WORKSHOP REPORT

Is Mathematics Inclusive or Exclusive? Putting Colour, Culture and Context in the Curriculum

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Keywords: Decolonising, awarding gap, inclusive pedagogy, race, intersectionality.

Abstract: The workshop, "Is Mathematics Inclusive or Exclusive? Putting colour, culture and context in the curriculum" was held in January 2022 with the goal of supporting a national discussion around race and the mathematics curriculum in UK higher education. This report summarises the talks and discussion, which related to racial and ethnic inclusion in the history of mathematics, race and culture in mathematics education, and ethics and inclusion in mathematics. It concludes with a proposal of actions for individuals, departments and institutions and the mathematics community in UK higher education to move work on this area forward.

1. Overview

The workshop "Is Mathematics Inclusive or Exclusive? Putting colour, culture and context in the curriculum" was held online on 25-26 January 2022. It was hosted by the International Centre for Mathematical Sciences (ICMS, Edinburgh, UK), and organised by a committee representing several UK professional societies in mathematical sciences[1]. The goal of the workshop was to begin a discussion within the UK higher education mathematics community about how to best to improve the inclusion of ethnic and racial perspectives in mathematics teaching in UK higher education, and how to ensure that students from all ethnic and cultural backgrounds feel included and supported in their mathematical studies. This is set in the context of broad calls for decolonisation in higher education curricula, which means recognising the cultural dominance of Eurocentric knowledge systems and working to create spaces in which all global cultures and their contributions are valued. These calls, however, have most generally focussed on disciplines, such as history, where cultural considerations are more obviously central to the subject itself. So, one of the fundamental questions the workshop aimed to investigate was, what could or should racially and culturally inclusive curriculum and pedagogy mean in the context of mathematical sciences? What steps can be taken immediately at the level of individual instructor or department, and what work does the broader UK mathematical sciences community need to undertake moving forward to incorporate these ideas into mathematics teaching at university?

[1] Supported by the British Society for the History of Mathematics, the Institute of Mathematics and its Applications, the London Mathematical Society, the Operational Research Society, the Royal Statistical Society, and the **sigma** Network.

Speakers at the workshop came from the UK and abroad and covered three main areas: history of mathematics, race and culture in mathematics education, and ethics and inclusion in mathematics. In addition, break-out discussion groups permitted participants to share thoughts and raise questions, with a chance to feed back to the full group afterwards. The workshop concluded with a panel discussion aimed at understanding the similarities and differences between the US and UK contexts. Over 200 participants attended the workshop, from 14 countries on five continents and from 70 UK universities. Recordings from the workshop and other resources are available online through the workshop website (ICMS 2022).

2. Colour and Context: Race, Culture and Mathematics

The workshop featured two prominent speakers from the US mathematics community who are advocates for both research and practice that recognise the importance of culture and race in mathematics education. Danny Martin is an internationally recognised expert in mathematics education, known particularly for articulating and leading a research programme focussed on race and identity in the mathematical education of Black Americans. Aris Winger is a mathematician who has been active in improving racial inclusivity in university mathematics through his talks, podcast and writings, including two books with mathematician Pamela Harris.

Aris Winger opened the workshop with a talk entitled 'Mathematics, Race and Belonging'. In it, he led the participants in an interactive exploration (via anonymous padlet) of their beliefs and attitudes about mathematics and the relevance of race to the discipline. He began by setting out the major problem, belonging ("*Mathematics is the greatest subject in the world, but it may not be the most welcoming.*") and the cultural challenges in solving this: political division ("*Supporting all students in mathematics should not be political, but it can be made political.*") and time pressures ("*We have a lot of things on our plates. This is not something extra--it is something that has been on our plates, but we haven't been paying attention to it.*"). He then gave an overview of principles needed for work on racial inclusion in mathematics: expect and embrace discomfort, be fully present in discussions and listen actively and respectfully to all points of view and keep students of colour at the centre of the discussion.

Winger then presented two perspectives on mathematics that influence how we think about belonging: mathematics as a body of knowledge, and mathematics as a human activity. The first of these leads to a view of mathematics as a discipline that belongs to the experts, like medicine. The second leads to a view of mathematics as something everyone can and should do, like sport or games. These views are often set in an unnecessary opposition—rigour versus inclusion—and lead to the question, do we need gatekeeping in mathematics, or do we need to ensure broad access to a rigorous mathematical education?

