The Race and Ethnicity Hub
BHM Event Decolonising the curriculum through the history of mathematics

June Barrow-Green and Brigitte Stenhouse:

As I say, as Katrina said, it's going to be the two of us presenting. And the format is going to be that I'm going to start by telling you about a project that we are in the process of developing. And we hope that we will get funding to fully develop it and for it to be usable.

And then I'm going to show an example of how one might use this particular resource, which is what the project's about. And then Brigitte is going to show it another completely different way of using it. So hopefully, this will all kind of complement-- everything will complement each other. So, let me begin.

So, the idea for this project came about because I received-- a message was forwarded on to me as the resident historian of maths in the maths and stats school. And this was a comment from a tutor on M208, which is our Pure Mathematics module, 60-point module.

And the tutor wrote, "When I got to reading page 272 of Book E, I let out a silent cheer. The picture of Emmy Noether, and the blue box with a short mention of her, is, I think, the only picture of a woman on the whole of M208-- except, perhaps, one of the bell-ringers." And then "Whilst it's true that most famous mathematicians of the past were men-- and many of them bearded men-- I wonder whether the absence of pictures of women is sending the wrong subliminal message to M208 students?"

So for those of you who are not mathematicians here, the bare fact of the matter is that an awful lot of the mathematics that is taught to undergraduates-- not just that they're OU, but everywhere-- is based on mathematics that was developed in the 19th century. And in the form, it was developed in the 19th century. A lot of it is how it's still presented largely today. And of course, it was developed by men. And an awful lot of those men did have beards. And of course, they were white European men.

And so, of course, you see in the modules names of people are attached to theorems and so on. And so, of course, that's an opportunity to say something about them-- hence, the pictures of the men with beards. But what that doesn't tell is the story of how this mathematics really came to be developed across the centuries and also what was going on elsewhere maybe in a slightly different way.

So what I thought-- having seen this message from the tutor, I thought, well, what I need to do is perhaps try and gather together some sources that show examples of women mathematicians at work and find some way of making them available to all students. Now, of course, we can't rewrite all our maths modules. But what we can do is do something that will point them in the direction of some other materials.

And so that was what I was thinking when I then got another message. I got an email from a colleague at the LSE, who was, again, writing to me as a historian of mathematics asking for ideas about resources for their undergraduates to become more aware of the diversity of mathematicians in general. And so, of course, then, I thought, actually, of course, what we should be doing is trying to build some sort of resource, which doesn't just concentrate on the difference in gender, but also just on diversity in every single way.

So, we got together to think about this and discussed what this sort of resource might look like. So, if we have a bunch of sources-- primary sources, secondary sources-- and we want students to look at these, then who are the students, undergraduates? Maybe other people, maybe math teachers, how accessible is it going to be? If it's going to be something that's available for Open University students?

I mean, my thought had originally been for M208 students. And then I thought, well, of course, I should be doing something for all of our undergraduates. But then with the contact from the LSE made me realize in the discussion that actually it makes no sense for everybody to be reinventing the wheel. Why not do something that would be available to anyone, anywhere?

So, to make it open access and think about, well, what would the purpose of this be? And how would we be able to guide students towards looking at some of this material? Well, of course, one of the things that does get the students looking at things is if there's some assessment, and that counts for something.

So maybe that is a way of building it into our modules where if we can't actually rewrite the modules, but we can actually adapt our assessment and use the resource in that way. So what that basically led to was thinking about, OK, let's build this resource and put it on OpenLearn. So that that's the kind of thinking.

And so, then the next thing to sort of think about is, well, what should this resource contain? Well, obviously, it has to be kind of guidance about using it. The primary sources-- so those are the original pieces of mathematics. Whether there is a piece of Egyptian mathematics, for example, with a transcription or translation; a piece of 18th century mathematics. Maybe it's a mathematical diagram. Maybe it's a picture of a mathematician at work and so on.

And then secondary sources-- this is people writing those primary sources and how views have changed across time. And assessment suggestions, because, of course, I'm used to working with historical resource. But most of my mathematical colleagues at the OU and elsewhere are not. So, they're going to need some help in being able to use these sources constructively, and also links to other sources.

