justice issues, and to expose and challenge exploitation and social injustices.

Collective mathematical agency

Bernstein (2000) highlights the distinction between school mathematics and real-life mathematics, which he attributes partly to the mathematics curriculum being designed by those with limited understanding of the work that real mathematicians do. Boaler (2009) describes school mathematics as an impoverished recontextualisation of mathematics, because the experiences of students are so far removed from a real mathematician's work. A clear example of this is the extent to which mathematics learning at school is perceived by many to be an individual pursuit. However, in real life, most new mathematical knowledge is generated by mathematicians working collaboratively in groups, and people generally work in teams in applying mathematical ideas to solve real-life problems. Yet a glance into most secondary mathematics classrooms is likely to reveal students seated in rows, working in silence on individual exercises. Indeed, in some schools in England that adhere to the direct instruction philosophy referred to earlier, students are actively discouraged from discussing their work with each other. In primary schools, while students often sit together to work on tasks, they are rarely provided with genuinely collaborative mathematics tasks, or given guidance on how to work effectively as part of a team.

There are notable exceptions, including the Railside Project in California (US), in which teachers adopted a complex instruction approach to facilitate group work, raising levels of student achievement and narrowing the achievement gap between different ethnic and socio-economic groups of students. Students also developed more positive attitudes towards mathematics, and took on more responsibility for each other's learning (Boaler, 2008). Hunter and Hunter (2023) describe a project with Pacific-heritage students in Aotearoa/New Zealand in which the socio-mathematical norms of the traditional classroom, based on competition between individuals and grouping students by attainment, were disrupted by adopting a productive discourse approach that embraced small group work, discussion, enquiry, mathematical reasoning and argumentation. They found that by building on values and ways of being that resonated more closely with the collectivist nature of their community's culture, students developed a more positive disposition towards learning mathematics that conflicted less with their own cultural identity. These examples demonstrate the feasibility and benefits of an alternative approach to learning mathematics, in which value is assigned to communal effort, trust and solidarity among learners (Radford, 2012).

In seeking to provide positive and supportive learning experiences for students, we need to be careful not to lose sight of the purpose of education. Biesta (2015) highlights the danger of learnification, whereby learning becomes an end in itself, with no apparent or clearly articulated purpose. Biesta (2021) argues for a world-centred education, in which teachers are responsible for directing students' attention towards the world in which they live. He sees this as vital for enabling future generations to make sense of the world and what it demands of them, so that they are prepared to tackle the increasing social, economic and environmental challenges facing global society. His argument reinforces the increasing calls from UNESCO (2015), and other international educational organisations, for school curricula that focus more on developing the knowledge, critical understanding and collective agency needed to address these challenges. The extent that mathematics education can contribute towards fulfilling these aims was highlighted in the previous section.

SMA should therefore involve students developing collective mathematical agency, demonstrated through a willingness to work with others in using mathematics to construct an argument for change, and developing confidence to influence society by taking collective action informed by mathematical argument.

The PMSJ research project

The PMSJ research project was a collaboration between the three authors (two mathematics teacher educators and a senior primary school teacher) and six teacher researchers based in two culturally diverse primary schools located in London. The aim of the project was to work with the teacher researchers in pursuing their common interest in developing strategies for addressing issues of social justice in the mathematics classroom. We focused on operationalising the theoretical concept of SMA described above. We adopted a critical model of participatory action research (Skovsmose and Borba, 2004; Wright, 2021), which resonated with our intention to challenge dominant discourses within mathematics education that deny the value-laden and multicultural nature of the subject (Hernandez et al., 2013).

The participatory principles of the project meant that the teacher researchers had a significant input into the research design. We (all nine of us) established a research team which met five times between November 2021 and June 2022. During these meetings, we engaged with theory underpinning the conceptualisation of SMA and discussed how we would go about operationalising SMA in the classroom. We agreed the broad outlines for two research lessons, and devised prompt questions for the teacher researchers to use in evaluating the lessons. Between the research team meetings, we broke into three subgroups (each with a pair of teacher researchers and one of the authors) to complete the final planning and preparations for the research lessons. This allowed the teacher researchers to tailor the broad outline for lessons to their own classes, which spanned the primary school age range (5 to 11): Emma and Kate worked with their Year 1 classes (age 5 to 6), David and Aidan worked with Year 2 (age 6 to 7), and Rose and Layla worked with Year 5 (age 9 to 10) and Year 6 (age 10 to 11) respectively. (All names of teacher researchers are pseudonyms.) The teacher researchers used the evaluative questions to present their reflections on the lessons during subsequent research team meetings, which prompted further discussions around the implications for operationalising SMA.