Finally, Winger asked, what does race have to do with mathematics? This brought out a wide range of views. Concerns were raised that relating race to mathematics can lead to a view of mathematics as a 'European tradition' and a 'western way of thinking'. Other comments put forward that Mathematics is not value neutral in terms of what topics we choose to study and whose contributions are recognised. Winger summarised with three questions: who do we imagine as mathematically adept? How do we teach and advise different students? What mathematics do we do? "*Social inequality is a math problem*," he pointed out, "*but we are not working on this problem with the same intensity and fervour in mathematics as in other disciplines, and this relates to race*." Winger concluded with a particular message to white mathematicians: "B*eing white in the UK means something. The future of the discipline is tied to how we understand whiteness and being white, to white supremacy and fighting it. Examining the discomfort associated with these ideas is where we need to start in order to make the discipline better*."

Danny Martin gave the final talk of the workshop, 'Rethinking Equity and Inclusion as Racial Justice Models in Mathematics (Education)'. He posed three questions:

1. What do white supremacy and antiblackness have to do with mathematics education?

2. What are some of the limitations of equity- and inclusion-oriented justice projects, especially in relation to Black learners and mathematics education in the US?

3. Beyond equity and inclusion, what are some justice projects that can respond to the material realities, needs and desires of Black people inside and outside of mathematics and mathematics education?

Note that the phrase "white supremacy" is used here to refer not to individual racists or extremist groups advocating a white ethnostate such as the KKK, but more broadly to social systems which uphold the privilege and power of white people and centre and normalise them and their experiences. He then proposed that white supremacy and antiblackness are adaptive social systems that self-correct, so that work that contributes to inclusion at some levels and in some contexts does not preclude exclusion at other levels and in other contexts. In this way, they can uphold and entrench inequality under the pretext of social justice. He mentioned for example that desegregation in the US, which was supposed to lead to inclusion for students, led to the firing of large numbers of Black teachers as Black schools closed. "*This idea is challenging and difficult for individuals engaged in diversity work,*" Martin noted. "*The vision is that if we engage in this work, it will lead to the success of Black students.*" He discussed the decades of mathematics education reform in the US, particularly with the equity-themed discourse of "Mathematics for All" that began in the mid-1980s. This has not led in the intervening years to any greater proportion of Black Americans among mathematics majors and has in fact been accompanied by a substantial decline (from about 8% to about 4%) since the mid 1990s. "*It is very difficult to dismantle systems that benefit so many people individually and collectively. We need to rethink mathematics reform from this viewpoint.*" To do this, we need to be aware of the social issues and the social science research around race and identity. This research indicates the impact of, for instance, microaggressions and the assertion of the neutrality of knowledge and knowledge production in the discipline. He discussed the concept of "white institutional spaces" in the US and how these lead to inclusion efforts resulting in marginalisation and assimilation, and which do not change the nature of the space.

Martin recognised that different geopolitical contexts have different racialised social systems, and these effects play out differently in different locations, but that the existence of the racialised system is the commonality. One aspect of this is the concept of identity, and in mathematics in particular, how do students from different ethnic backgrounds construct a mathematical identity? And, how do their racial and mathematical identities intersect and interact? "*What we are finding from our research [in the US] is that being Black matters to Black people who do maths,*" he recounted, "*Over the past 20 years we have found that across educational levels, what works is to open up a space for a non-deficit approach, which focuses on identity, socialisation, resilience and success, where success is put in a broader context of humanity, and mathematical success can be actualised in different ways, not only through obtaining a PhD.*"