Then, if this resource is going to be useful, students have to be able to find the thing that they're looking for. So, you have to think about how the resource is going to be organized. And so, there are many different ways of cutting the cake. So, it could be mathematical, different subjects, different ideas. Geographical-- it could be by country or it could be by communities.
Chronologically-- over time. Biographically-- by gender. Or other-- there could be other ways of sort of tagging the material in the resource. Could its connection to another discipline, for example, or whether it's educational, or maybe the way mathematicians have communicated.

Because the way we communicate now, of course, is very different using journals and periodicals and books and things compared to in the past. And to give an indication of this complexity here, this slide is really just to show that. I don't expect anyone to see it, read every little bubble on it. But just to show that this is not a trivial task to find a resource, to find some primary source and/or some secondary source, and then target in a way that makes it accessible to students.

But that on its own is not enough because you can just go and find something. But you need to be able to be given some help to interpret it. And that's what we also want to do. So, for everything that's there, we want to have some kind of way of bringing the student in to be able to interact with that source.

Now, it can't be too complex. It can't be to [AUDIO OUT] together because the student is just not going to be-- they're just going to lose interest if they just see a whole pile of text. So, we want to be able to have enough information about the source that will enable the student to go off and find out other things for themselves, raise some questions for them, and so on.

As I say, for each item that we want to put in it, then we want to have this guidance and have it marked up in a way that makes it findable, makes it something that if they're interested in a particular thing, then they can find it. And so, what I'm going to do now is to talk about, say, a particular search in the resource.

So I'm just saying, well, OK, I'm interested in African mathematics. And I'm interested in what we would call early, modern historical terms, 16th and 18th century. What items are there that will speak to me about that fulfil both of these criteria?

And if I do that, then I come up with the names of two people-- Thomas Fuller, who lived between 1710 and 1790; Benjamin Banneker, who lived between 1731 in 1806. And so, I think, oh, well, I wonder what's in the resource about these people? I'll start at the top.

So I'll look at Thomas Fuller and see what's there. And what do I find? Well, I find an article from a periodical published in London in 1788. And the title of the article-- I don't expect you to be reading the article. But that's the title of the article says, "An account of the extraordinary Powers of Calculation, by Memory, possessed, by a NEGRO SLAVE in Maryland, communicated in a letter from Dr Rush, of Philadelphia, to a gentleman in Manchester."

And in fact, Dr rush wrote two articles about this particular Negro slave. And this is just one of them that I'm showing you here. And there was a third item, which was a notice of Thomas Fuller's death. And that was in the Columbian Centinel, where, again, I'm just showing a little bit of the article here.

It says, "Died-- NEGRO TOM, the famous African Calculator, aged 80 years. He was the property of Mrs. Elizabeth Cox of Alexandria. Tom was a very black man. He was brought to this country at the age of 14 and was sold as a slave with many of his unfortunate countrymen. This man was a prodigy. Though he could neither read nor write, he had perfectly acquired the art of enumeration."

And then at the, end it says, "Had his opportunity of improvement been equal to those of thousands of his fellow-men, neither the Royal Society of London, the Academy of Sciences at Paris, nor even a NEWTON himself, need have been ashamed to acknowledge him as a Brother in Science."

So, these are documents that were written at the time of-- that Thomas Fuller-- well, one, while he was alive, it was published in 1788 two years before he died, and then one on his death. So, these are contemporary documents that tell us about Thomas Fuller. And so, we can ask questions from these documents. We can say, well, who was he?

How do we know about him as a mathematician? How do we know about him, per say? How's he been represented in history? For what purpose? How did he learn to calculate?

Now, you'll see up here on the screen I've got four pictures. And I think it's pretty obvious that they're not four pictures of the same person. But they're for pictures I just got from the internet when I googled Thomas Fuller and images. And so, this is just a little warning that, of course, we have no idea what must Fuller look like.

And so, these are people feeling that these are representative images. And personally, I find this is not helpful at all. And I really counsel against using images like this. And I just wanted to put them up there so you could see.

OK, so who was Thomas Fuller? So, what we can learn from these sources is that he was born in around 1710. He arrived in America in about 1724.

He was probably given that date. We can find out from elsewhere that he was probably one of some 150,000 slaves who were shipped in that period from somewhere between Liberia and Benin. That's on the West Coast of Africa, up the top, the sort of pink part out there.