During early research team discussions, we decided that there would be more opportunity for operationalising SMA outside of designated mathematics lessons, as both schools followed a mathematics mastery style scheme of work that they considered to be too prescriptive. Instead, we sought to apply the mathematical ideas that students had learnt during these lessons to the project-based work that teacher researchers commonly undertook with their classes at other times. Subsequent planning discussions focused on identifying genuine links between mathematics topics that had been tackled recently and the social justice issues inherent in projects that were already being considered. Attention was given to how mathematics concepts might be utilised to develop greater understanding of the issues, and how these links could be made more explicit to students, for example, through questioning. It should be noted that, as is the case in most primary schools in England, the teacher researchers are generalists, that is, they plan and teach all curriculum subjects to one class of students, who they stay with for the entire academic year.

One of the research lessons focused on using mathematical ideas to consider voting methods that might be used to make a fair choice between various options available. Emma's Year 1 class (age 5/6) considered how to choose between various fun games on offer to the whole class during golden time (commonly used as a reward for effort over the course of a week). Emma initially gave students one counter each and invited them to vote for their preference, with the most popular game being selected. She then facilitated a discussion on whether this method of choosing was fair or whether alternative methods, such as providing each student with more counters and allocating these according to preferences, would be fairer. They also considered the fairest way of interpreting the outcome of their vote, for example, whether all time should be allocated to the winning option, or whether time should be allocated proportionally to more than one game. Another research lesson focused on how to use statistics (for example, percentages and pictograms) to support arguments (generated by groups of students) for adopting different proposed solutions for addressing various environmental issues (for example, litter, pollution, low emission zones, deforestation, climate change). Aidan facilitated a discussion with his Year 2 class (age 6/7) around which of the statistical diagrams students had recently encountered in designated mathematics lessons would be most appropriate to use and why. In some classes, voting methods were revisited in deciding which of the arguments put forward was considered to be the most convincing.

Data analysis

All research team meetings were audio recorded. The authors conducted two interviews with each teacher researcher, either individually or in pairs (the same pairs that were used for detailed planning of the research lessons), once before the first research lesson and once after the second research lesson. These interviews were also audio recorded. The teacher researchers' experiences, as captured through the audio recordings of research team meetings and interviews, form the basis of our data analysis for this article. In line with a participatory methodology, we consider data based on teacher researchers reporting their experiences to be reliable, given their in-depth knowledge of their own students and the classroom situation (Wright et al., 2022a). It should be noted that each teacher researcher kept a research journal, and co-designed and administered short surveys with their students before and after

the research lessons, all of which they drew on during discussions in meetings and interviews. This triangulation contributed further to the trustworthiness of the data. The interviews and extracts from the research team meetings (those focusing on evaluating the research lessons) were transcribed and fully anonymised by replacing all names (except those of the authors) with pseudonyms. Ethical approval to conduct the study was granted by the UCL Institute of Education Research Ethics Committee.

Thematic analyses, based on Braun and Clarke's (2022) framework, were carried out on the data, using a combination of deductive coding (derived from our conceptualisation of SMA) and inductive coding (generated from our reading of the data). NVivo software was used to code the data and facilitate the thematic analyses. An iterative process was used to develop the coding scheme. This involved adding new codes and amending existing codes to take account of any data that could not be adequately coded with the initial coding scheme. The coding was then used to generate initial themes, by rereading extracts of text to which each code had been applied, identifying broad patterns of meaning, and looking for similarities, differences and connections with other codes. The initial themes were then developed and reviewed by comparing and discussing these initial themes. Further discussions led to the refining, defining and naming of themes (Braun and Clarke, 2022). Those themes that are relevant to this article are reported in the next section.

