Queen Mary
University of London

'Beyond the Formula': Empowering students through co-creation of inclusive mathematics curricula

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Diversity in Mathematics: An Overview

- Why do we need it?
- How did we embed it in our modules?
- Student feedback from surveys
- Themes from focus group discussions
- Impact highlights and next steps

Need for Diversity in Mathematics

- STEM subjects usually taught through **memorisation** and repetitive application of **formulae**
- Often **limited emphasis on historical aspects and contributions** by diverse individuals
- If done, mostly confined to **white, male, European** mathematicians/scientists/engineers
- Consequently, **very few students relate** to these STEM figures (no role models)
- Adds to the stigma that studying **mathematics is esoteric, inaccessible and difficult**

How did we embed diversity in our modules?

- **Co-creation** of teaching toolkit with **3 current undergraduate students**
- Toolkit includes **visually appealing posters** comprising short biographies and mathematical snippets of contributions made by **both historical and present-day 'STEM champions'** from diverse and under-represented backgrounds (e.g. African, Islamic, Asian, female, disabled, LGBTQ, those with non-traditional career pathways) and **formative practice quizzes** to assess conceptual understanding
- Implemented across **two large Year 1 and Year 2 undergraduate applied mathematics modules** for 800 engineering students (for the **past 3 years**)
- Embedded as **asynchronous, formative resources** on QMUL VLE

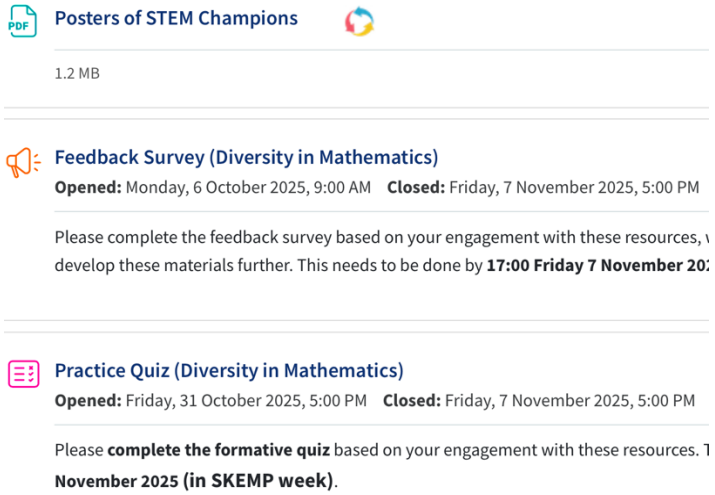
Module Implementation

Motivation

The profiles of past and present diverse individuals provided below form part of an ongoing scholarship research initiative to diversify STEM curricula being undertaken by **Dr. Rehan Shah** in SEMS with current undergraduate student co-creators **Ms. Ava Dahlia Belafonte** (and recently **Ms. Amelia Stringfellow** and **Ms. Nilah Holmer**). These are designed to increase students' awareness of diverse representation and provide positive role models through exposure to mathematicians, scientists, and engineers from under-represented backgrounds (female, disabled, and queer) and non-traditional pathways in academia and industry.

STEM Champions

1. **Sofia Kovalevskaya (1850- 1891)**
2. **Emmy Noether (1882 - 1935)**
3. **Taqi ad-Din Muhammad ibn Ma'ruf ash-Shami al- Asadi (1526-1585)**
4. **Nalini Joshi (1958 - present)**
5. **Argelia Vélez-Rodríguez (1936 - present)**
6. **Kathleen Ollerenshaw (1912 - 2014)**



Tasks (will count towards formative engagement)

- **Engage and go through the resources** provided below
- **Complete the feedback survey below by end of SKEMP week Fri 7 Nov 2025 (17:00)** based on your engagement with these resources (responses will be monitored, checked and count towards formative engagement) **(note: feedback responses left blank, or with only punctuation or binary yes/no text responses will be discounted and will you have to the survey again)**
- **Complete the practice quiz below (released at end of Week 6) by end of SKEMP week Fri 7 Nov 2025 (17:00)** (responses will be monitored, checked and count towards formative engagement)

Mary Somerville (1780 - 1782)

Queen Mary University of London

Brought continental calculus to Britain, known as the 'Queen of Science'

"Whatever difficulty we might experience […] in choosing a King of Science, there could be no question whatever as to the Queen of Science." – The Morning Post 1872

A Scottish writer and Polymath who is dubbed as the worlds 'first ever scientist' as well as one of the first female members of the Royal Astronomical Society. Awarded a silver medal in 1811 for solving the Diophantine problem, which include 'Fermat's Last Theorem', thought to have been unsolvable for 400 years. In addition to this, she can be credited with being one of the first people to suggest Neptune's existence and mentoring Ada Lovelace.

Somerville grew up as 1 of 6, and unlike her brothers, did not receive formal schooling as a young child. Only being taught to read by her mother but not to write. Her first interaction with science came from her art teacher who introduced her to 'Euclid's Elements'. In 1817 she was introduced to the works of Laplace, Poisson and Poinsot whilst visiting Paris. Following this visit, Somerville used her connections in Paris to bring these concepts to Britain.

Scientist (noun):
First used in print in 1834 in William Whewell's anonymous review of Somerville's work, " The Connexion of the Physical Sciences'

Somerville was the first person to be dubbed a 'scientist' in print, as her work was becoming so separate to the standard terminology at the time of 'philosopher'. She was a revolutionary in her field.

"Age has not abated my zeal for the emancipation of my sex from the unreasonable prejudice too prevalent in Great Britain against a literary and scientific education for women".