He lived in Alexandria in Virginia. He was the property of a Mrs. Elizabeth Cox, and he was illiterate. In around 1780, when he was 70 years old, he was visited by two gentlemen from the Pennsylvania Society for the Abolition of Slavery who reported on him. And it was their report that Dr Rush used. And then we know he died from that notice in the Centinel in 1790.

And so, what do we know about him as a mathematician? Well, in these reports that particularly from the longer Rush report that I didn't show you, the gentleman from the Abolition Society asked him various questions. And so, such like, how many seconds in a year and a half? And then he gives the answer.

And then they also record how long it took him to come up with the answer. And they also checked that the answer was correct. Interestingly, they also reported that he could calculate with the most perfect accuracy how many shingles a house of certain dimensions would require to cover it, and how many posts and rails were necessary to enclose, and how many grains of corn were necessary to sow a certain quantity of ground.

From this application of his talents, his mistress has often derived considerable benefit. I think this is an important part of the document because it tells us that Thomas Fuller had extra value to his owner other than just his physical ability. He was clearly very useful to her because of his powers of calculation.

And remember, this is a period where there was no compulsory education for people. His mistress, or his owner, probably had had no mathematical education herself. So actually, to have somebody who could do those kinds of calculations for her would have been immensely valuable.

It also perhaps explains-- the sources don't tell us this, but one might be able to conjecture-- the fact that he was known about when he was age 70, because by that point he obviously would not have been as valuable as a physical possession. I mean, it's terrible to talk about him in this way. But I mean that's—

So he wouldn't have been as attractive to other owners. And also, this does tell us that he was very grateful to his owner for not selling him. One, again, can see that perhaps she had very good reason for not selling him because he was particularly valuable to her.

So how do we know about him? Well, these sources that I've mentioned-- the two by Benjamin Rush, the first one I showed you; and then the obituary notice-- Benjamin Rush is an interesting person himself. He was a very vocal abolitionist and social reformer. He was also a controversial physician. And you can read up about that if you're interested.

But he was a signatory to the Declaration of Independence as well. And his actual job was that he was professor of chemistry and medical theory at the University of Pennsylvania. And so he's a kind of key figure in this story because it's due to him that the information that we know about. Fuller is in the public domain.

And in fact, these sources, these original sources, were reproduced both shortly after they were first published and then again into the 19th century. So, you do see them being reproduced. But what you also see are a number of secondary sources. So, people having seen these original sources and then using them in various different ways.

And what I just want to highlight here is the fact that more often than not, Thomas Fuller's name comes up in articles to do with prodigies. So, for example, in this American Journal of Psychology and so on, you can see it's very, very prevalent. But what I also want to point out, particularly, is this article at the bottom by John Fauvel and Paulus Gerdes published in 1990. And that's John Fauvel on the left. And he was a colleague of mine here at the OU. He sadly died in 2001. There may be one or two people listening who knew John, who was an amazing historian of mathematics. And he was very interested in ethnomathematics and in all kinds of different aspects of mathematics, sort of maybe a bit more out of the mainstream of history of mathematics.

And Paulus Gerdes, who sadly died in 2016, was the expert on Africa and mathematics. He worked in Mozambique. And he's written an awful lot on mathematics and Africa. And his work is really, really to be valued.

And how I came to learn about Thomas Fuller was through this article of John's. I remember him talking to me about it. And I'd also like to point out that it was published in 1990. So, it's

30 years ago. So, John was really ahead of the curve in thinking about these kinds of things with regard to within sort of history of maths in the general sort of mainstream.

And this article is now on open access. And I really, really recommend people read it if they're interested in these issues. And an awful lot of what I've been saying has been drawn from this article.

And in particular, John and Paulus have talked about representations of Fuller. So how he has been used in history. And so, as evidence, I mean, one of the absolutely key things that he was obviously being used as evidence in the abolitionist cause. Because, of course, the slave owners were very much at pains to try and convince people that their slaves were no good for anything other than physical work.

And so, the example of someone like Thomas Fuller was really very important for the abolitionist to be able to show that, of course, this was complete nonsense. And lack of education and opportunity, et cetera, I don't need to go into those arguments. He's also very much used, as I pointed out, in the context of mental prodigies.