Findings

Three broad themes emerged from the thematic analysis: (1) students developing SMA; (2) teacher researchers rethinking their views about mathematics; and (3) teacher researchers developing agency and efficacy in promoting students' SMA. We report on each of these broad themes in turn, outlining the subthemes that emerged in each area, and drawing on selected quotes from the teacher researchers to exemplify these subthemes. For a fuller report of the findings from the thematic analyses, see the PMSJ project report in Wright et al. (2023a).

Theme 1: students developing SMA

Subtheme 1.1: students' willingness to exercise greater control over their own learning

The teacher researchers noted the extent to which students engaged positively with the opportunities provided for them through the research lessons to take greater ownership over their own mathematics learning:

> The children were very engaged. I think the fact that they were attributing it to a real-life problem or challenge. So, they really took ownership over setting their own investigations, and then understood very much how maths can be related to real life. (Layla, Year 6 teacher, Meeting 5)

The teacher researchers appreciated the value of encouraging students to apply mathematical ideas in making sense of real-life issues:

> And, I think, once you start to see the children actually grapple with these issues, and form quite well-articulated opinions … I think it's really important that we give them a chance to start to understand the problems, and give them a voice, really, to say what they think. (Rose, Year 5 teacher, Interview 2)

Subtheme 1.2: students' appreciation of the relevance of mathematics to their lives

The teacher researchers described how students became increasingly aware of how the mathematics skills they have learnt can be applied to develop understanding of real-life situations:

> I think it's made them understand maths in a broader context and for the wider world … We've taken maths they already understand and applied it, rather than them learning new maths. (Layla, Year 6 teacher, Interview 2)

Students seemed to appreciate the applicability of mathematics to their own situations:

> I think the major impact is just that they're actually learning how to give an opinion … And understanding that they can apply maths to situations that are not just in the classroom, and things that affect them. (Emma, Year 1 teacher, Interview 2)

Fairness was one issue about which students successfully applied mathematics to generate greater understanding:

> And I think they've got a much deeper understanding of what 'fairness' means. (Rose, Year 5 teacher, Interview 2)

Students began to recognise more quickly when mathematics was being applied, and began to apply it to other situations more readily without prompting:

> I can see that it's had a real impact. They just sit there like, 'Oh, we're using maths for something else.' And now you can see that they are more inclined to, sort of, vote on things. (Kate, Year 1 teacher, Interview 2)

Subtheme 1.3: students' dispositions towards using mathematics to argue for change

The teacher researchers overcame any initial concerns they had that students might be reluctant to apply mathematics to argue for change, once they saw how enthusiastically students engaged with such opportunities:

> OK, so why don't we do some voting within our classroom … And this, I guess, was one of the areas that I was slightly concerned with in terms of my class and how this was going to go, but actually I found all the children were really engaged and were really passionate about putting forward why their idea was the strongest. (David, Year 2 teacher, Meeting 5)

They described how students were willing and able to use mathematics effectively to strengthen their arguments relating to social justice issues:

> The children had a better overview at the end, and were able to feedback during the plenary, and actually give answers that had reasoning behind them, rather than just: 'This is the answer and that's it' … the children have more to say about social justice, or fairness, equality, doing the maths, where it made an impact on their own lives, in comparison to when we've looked at fairness, equality, all that, in previous tasks. (Emma, Year 1 teacher, Meeting 5)

Students appeared to show interest in how mathematics can be used to build an argument:

> So, the children collated the results of how they commuted to school. We used a tally chart, and they were quite shocked to realise that … the majority … came to school by the car … And I think they were quite interested to see how … the maths was actually quite important there to help us, not only just work things out, but interpret the data as well. (Aidan, Year 2 teacher, Meeting 3)

Subtheme 1.4: students' willingness to work collaboratively in solving problems

The teacher researchers recognised the value of students working collaboratively to solve problems in mathematics; however, they appreciated that they needed to give more attention to supporting students doing this effectively:

> It's been … important for me to try and allow them to collaborate more and work together more, particularly in maths lessons, to try and solve problems … Because you realise that children, perhaps, don't really understand what collaboration … good collaboration … should look and sound like. (Rose, Year 5 teacher, Interview 2)

Providing more opportunities to tackle meaningful mathematical problems appeared to enhance students' willingness and enthusiasm to engage in collaborative problem solving:

> So, we had five different teams … and each of them were trying to convince the class that their idea was best … We saw some really nice work … they were all given the opportunity to share and input their ideas and thoughts as to why theirs was the strongest idea. (David, Year 2 teacher, Meeting 5)