3. Visibility and Culture in the History of Mathematics

Three short presentations and a longer plenary demonstrated the contribution that history of mathematics can make to inclusive mathematics curricula, by emphasising the contributions of many different cultural and occupational groupings to ways of doing mathematics, and promoting diverse role models The importance of such role models, and unfamiliar perspectives on mathematics, in enhancing inclusion came out strongly in breakout discussions (section 6) June Barrow-Green, Chris Hollings, and Edmund Robertson outlined resources being developed at their respective

universities. In ‘Diversifying the Curriculum through History of Mathematics’, Barrow-Green talked about an online resource that she and Brigitte Stenhouse are currently developing at the Open University. It will contain original and secondary source material to exemplify the rich diversity of contributions to mathematical development. It is aimed at students but will be openly licensed and freely available to all on the Open Learn platform (Open University, 2022). Hollings’ talk on ‘Diversifying Mathematics in Oxford’ gave three mini case studies of interventions he has been involved with:

1. The Diversifying STEM Curriculum Project worked with student interns to co-create resources for lecturers in STEM subjects to help them present a more diverse image of their subjects (Oxford University, 2022).

2. Using examples drawn from the mathematical practices of various cultures (ethnomathematics) around the world, as exercises in mathematics tutorials. Hollins gave a specific example of using Australian Aboriginal kinship relationships as an exercise in group theory.

3. Designing a series of posters to portray a more diverse image of mathematics, making the environment within which the curriculum is taught more inclusive (Oxford Mathematical Institute, 2022).

Robertson’s ‘MacTutor: My own Personal Journey’ chronicled the development of the MacTutor history of mathematics website (St. Andrews, 2022), which contains biographies of around 3000 historical mathematicians and 2000 pages of related material. The biographical subjects come from 94 different countries, with deliberate attempts to increase the coverage of under-represented groups such as women (currently around 1250) and Africans (over 400 men and 200 women with PhDs in mathematics). MacTutor is openly licensed and aimed at a general audience.

All three speakers are developing resources that fulfil the need for powerful role models of diverse mathematicians – a need expressed strongly by participants in subsequent breakout discussions – but vary in the amount of pedagogical support they provide for staff wanting to diversify their curricula. They range from the Open University’s stand-alone lessons that students could study independently, through resources designed for lecturers at Oxford, to MacTutor which provides a far greater variety of potential models but leaves it to staff or students to work out how to use them.

A tension between complexity and simplicity came across strongly in Barrow-Green and Hollings’ talks and in ensuing discussions. One of the main messages of history is that mathematics is a human activity shaped by a complex web of interacting historical and cultural factors. This understanding can challenge many of the persistent myths about mathematics that may deter students: ‘mathematicians are born not made’, ‘black people/girls are no good at maths’, ‘mathematicians burn out at 30’. It can provide insight into the process of practicing mathematics in many contexts and levels and understanding of past (and present) barriers to education, knowledge, resources, and recognition. But this very complexity can be overwhelming, preventing students and staff from engaging or finding space for it within the curriculum. A challenge for historians is to work with educators to develop ways of organising and presenting material so that it is attractive and engaging without losing the benefits of insight.

Hollings made two further important points. First, that if we, as historians, are to be more inclusive, we need to broaden views of what counts as mathematics, recognising mathematical cultural and social practices (including Western ones) whose aim is not just to develop new mathematics. This recognition is pursued in the discipline of ethnomathematics. Hollings’ second point is that to inspire diverse students we not only need to show that mathematics was a global activity in the past, but also the mathematics that is going on all over the world today. Each in his poster series include

current as well as past mathematics. This is an area where MacTutor can help, with a number of its biographies covering living mathematicians from minority backgrounds.

In her plenary, Karine Chemla first highlighted two ways in which diversity is commonly approached in history of science, and in particular, history of mathematics, that she considers deeply problematic. She illustrated her points from writings on Chinese mathematics. The first is a crude partitioning of the world into nations, cultures, and civilizations. She contrasted Lucien Febvre's 1949 argument that historical research should focus on "*everything that circulated from one group to the other*" and that "*the partitioning of the World is nothing but a fiction*" (Febvre 1953) to Joseph Needham's 1950 aim to "*outline the various patterns of the great cultures and civilisations, their particular world-outlooks which were characteristic of them,*" (Petitjean 2006). Drawing on an example of Geneviève Guitel's comparative study of written numeration systems (Guitel 1975), she showed how a methodology based on written evidence brings with it a hidden assumption that language is the primary categorisation for number systems; the conclusion that number systems are best characterised by language culture follows naturally but is only warranted in so far as the initial assumption is warranted. Research by Chemla and colleagues challenges this assumption, evidencing the existence of non-written and often non-verbal numeration and calculation practices that differ from one specialist group to another within a single language culture but are common to similar specialist groups in different language cultures – suggesting a connection and circulation of practice among the groups. This is diversity of a different and more complex kind than a simple partition of nations, cultures and civilizations.