And then thirdly, in this category of a mathematical Mozart. So, by which we mean somebody who showed talent very young and then went on to develop as a real genius or that absolutely is top of their field. And in mathematics, a classic example of this is Gauss, who showed his ability to calculate. And within mathematics, very young and went on to become one of the greatest mathematicians of all time.

And then those are often kind of contrasted with what's kind of known as an idiot savant. So there are people who have remarkable powers of calculation. But in terms of other mathematical abilities, don't seem to-- their mathematical abilities don't seem to develop in other ways.

And when you look at the secondary sources about Fuller, you see people having differing views on this. And I would point out particularly, for example, the bottom one here where Meyers in 1903 described Fuller as having low intelligence. But actually, if he had read the sources carefully, there is absolutely no evidence for that at all.

In fact, I would argue along with John and Paulus that the evidence actually is in the opposite direction, because one the things that's remarked on is that one of the gentlemen who went to see him remarked in Fuller's presence that it was a pity he had not had an education equal to his genius. And Fuller himself then says, no, massa, it is best I got no learning. For many learned men be great fools. And I would, as I say, agree with John and Paulus that this definitely does not put him in the class of someone with low intelligence.

So the final question-- I just want to kind of ask from these sources-- is well, how did Fuller learn to calculate? Well, we really have no idea. He was clearly self-taught in some way. There wasn't, as I say, that kind of educational opportunities for him either obviously in America or what it is now known as the United States.

But in Africa, we really don't know. I mean, one of the things that the slave trade did as well as all the other awful things it did was kind of destroy an awful lot of the original sources and things for anything that we might try and find out about what was going on in the Indigenous cultures. But one piece of evidence we do have, which is quite interesting-- and this is going to be my last slide, and I just want to leave it with you because it's a sort of call for further research, which actually John and Paulus made. And I'm not aware that anyone has kind of taken this up, but I think it's very interesting.

So Thomas Clarkson in his famous paper or his essay that was written in 1788-- so exactly the time when Fuller was being interviewed by the gentleman from the Abolitionist Society-- wrote, "It's astonishing with what facility the African brokers reckon up the exchange of European goods for slaves. The European, on the other hand, takes his pen, and with great deliberation, and with all the advantages of arithmetic and letters, begins to estimate also. He is so unfortunate often, as to make a mistake; but he no sooner errs, than he is detected by this man of inferior capacity, whom he can neither deceive in the name or quality of his goods, nor in the balance in his account. Instances if this kind of very frequent; and it is now the general complaint of the captains sent upon the coast, that the African brokers are so nice in their calculations, that they can scarcely come off with a decent bargain."

So, there is evidence here that actually mental calculation was something that was very much part of the culture. And it would certainly be very interesting to be able to, if it was possible, to uncover further sources and so on, relating to this. So, with this, I'm ending my part of the presentation.

I hope you will see that the idea that we have for this resource will hopefully be something that students will really be able to get something very valuable from. And I'm now going to hand over to Brigitte, who is going to talk about a different very different sort of tranche of sources, which tells us about something-- well, we're moving into the 19th century and then into the 20th century. So over to you, Brigitte.

BRIGITTE: Thank you, June. I'm having problems with my headphones. They're not really working very well. So as soon as you can't hear me anymore, please write something in the chat, and hopefully the microphone on my laptop will work. But anyway, I will assume people can hear me until something a arrives in the chat.

So as shown by June, when trying to recover stories of Black mathematicians, we are very much limited by the volume and type of sources available. Indeed, the very need for them to be recovered rather than already being part of the historical canon is a huge problem. As well as a lack of sources in a protagonist's voice, Black mathematicians are usually spoken about rather than speaking themselves.

Historians have long grappled with the problem of teasing out the stories of those who have recorded in less detail. And a very fruitful research methodology is that of prosopography. This is described by Lloyd in her PhD dissertation, the title of which is on the slide on the bottom right.

So Lloyd says, "Prosopography was developed as a method of studying historical groups when faced with a paucity of evidence. It is a way to draw meaningful conclusions from a large collection of small pieces of historical data, such as a collection of addresses. In "A Short Manual to the Art of Prosopography," Verboven et al define the prosopographical method as a system for organizing mostly scarce data in such a way that they acquire additional significant connections and patterns influencing historical processes."