This enthusiasm often translated into quite passionate group discussions involving mathematics:

> And then they worked with their talk partner to talk about their views. And there was some quite heated discussion amongst them. And at that point, they were really keen then to come up with some different ideas, which they thought might be fairer. (Kate, Year 1 teacher, Meeting 3)

Theme 2: teachers rethinking their views about mathematics

Subtheme 2.1: teachers' development of a broader view of mathematics within the curriculum

The teacher researchers recognised the constraints of the mastery mathematics style schemes of work adopted by both schools, and they expressed a desire to go beyond this:

> Particularly maths mastery sometimes feels that way [narrow], and that we've got a lot to get through … it's quite nice to step back from it and think about … how can we add value and provide a richer curriculum for the children? (David, Year 2 teacher, Interview 1)

Through their involvement in the project, the teacher researchers began to appreciate the need to make mathematics more meaningful and purposeful by relating it more closely to students' everyday real-life experiences:

> It's made me think 'Well, how can I draw on examples in maths lessons from the real world, how can I get children to think about maths differently, and how can I get them to use maths to show a different perspective?' (Rose, Year 5 teacher, Interview 2)

Subtheme 2.2: teachers' recognition of the links between social justice issues and mathematics learning

The teacher researchers developed a stronger appreciation over the course of the project of how social justice issues can be tackled through teaching mathematics:

> And it was looking at the world and thinking 'Well, how can I get some of these issues within these lessons?' … understanding how maths can be used in a different way, and seeing that in practice has been quite a big impact on me and my teaching. (Rose, Year 5 teacher, Interview 2)

They began to appreciate the potential benefits for society of integrating social justice issues into mathematics learning:

> It's a great opportunity to bring in, like, issues that are going on in the world today that, you know, they are ultimately going to be responsible for in the future … getting the next generation ready. (Aidan, Year 2 teacher, Interview 2)

Subtheme 2.3: teachers' appreciation of the capacity of younger children to engage with mathematics and social justice

The teacher researchers described how they overcame an initial scepticism about younger children being able to engage in complex issues relating to social justice:

> So, it's opened my eyes … not kind of pigeonhole 7-year-olds into 'they won't understand that or that, this isn't relatable to them at their age' … Actually, they can do more than you realise, you just need to give them the right framework to be able to do it. (David, Year 2 teacher, Interview 2)

They began to articulate the importance of children engaging with social justice issues in learning mathematics from an early age:

> I think, going forward, as they get older, if we continue going with this … children will then be able to look at data in different ways … when they see a poll, as teenagers, … they can realise that, actually, you can manipulate figures, for example. And I think … across the board, from 'tinies' up to the end of your school life, we can use this sort of thing to build. (Kate, Year 1 teacher, Interview 2)

Subtheme 2.4: teachers rethinking strategies and approaches to teaching mathematics

The teacher researchers reported how the project had a positive impact on their thinking and practice, particularly in their orientation towards collaborative and problem-solving approaches in the teaching of mathematics:

> I think it's got me to think 'How can I include collaboration a little bit more in the lessons, and draw out the problem-solving aspect of maths?' … We have a very set way of teaching maths … The delivery of the lessons and the way I ask the students, and the way we interact with the maths on the board, that has perhaps changed. (Rose, Year 5 teacher, Interview 2)

The teacher researchers began to appreciate the value of small-group discussions in learning mathematics, particularly for students who are less confident to articulate their views:

> In a small group, in a quieter environment, particularly for our children who … they don't need help all the time and they're not one of the 'high flyers' … they just don't want to talk … if they're in a small group they can get involved in these investigations … it allows them to think and get their voice heard and say what they want to say. (Kate, Year 1 teacher, Interview 1)

Theme 3: teachers developing agency and efficacy in promoting students' SMA

Subtheme 3.1: teachers challenging students' assumptions about mathematics

The teacher researchers reported becoming better prepared to challenge students' assumptions about mathematics:

> Quite a lot of the children had that assumption, you know, that maths was just for answering questions in school. And I've tried to reiterate in every lesson … where the benefits of this type of learning will help in the real world, and just almost overemphasise them so that they don't say that again. (Aidan, Year 2 teacher, Meeting 3)