Chemla's second concern is that historians of science and mathematics have tended to partition peoples into groups whose styles of thought and intellectual activity are characterised by different parts of the world. They assume that knowledge activity can be characterised by specific features that are then used to contrast these parts of the world with each other, and that these features are enduring. Drawing on the example of the Chinese mathematician Wu Wenjun (1919-2017) who turned to automated theorem proving and history of mathematics during the cultural revolution, she shows the consequences of this type of history in constructing national narratives. On the basis of allegedly differing but enduring styles of thought in the ancient mathematics of East and West, Wenjun was able to present his research on automated theorem proving as a return to a specifically Chinese tradition that has modern significance. This narrative was adopted by President Jiang Zemin in 2001 when awarding Wenjun the highest distinction in science and technology in China. Similar examples can be found in all parts of the world and all disciplines.

Chemla's essential claim, evidenced by a case study of numeration systems, is that diversity exists, but it is not to be found within the boundaries of people, cultures and civilisations. Such crude categorisations may prevent us from understanding the actual nature of mathematical activity and the collectives that are meaningful in mathematics. There are other ways to approach diversity that may be more useful in the classroom, for example, for pupils to consider *practices* of numeration and computation and to think about diversity in more fluid terms.

4. Ethics and Inclusion in Mathematics

Two talks from Tarik Aougab and Kutoma Wakunuma focused on how ethics and inclusion can be addressed through changes to curriculum, either through innovative approach to curriculum design, or discussion of ethics in mathematical modules.

Tarik Aougab gave an overview of a module Ethics and the Use of Mathematics introduced in 2020-21 in Haverford College. The course was a response to the concerns expressed by students involved in the Black Lives Matter movement. Unlike most modules in mathematics, it is run as a seminar: each week students are given pre-reading and then meet to discuss a specific topic. In the first two weeks, a set of ground rules is agreed by all students and staff involved, then, seminar-style, different

topics of mathematics and ethics are discussed in weeks 3-8. The topics discussed in the modules covered: use and abuse of mathematical methods such as predictive policing, facial recognition and surveillance, controversial publications such as those related to the Variability Hypothesis, which claims that males generally display greater variability in traits than females do; mathematical perspectives on economics, hierarchies and the role of imperialism in science. In the final weeks of the module, students pick a specific topic from the list already discussed and prepare a project (either individually or as a group) in the form of pedagogical material, which can then be used in other courses. Resources created in the module will form a library from which all lecturers can draw materials to integrate into their modules.

Kutoma Wakunuma from Centre for Computing and Social Responsibility, De Montfort University, discussed design of mathematical curriculum from personal perspective of a student in primary and secondary education in Zambia, and from a professional perspective of theory of curriculum design. Wakunuma's personal experiences were marked by the lack of role models, poor resources and lack of encouragement, which lead her to see mathematics as a subject not worth or appropriate to pursue. She argued that some of these issues can be eliminated by a better curriculum design, one following the theory of curriculum design which uses the four AREA dimensions:

- Anticipating: consider what the curriculum might mean and for whom it might be meaningful;
- Reflecting: if the above questions suggest that the curriculum might not be inclusive, consider what can be done to improve it,
- Engaging: consider who needs to be engaged to ensure that the curriculum works for all,
- Acting: make changes following the first three steps.

This approach enables us to provide a more relevant and inclusive curriculum, which reflects values of wider range of stakeholders.

5. Panel Discussion: Mathematics, Race and Belonging

The panel consisted of Aris Winger, Danny Martin and Vijay Teeluck. The first two are internationally recognised experts from the US mathematics community, and the latter works on projects aiming to support BAME (Black, Asian and Minority Ethnic) students through her role as a senior lecturer and Maths Support Tutor in the UK. The main points of the discussion centred on pertinent questions posed by the chair which included racialised systems, a sense of belonging, success in the mathematical realm, closing the awarding gap in the UK, white supremacy, maths as a collaborative space, and how racism influences the way mathematics is shaped.