This method has previously been used to much avail by historians of mathematics and science, for example, by Lloyd herself when she investigated the engagement of women with the Royal Institution at the start of the 19th century. And on the left-hand side of the slide, per the title of Sloan Despeaux work, because she's done a study of the engagement of mathematicians with question and answer sections of periodicals in the 19th century.

So, you can see here that you just have a name sometimes on occasion. But often the same names share multiple times. Sometimes they change location. And sometimes you find out that job affiliation. And importantly, a lot of these people were working class or operating outside of why we would usually look for mathematicians, as we kind of understand them, usually.

Such studies are both especially rewarding and especially difficult when studying women, who've traditionally changed their name on marriage often multiple times during their life. And sifting written archives for traces of Black historical actors is complicated by, I mean, the fragile and changing notions of race and ethnicity from the early mounting period up to today. And also, the fact that an actor's ethnicity is often just not recorded but must be deduced from context.

So, one of the most famous prosopographical of Black female mathematicians is, of course, that of Margot Lee Shetterly, which resulted in her book Hidden Figures-- The Untold Story of

African American Women Who Helped Win the Space Race and the 2016 film of the same name. The film is actually on Thursday on film full. And I've just put a link to the TV listing for the film. And everyone should go and watch it because it's great, but also read the book.

So using a combination of census data, NACA and later NASA personnel records, newspaper and university archives, as well as oral history interviews, Shetterly has teased out the story of the women who worked in the segregated West area computing group at NACA and afterwards in the desegregated NASA offices from 1943 up to the first ever moon landing in 1969.

And NACA is the National Advisory Committee for Aeronautics, which became NASA in 1958. Whilst Shetterly narrative hinges on the lives of Dorothy Vaughan and Kathrine Goble Johnson, along the way we meet a vibrant community of Black calculators, mathematicians, and engineers, rather than isolated individuals. According to Shetterly-- so this is a quote.

"These women showed up in photos and phone boots, in sources both expected and unusual. A mention of a Langley job in an engagement announcement. A handful of names from the daughter of one of the first West computers. A 1951 memo from the Langley personnel officer reporting on the numbers and status of its black employees. I can put names to almost 50 black women who worked as computers, mathematicians, engineers, or scientists at the Langley Memorial Aeronautical Laboratory from 1943 through 1980, and my intuition is that 20 more names could be shaken loose from the archives with more research."
Whilst alone a name and a job title don't tell the story of Black women's work at NACA, discrete data points were combined to give a detailed and insightful perspective on the 20th century space race in the USA. Shetterly begins by focusing on the West area computers, a group of explicit exclusively African American women whose job was to execute the mathematical calculations given to them by engineers, who were almost exclusively white men.

Computing work usually came to the head computer, Virginia Tucker, a white woman, who parcelled out the tasks to section heads, who in turn, divided the work between the women in their sections. This work was not just mindless number crunching. Kathryn Goble Johnson's desk housed a library of graduate school mathematics textbooks next to a mechanical calculator, whilst Dorothy Hoover's work included differentiating equations that could be as long as 10 pages.

Over time, if an engineer was impressed by the work of a particular section or even computer, they would bring the work directly to them. Subsequently, computers were temporarily assigned to engineering groups for postings which lasted from a couple of weeks up to a few months. Eventually, computers and mathematicians were hired directly into research groups, and the competing pools with disbanded.

Career trajectories of these women varied greatly. For example, Mary Jackson was promoted from a computer to an engineer in 1958, becoming NASA's first black female engineer. Meanwhile, Dorothy Vaughan lost her job as a supervisor when the West area computers were disbanded. And she retrained as a computer programmer.

And so these pictures-- and I can share the sides if anyone wants them because the PDF links to where you can find the photos online. And so, we see Dorothy Vaughn on the front left of the middle image. And then the right-hand side image is Christine Darden, who also worked at NACA. And she's inside of one of the wind tunnels that they used for their research.