They began to report some success in broadening their students' views of mathematics by making it more meaningful:

> I think, in Year 1, maths is very much … it's in the classroom, it's in the maths lesson. They're quite specific about that. And they were starting to see, actually, how we can use maths, how we can use numbers in different ways. (Kate, Year 1 teacher, Meeting 3)

They also described how relating mathematics more closely to their experiences helped some students to begin to overcome their anxiety about the subject:

> Speaking about those children who have those maths anxieties, who have those quite negative views, I don't think I've fully been able to overcome them. But, I think, by presenting maths in a different way, I've had less of a 'I don't want to do this, this is boring' reaction. (Rose, Year 5 teacher, Interview 2)

Subtheme 3.2: teachers navigating the constraints of the curriculum

The teacher researchers demonstrated an awareness of the constraints they faced in following the mathematics schemes of work:

> We do a maths mastery programme, which is just jam packed in terms of the amount that we have to get through. (David, Year 2 teacher, Interview 1)

They began to develop a nuanced critique of the curriculum, and to articulate more clearly some of the contradictions in its aims:

> I think there are time constraints, in the curriculum … if we could have more time for them to complete investigations, based on talk tasks … the maths mastery framework gives you that opportunity, but timewise it doesn't work. (Kate, Year 1 teacher, Interview 1)

They reported some successes in overcoming these time constraints by identifying genuine links between mathematics and social justice:

> It's trying to make it work and weave into your existing curriculum, but also so it's not tokenistic and you're just, kind of, throwing it in there, and make it meaningful. (Rose, Year 5 teacher, Interview 2)

They identified opportunities within the existing *mathematics mastery* curriculum for incorporating some of the ideas developed through the project, although this appeared to be easier when addressing the needs of higher attaining students:

> Because we do a 'mastery' approach … I think it's got me to think: 'How can I include collaboration a little bit more in the lessons? And draw out the problem-solving aspect of maths?' … That kind of critical thinking for the 'greater depth' children has been impacted, I think, a lot in my maths lessons, from being part of this project. (Rose, Year 5 teacher, Interview 2)

Subtheme 3.3: teachers' appreciation of the benefits of peer support and collaboration with colleagues

The teacher researchers recognised the potential benefits of being part of a collaborative research project:

> Anything that involves research, and just looking into things in more depth, and anything that will improve my practice, is something I'm going to be interested in. (Kate, Year 1 teacher, Interview 1)

They articulated clearly the value of having time to share ideas with colleagues:

> Always, in our profession, any sharing of best practice, sharing of similar challenges … we just don't have the time to do it enough … As teachers, everybody would welcome any opportunity to do that. (Layla, Year 6 teacher, Interview 1)

They described the benefits of working with teachers across different schools:

> I think it's been really good to work with a fellow Year 2 teacher, but from a different school. So, it's good to broaden your horizons and meet new people and get new ideas. (David, Year 2 teacher, Interview 2)

They appreciated how the participatory and collaborative nature of the research project provided the support and encouragement needed to try out new ideas:

> The collaboration, the meetings with other teachers. I liked it when we shared all ideas, and we heard what other year groups were doing … If you're trying to do something new, you just need to get a group of like-minded people, who will have different skill sets, to kind of work with each other, but also challenge and suggest new ideas. (Rose, Year 5 teacher, Interview 2)

They articulated the importance of support and leadership from senior leaders when implementing innovative curriculum reforms:

> I think it's difficult to come from individual teachers in classes, and I think it's something that needs to come from management, and be a whole school thing, and a whole school ethos. (Aidan, Year 2 teacher, Meeting 5)

Discussion of findings

In this section, we return to our conceptualisation of SMA, taking each element in turn, and we consider what further insight can be gained from the findings regarding its operationalisation.

The teacher researchers embraced the opportunity to collaborate with colleagues in sharing ideas and reflecting critically on their own practice. They also appreciated the mutual support provided by the research team in trying out new approaches in their classrooms (Subtheme 3.3). In doing so, they were able to question previous assumptions they had made relating to teaching mathematics (Wright, 2021), for example, they developed a greater appreciation of the benefits of problem solving and collaborative approaches to learning (Subtheme 2.4). The research lessons they developed provided opportunities for students to engage with the type of activities, involving exploration, argumentation and collaboration (Mason et al., 1985), which students need to develop an appreciation of disciplinary meaning (Subthemes 1.3 and 1.4).