Although it was accepted that the racialised systems in the UK and USA were broadly different, there were similarities with schools playing a part in social reproduction which is guarded by white supremacy and anti-blackness. Martin voiced that schools should be independent institutions but are an arm of the state and carry out the objectives of the state in different ways through policies and legislation which has an absence of local control, therefore, reproducing hierarchies that exist in society. Teeluck echoed that these inequalities within the UK system play out with higher numbers of Black students being disproportionately excluded, and Winger reiterated that this is the way structures work i.e., we should not expect the education system to be different especially with respect to the disparities that go on in society.

Winger advocated developing an analogous understanding through listening to marginalised people and providing an authentic space in which their experiences could be heard - otherwise the white space becomes the dominant space. On a macro scale, Martin suggested that racism relies on

capitalism and that researching the interconnectedness of racial exploitation and capital gain would allow for further understanding of racial stratification. The panel discussed elements of success in tackling the marginalisation of non-white students, however, Martin stressed that it was important to allow Black people to self-determine what they do with mathematics and that comparisons to white success (e.g., the awarding gap) was only normalising the white students and reinforcing that Black students are inferior. Hence, it was vital to examine the nature of the gap discourse and not only what it says ideologically but what it implies.

When aiming to move away from white supremacy, Winger was clear that one of the main markers was 'Who is upset?' when actions are taken to challenge the current systems. Reference was made to a joint publication, 'Asked and Answered: Dialogues on advocating for students of color in mathematics' [Harris and Winger, 2020]. Martin touched on the topic of reparation; not only would this mean surrendering privileges that we have and that continue to benefit us at the exclusion or detriment of someone else but also paying the debt that is owed to the descendants and beneficiaries who were enslaved in the US.

When considering factors which exacerbated inequalities and racism in maths, Martin stated that mathematics was no different than any other social enterprise and that it was a particular type of political project with relationships to militarism, the economy, the war on terror and international competitiveness. Teeluck referred to lack of BAME staff as role models and the methods of student assessment that perpetuate these inequalities. Moreover, Winger strongly advocated that the nature of the discipline is determined by the people, and that new directions would mean re-thinking who is going to be taking part in these conversations.

Figure 2. Panellists from left to right: Danny Martin, Aris Winger, Vijay Teeluck

6. Issues Raised in and from Discussions

There were several opportunities for discussion and participant contribution at the workshop, and they were quite actively used, indicating the benefit to the community of providing such fora for discussion of the topics of the workshop. This was echoed in participant comments, such as "*A really engaging and emotive workshop*".

The prompts used by Aris Winger in his talk demonstrated a range of experience and perspectives. For example, the responses to the prompt about if members of our community view mathematics more as a body of knowledge, or as a natural human activity got responses from "*You can't access modern mathematics in a creative sense if you don't first master a vast body of knowledge*" to "*Framing it as something everyone can do is helpful in outreach and making people feel like they can get involved*". There was a clear tension between the notion of higher mathematics as an elite, gatekeeping body of knowledge and mathematical thinking as something everyone needs to do in order to be the best they can be, but also with some indication that engagement at different levels is

seen differently in this regard. This suggests a refinement: is gatekeeping required anywhere in mathematics, and if so where and why, and how can this be achieved while also ensuring equal access?

The prompt 'What does Race have to do with Math?' also generated substantial discussion, with comments ranging from "*nothing*" to "*everything*". Notable comments included that "*mathematics is something done by people who call themselves mathematicians*" who are perceived as predominantly white, males, and results in (unintentional) exclusion and that 'race' is one of [the] lenses by which we construct the mathematician, which is inseparable from the maths. Other comments were about the Euro-centric nature of mathematical terminology and that the experience of mathematics has links to one's identity and thus the way it is taught can make a big difference in terms of getting our students to understand how maths has influenced our world and whether they feel included in mathematical thinking. Again, this suggests that mathematics as done by researchers is seen to some extent as a separate and different activity from mathematics as done by students, with race relating in the case of researchers to how the identity 'mathematician' is constructed by society, whereas for students to how it is related to the construction of their own identity as related to mathematics, with these being linked through the concept of role models. It was not clear where in this distinction individuals who use mathematics in a non-research career fit.