But how does all of this complement an undergraduate course in mathematics? One of the most touted reasons for including a diverse range of mathematicians in the course materials we use is to provide students with role models. Shetterly herself noted that she was sensitive to the cognitive dissonance conjured by the phrase "Black female mathematicians at NASA." Shetterly's personal experience was quite different, having grown up in Hampton, the daughter of a climate scientist, who himself worked at Langley Research Centre.

I hope you'll excuse this long quotation, but I feel it's best said in Shetterly's own words. So Shetterly, I'll read the quote here from the slide. "Women occupied many of the cubicles" at NACA or NASA, as it was. "They answered phones and sat in front of typewriters. But they also made hieroglyphic marks on transparent slides and conferred with my father and other men in the office on the stacks of documents that lay at their desks. That so many of them were African American, many of them my grandmother's age, struck me as simply a part of the natural order of things; growing up in Hampton, the face of science was brown like mine. As a child, I knew so many African Americans working in science, math, and engineering that I thought that's just what black folks did."

And then the second part is from the end of Hidden Figures. For me, and I believe, for many others, the story of the West computers is so electrifying because it provides evidence of something that we've believed to be true. That we won with our entire beings to be true, but that we don't always know how to prove. That many numbers of Black women have participated as protagonists in the epic of America.

And I hope this showcases to you the importance and the power of providing students with role models so that they can picture themselves as mathematicians and scientists and perhaps go some way to combat the feeling of unbelonging or imposter syndrome that can be fostered by constant microaggressions that Black and brown people continue to face in academia.

By focusing on communities of researchers or practitioners, we also avoid the dangers of the so-called Madame Curie complex. That is celebrating each and every woman as a genius or a pioneer in order to justify their inclusion in the historical narrative. If the only person who looks like you or sounds like you is spoken about as being uniquely amazing, a one in a million mind with the inhuman strength to overcome systemic barriers and still produce ground-breaking research, this can be incredibly off-putting to someone who doesn't see themselves as the next Nobel Prize winner and discourage them from pursuing their own research.

But I by no means believe that diversifying the people whom we identify and celebrate as mathematicians only benefit students by providing role models. And I'll go through a few additional insights which stand to be gained. I'd be very grateful for any comments or suggested reading anyone in the audience might have, as this is very much a work in progress.

So firstly, by looking at original sources, students are exposed to the realities of research mathematics. Whereas in an undergraduate course, there's a lot of pressure to memorize pre-existing proofs. In reality, mathematicians are working with concepts or ideas which are not yet fully formed.

The certainty that attracts so many to mathematics is pulled away. How do you know you have the truth when your conclusion is entirely new and there's nothing exactly equivalent to compare it to? I have shown here as an example a selection of pages from the first paper published by Katherine Goble Johnson in collaboration with engineer Ted Skopinski, entitled Determination of Azimuth Angle Burnout for Placing a Satellite Over a Selected Earth Position-- very long title.

This paper lays out the equations describing an orbital spaceflight and specify the craft's landing position. Written in 1959, this paper went through 10 months of editorial meetings, a very standard practice at NASA, in which mathematicians and engineers combed through the equations, and to whom Johnson and Skopinski were expected to defend their deductions and conclusions. Never before had the USA successfully sent an astronaut on an orbital space flight.

And it was imperative to know where the craft would land so that Navy ships could be on standby to scoop the astronauts out of the ocean. This is not a calculation that could be tested by trial and error. Faith had to be put in the mathematicians and in the mathematics.

And this is like a major plot point of the film. So, I won't ruin it, but major, major plot point. In contrast, the content which undergraduate students are presented with is sterilized and reformatted to such an extent that it often appears as perfect and complete, with each line presented and proven in succession before arriving at the key theorem of the chapter or module. The labour, confusion, failure, and collaboration that goes into producing mathematical knowledge is completely lost.

And so, too, are the people who cannot easily be identified with the end result. Those who are commemorated are often white male European mathematicians who have eponymous theorems. But they are by no means produced the result in isolation.

Pertinently, this paper does not give us anything that could be named the Skopinski-Johnson theorem, for example, but does clearly demonstrate a form of valued and important mathematical practice carried out by a Black woman. And so just this is the front page of the paper with the name highlighted. So, we see here it's written by T.H. Skopinski and Katherine G. Johnson.