Through engaging with research literature, the teacher researchers developed an appreciation of the limitations of the commercial schemes of work that the schools were using, and recognised the need to go beyond these in providing a more meaningful mathematics curriculum for all students (Subtheme 2.1). They provided opportunities for students to develop agency (Alderson, 2020; Manyukhina and Wyse, 2019), and they reported how students responded positively to being able to exercise greater control over their mathematics learning and to apply mathematics to solving problems relating to their own real-life experiences (Subthemes 1.1 and 1.2). The project therefore demonstrated an effective structure that might be adopted, with the potential for teachers to successfully navigate the constraints of the curriculum (Subtheme 3.2), and to cultivate students' powerful mathematical knowledge (Muller and Young, 2019).

While the teacher researchers were already committed to addressing issues of social justice in their classrooms, their involvement in the project enabled them to appreciate and identify the strong links that exist between mathematics concepts and social justice issues (Subthemes 2.2 and 3.2). This enabled them to design activities and stimuli that enabled students to use mathematics to develop a greater appreciation of their own situation, and of the world around them (Abdulrahim and Orosco, 2020), particularly in relation to understanding and addressing issues of power, equality and social justice (Subthemes 1.2 and 1.3). They overcame an initial reluctance to tackle social justice issues with younger students after witnessing their capacity and enthusiasm for engaging with the notion of fairness (Subtheme 2.3). The developing confidence among teacher researchers to challenge students' previous assumptions about the subject (Subtheme 3.1) also helped students develop a more critical understanding of mathematics, resonating with Bassey's (2020) wider argument that learners should be encouraged to think critically about social issues as a prelude to engaging in meaningful activism.

Through trying out and evaluating the research lessons, the teacher researchers developed a greater appreciation of the value of collaborative learning in terms of both enhancing the quality of mathematics learning and reducing mathematical anxiety of students (Subthemes 2.4 and 3.1). Through integrating group work into their explorations of social justice issues, they witnessed the enthusiasm with which students were willing to work collaboratively in solving real-life problems and constructing an argument for change (Subthemes 1.3 and 1.4). This developing collective mathematical agency, along with critical understanding, resonates with calls for school curricula that develop the skills necessary to address challenges facing global society (UNESCO, 2015).

Concluding remarks

The discussion above highlights the significance of our findings, in that they demonstrate an effective approach to curriculum development that a group of six teachers from two primary schools adopted to

enhance their students' SMA. The approach generated enthusiasm among non-specialist teachers of mathematics as they began to appreciate how achievable, enjoyable and rewarding such aims can be.

We recognise the limitations of this small-scale study, and we hope that it will prompt and inform future larger-scale projects with a similar focus that can explore how transferable the findings are to different contexts. While the voices of the teacher researchers came across clearly in the study, we feel that there is more space for the voices of students to be included in the data. The teacher researchers did employ student surveys in this project, the analysis of which are reported elsewhere (Wright et al., 2023b), but time did not allow for the collection of further student data, for example, through interviews, which have been used effectively in comparable projects (Wright et al., 2022a). The study was relatively short in duration (one academic year), although we are currently carrying out a follow-up study on the longer-term impact of the project on wider practice in one of the schools, the findings of which we hope to report in future.

Given the above limitations, we believe that there is sufficient evidence from the project's findings to argue that focusing on the three elements of SMA, namely developing powerful mathematical knowledge, critical understanding of mathematics and collective mathematical agency, has the potential to enhance the role of teachers and learners of mathematics as agents of change in addressing the increasing challenges facing our global society. This is the first research project with a primary focus on operationalising SMA, a recently developed concept (Wright, 2022), and we hope it will become the first of many.

Declarations and conflicts of interest

Research ethics statement

The authors declare that research ethics approval for this article was provided by the UCL Institute of Education Research Ethics Committee.

Consent for publication statement

The authors declare that research participants' informed consent to publication of findings – including anonymised quotes – was secured prior to publication.

Conflicts of interest statement

The authors declare no conflicts of interest with this work. All efforts to sufficiently anonymise the authors during peer review of this article have been made. The authors declare no further conflicts with this article.

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