Discussion break-out groups were asked to consider how to put history and stories into the curriculum in UK. What came through strongly in the discussion groups was the importance of diversity in role models, with mathematics in non-research careers specifically mentioned: "*It would be really great to have some short videos of diverse mathematicians from industry talking about some mathematics idea that they found really inspiring when they were students, or that they struggled with, or that they use in their work*." Several groups referred to drawing on existing graduate students as speakers and as sources of information. The Algebra group offered a useful example: In which respect is the elimination of Ancient China different from Gaussian elimination? - discussion of this question was found to be a way to develop understanding. Other members proposed that adding in something about how a mathematical concept got its name doesn't take up much time, for instance, lecturers could give a link to a debate, and it does help generate interest. There were also suggestions regarding links between arts and maths in particular "*African textiles, Aboriginal art and Native American Indian textiles (symmetry, rotation, reflection, pattern, sequence etc.)*", and the importance of including applications to topics learners are concerned about such as climate and justice. The role of project work in giving room to such aspects in the curriculum was proposed. Another theme was the possibility to reach out to students to come up with diverse examples of applications**.** Overall, there was interest in the development and dissemination of more resources to help with incorporation of history and stories in teaching, with a discussion about how we pool resources, as items developed in one place might be useful for folks in another. A platform for sharing these types of resources was suggested.

Regarding the inclusion of ethics into the curriculum, one chat theme started with the question How do you ensure that a Math Ethics course isn't just a different form of indoctrination? A contributor introduced the notion of decolonial practice as helping with this, in which "*Student voices are heard as opposed to a transmission model; students are co-creators of knowledge, teachers are encouraging deep thinking and providing a wide range of resources*". The model proposed by Tarik Aougab was seen as "*courageous*", and was positive about this, but less positive about the perceived barriers to curriculum change. One role for the community could therefore be in lowering those barriers, or even considering how course accreditation standards could be adapted to include ethics.

Finally, from all discussion, there was evidence of technical vocabulary of relevance to these topics that is not necessarily widely understood, with terms such as 'brave spaces', 'intersectionality', 'solidarity', 'decolonial'. The term 'BAME', though commonly used in the UK, is also one that

deserves unpacking, in terms of combining in one acronym a collection of very different groups. This suggests the utility of a resource that lays out these terms with definitions and examples of their relevance in mathematics and mathematics education.

7. Conclusions and Next Steps

This workshop was just the beginning of a larger discussion and project in the UK to improve racial inclusion in HE mathematics education and more broadly. It suggested several ways forward.

Actions for individuals include:

- Read relevant literature on race and education from social sciences—Danny Martin's talk and references can serve as a starting point,
- Integrate existing materials showing diverse history and case studies into your teaching, either linked to lecture material or just as a showcase at the start of lectures —see multiple linked resources on the workshop website,
- Co-design ethnic diversity, ethics, social justice related resources to integrate into existing modules with students through projects or a seminar – Tariq Aougab's talk and syllabus or Chris Hollings' talk and example projects can serve as a starting point.

Actions for departments and schools include:

- Initiate discussions—embrace difficult and uncomfortable conversations about race and belonging in your departments, as it is through discomfort that we move forward. Aris Winger's talk recording can serve as a starting point, framework and set of guidelines for discussions,
- Analyse your curricular design for inclusivity—Kutoma Wakunuma's talk on the AREA framework (see also the UKRI Framework for responsible innovation (UKRI 2022)) can serve as a starting point.

Actions for the community and professional societies include:

- Undertake qualitative research at the national level on the experiences of ethnic minority students,
- Provide support for projects to develop resources for incorporating ethics and race in teaching,
- Develop an easily searchable and accessible resource bank for sharing such resources,
- Work on changing the culture and accreditation standards to include ethics and inclusion in UK mathematics courses,
- Organise follow up/follow on events to provide further opportunities for collaboration and discussion.

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