I didn't have time to check whether all the women are kind of highlighted as such by including their first name. But it is interesting to note here that Ted Skopinski has only given his initials. And it was published in September 1960 after those 10 months of editorial meetings. And again, if anyone wants the slides, the NASA papers are all digitized, by the looks of things, and really easy to find in their database. So, a whole host of things to explore there.

The research at Langley clearly relied on a highly trained workforce. Black applicants definitely faced a huge barrier to entry at a time of underfunded and segregated education in the US. In fact, many cities didn't provide public schools for Black children beyond elementary school. So aged 11, I think. And the children were reliant on high schools affiliated to their local Black college.

As they pass through the halls of the Langley Research Laboratory, Shetterly introduces us to numerous individuals who bravely desegregated schools and universities by becoming the first Black students at institutions which were formerly restricted to white applicants. In 1940, Katherine Goble Johnson herself was one of three Black students chosen to desegregate the West Virginia University Graduate School. Initially, the West Virginia legislature, who were very hostile to desegregation, had offered the all-Black West Virginia State College $4 million to start graduate studies program in the hope that black? Students would then not try and desegregate the white university.

But the president declined it, hoping that if there was no other graduate program in the state, the University would be compelled to desegregate. When training to be an engineer with NACA in 1956, Mary Jackson had to petition the city of Hampton for special permission to enter the white Hampton High School to attend evening math classes. As Shetterly astutely notes, this permission would not have been required had Jackson wanted to enter the school as a cleaner.

Jackson's permission was granted, but they did not make these passes widely available, even though two years earlier, the US Supreme Court ruled that segregated schools were unconstitutional. The picture shown here, with horrific placards that I will not read out, is a protest against desegregation in Little Rock, Arkansas in 1959. Little Rock had made the headlines in 1957 when violent protests erupted as nine Black students attempted to attend the formerly white high school.

The governor of Arkansas had mobilized the Arkansas National Guard to prevent the students from attending the school. President Eisenhower had to intervene and instead command the guards to protect the students. Although the UK did not have legally segregated schools in the same way as the USA, even today inequalities in education persist, with OU itself still having an awarding gap for Black students. So, thanks to attending other Black History Month events, rather than talking about on attainment gap, I've just called it the awarding gap.

A friend who attended school in London once told me how his school was effectively segregated in the early 2000s. Her year group was so large that it was divided in two with separate lunch times and break times. The division was ostensibly based on attainment, but it resulted in Black and brown students having a separate lunchtime from their white contemporaries, with some students even requesting to change into classes with lower grade expectations so that they were not the only Black student in their class. And that was the early to mid-2000s in London.

As has been treated extensively by others, World War II was a time of economic upturn for the USA, which was still recovering from the crash of the '20s. At first, it was not clear that Black citizens would be able to benefit from the new jobs opening up in the defense and other industries, which supported war work.

In 1941, Asa Philip Randolph, Bayard Rustin, and AJ Musta proposed a March on Washington DC in order to demand that President Roosevelt opened lucrative war jobs to Black workers. Roosevelt thus signed executive order 8802 in 1941, which ordered the desegregation of the defense industry. This is especially potent to NACA, as dominance in the skies it was a key tactical priority for the USA during the war, which gave rise to the phrase in the 1943 Disney film-- the poster is on the slide-- Victory Through Air Power.

In 1943, a memo circulated outlining the workforce requirements of NACA. It said-- and I'm quoting here from the left on the slide-- "This establishment has urgent need for approximately 100 Junior Physicists and Mathematicians, 100 Assistant Computers, 75 Minor Laboratory Apprentices, et cetera."

On receiving applications from qualified Black women for these positions as mathematicians and computers, NACA form the West Area Computing Group in 1943. Although, I believe that you weren't supposed to identify your ethnicity-- in fact, it was illegal to give your ethnicity on an application-- Black applicants could often be identified by their college affiliation. And so the choice was made to form a new competing group specifically for Black women. So, a form of segregation.

In November of 1943, when Dorothy Vaughn joined the group, the cohort already consisted of 20 black women. Vaughn was appointed at grade P1 mathematician and was paid an annual salary of $2,000. This was a huge increase from her salary as a teacher, which was $850 a year.

The average monthly wage for Black women in 1940s America was $96 a month or $1,152 a year. Thus, by mobilizing her mathematical training, Vaughn had studied maths at Wilberforce University in Ohio. She completely transformed her socioeconomic status.

This is brought into sharper relief when you consider that before Roosevelt's 1941 executive order, again, Vaughan could have been hard at NACA as a cleaner a surface worker, which is obviously not the highly remunerated job of mathematician. However, women in NACA continue to face discrimination. It wasn't until the mid-1950s that Helen Willie successfully campaigned for all women computers with a maths degree to be regraded as mathematicians. Computer was a sub professional role, whereas mathematician was a professional and thus better paid role. And any men that joined NACA or NASA with a master's degree would automatically be graded as a mathematician.

Maternity leave was completely non-existent with many women taking disability or accumulated sick pay. Whilst others resigned and reapplied for that jobs once their children were old enough to be left in the care of others. The economic benefits of a mathematical education still hold true today in the UK.

According to a 2015 report from the Council for the Mathematical Sciences, around half of people whose jobs require mathematical sciences qualifications have estimated salaries of 29,000 pounds or above, compared with only 19% of the UK workforce in general. Therefore, it's certainly a pertinent question to ask whether access to such an education is equal, and moreover whether remuneration is truly based on skill level or other factors such as race or gender.

And, of course, you can't consider the benefits of increased economic opportunities without also considering the wider repercussions. These jobs at NACA existed because the USA was in the middle of World War II. And on the bombing of Hiroshima and Nagasaki in August 1945, everyone at Langley celebrated the role that they had taken in developing aircraft, which had enabled America's victory over Japan.

Again, I don't want to get too bogged down in scholarship on the relationship between science and war. But it is a recurrent theme in the history of mathematics. The OU, Milton Keynes campus, is located a stone's throw away from Bletchley Park where mathematics was used to break the German Enigma code during World War II. And my co-speaker June has written extensively on the work of mathematicians during World War I.

But the relationship stretches back much further. Mathematics is key to solving the longitude problem in the 18th century, which enabled mariners to locate themselves accurately at sea and gain dominance over the waves, which was essential to Britain and its imperial and colonial aims. I've shown on the right here a slot a painting by Cogniet, depicting a French expedition to Egypt in 1798 as part of Bonaparte's imperial campaign.

Bonaparte was accompanied by the well-known mathematicians Fourier and Monge, as well as another 160 scientists who assisted the army by mapping roads, building mills to produce food, and taking surveys to investigate the possibility of a Suez Canal. Bonaparte was very aware of the importance of mathematics and actively trained them through the Ecole Polytechnique.

Nowadays, there are huge issues with social inequalities and white supremacy being perpetuated through the application of algorithms. At the end of the presentation, we've made a slide with some links to further reading, including current discussions taking place in the math community on the role of mathematicians in predictive policing in the USA.

All this to say, if you consider when learning mathematics-- if all you consider when learning mathematics is a series of abstracted theorems and proofs, you're missing most of this story. Moreover, if we only celebrate those mathematicians with eponymous theorems or mythical reputations, such as Isaac Newton or Albert Einstein, we overlook the huge contributions made by people who've been consistently overlooked in history for their race, gender, or lack of wealth or social status.

It isn't about writing people of colour or women into the framework we already have, where they will be at most tokens and afterthoughts. It's about starting again with a new framework that exposes students to what I find to be a much more meaningful and engaging way to study and practice mathematics.

So, I return to an earlier question-- why is this important for mathematics undergraduates? Whilst they might not need to know the historical implications of mathematics for their maths exams, it'll be invaluable information when they progress into the workplace. For example, a key issue, which has been identified in the awarding of prestigious and financially advantageous awards such as the Fields Medal is that the criteria for the award can themselves carry implicit biases.

And for example, a Fields Metal is yet to be awarded to a single Black mathematician. Winning a prestigious award for research doesn't just mean a medal. It means a more competitive CV and a higher chance of being awarded further medals and grants in the future.

Undergraduates are the future researchers, collaborators, grant committee members, manages, hiring committee members, teachers, and so on. And awareness of the historical and persistent barriers to mathematical studies amongst our students is vital if we are to improve diversity in mathematical sciences more broadly.

And so, I can leave time for questions. I will just leave the slide with my conclusions up for a little bit. And thank you for listening.