Somerville had to work hard to gain acceptance for her work, and at the start of her career, even publishing under the pseudonym, 'A Lady' to avoid scrutiny. She even described her husband as having 'a very low opinion of the capacity of [her] sex'

Always keen liberal ,she was the first supporter of Mill's petition to Parliament to grant female suffrage as well as advocating for abolition of slavery.

Scan for additional information!

SCHOOL OF ENGINEERING AND MATERIALS SCIENCE – 'DIVERSIFYING STEM CURRICULA'

Mary Somerville (1780 - 1872)

Queen Mary University of London

Brought continental calculus to Britain, known as the 'Queen of Science'

In 1831, age 50, Mary published 'The Mechanism of the Heavens'. This was her translation of the first two volumes of Pierre Laplace's 'Méchanique Céleste'.

Somerville's explanations of celestial mechanics helped bring Laplace's work to the English-speaking world.

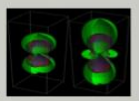
This illustration from '*The Mechanism of the Heavens*' depicts the Earth's orbit around the sun and is used to explain the changing of the seasons and the zodiac.

$$P_2(\cos\theta) = \frac{1}{2}(3\cos^2\theta - 1)$$

P_2: Legendre polynomial of the second order
θ: the polar angle (measured downward from the positive z-axis)

This equation shows the second Legendre polynomial which Mary Somerville used in explaining celestial mechanics and gravitational theory. It is fundamental in physics and astronomy, as it is used to describe spherical harmonics, which are essential for applications such as calculating gravitational potential, predicting planetary orbits and calculating tidal forces.

This diagram shows a 3D visualisation of this polynomial, representing how a physical quantity varies across the surface of a sphere.



$$F = \frac{Gm_1m_2}{r^2}$$

Newton's formula for gravitational attraction between two objects.

Somerville essentially 'translated' Newton's geometric physics into the language of Continental Calculus, using his formulations as mathematical explanations for complex systems and phenomena that he himself couldn't fully solve, such as the stability of the solar system (Newton was famously worried that the mutual gravity between planets would eventually make the solar system unstable).

She accounted for the fact that the planets are spheroids, using the formula to calculate how every individual particle of a planet attracts every other particle, allowing her to explain why the Earth's shape and rotation cause gravity to be slightly different at the poles than at the equator.

QUESTION: Using the above formula for the second Legendre polynomial, calculate the value of P_2 at the Earth's equator (HINT: at the equator, $\theta = 90°$)

Answer: $P_2(\cos(90°)) = -0.5$

The negative value here corresponds to the 'pull' or displacement away from a perfect sphere, mathematically describing the Earth's oblate shape!

SCHOOL OF ENGINEERING AND MATERIALS SCIENCE – 'DIVERSIFYING STEM CURRICULA'

Nira Chamberlain (1969 – Present)

Queen Mary University of London

OBE recipient for services to mathematics

The 'Gambler's Ruin Problem' and Stopping an AI Apocalypse

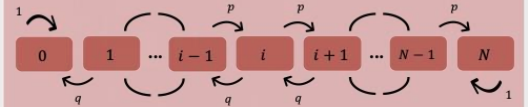
October 2024: Chamberlain hosted a talk at Nottingham Trent University discussing a hypothetical future where AI takes over the world economy. Using his PhD work on 'the gambler's ruin problem played over networks', he modelled a business wargame between AI and non-AI businesses to investigate.

The Gambler's Ruin Problem: A 1-Dimensional Example

A gambler starts with £i where $0 < i < N$. They play a series of games; each time, they bet £1 until they have either £N or £0. Given the game is fair, what is the probability P_i the gambler wins £N ? What is the expected duration E_i of the games?

Click here to watch the talk!

Let p be the probability of winning a single game and q be the probability of losing such that $p = q = 0.5$.



The above is a Markov chain for the scenario. $i = 0$ and $i = N$ are absorbing states, so the probability of the gambler leaving is 1.

Using a recurrence relation, $P_i = 0.5P_{i+1} + 0.5P_{i-1}$,

this leads to the following solutions: $P_i = {}^{i}/_{N}$ and $E_i = i(N - i)$

QUESTION:

Nira plays the game starting with £4 and his goal is to win £10.
a) Calculate the probability that he loses i.e. ends up with £0.
b) Prove that the expected game duration would be a maximum if i = £5.

Answers:

a) All probabilities add up to 1.
Therefore,
$P_{lose} = 1 - {}^{i}/_{N}$
$P_{lose} = 1 - {}^{4}/_{10} = 0.6$

b) E_i is a maximum when
${}^{dE_i}/_{di} = N - 2i = 0.$
$\rightarrow i = {}^{N}/_{2}$
$\rightarrow i = {}^{10}/_{2} = 5$

SCHOOL OF ENGINEERING AND MATERIALS SCIENCE – 'DIVERSIFYING STEM CURRICULA'

Queen Mary University of London

Student Feedback Responses (n = 214)

(1) Were you aware of any diverse mathematicians before coming across these biographies?

*"Before reading these biographies, I was **not aware** of any diverse individuals within the STEM sector. The large **majority** of mathematicians/scientists/engineers that I knew **were of white-European origin**."*

*"I was **not aware** of the diversity in the STEM industry. As a person of ethnic minority studying engineering, I was **pleased to see representation in this industry.**"*

*"Before engaging with these resources, I was **only familiar with** a few notable figures like **Katherine Johnson from Hidden Figures and Mae Jemison**, **the first Black woman astronaut.** Most of my **exposure came through documentaries and popular media** rather than academic sources.*

(2) What did you find most enjoyable or interesting about these exercises?

*"What I found most interesting was **learning more about the personal journeys and achievements of people** from different backgrounds in STEM and **how these influenced their work**."*

*"How the resources **connected the biographical stories of the individuals with the mathematics or engineering concepts** they worked on e.g. Gladys West's work on geoid modelling which contributed to modern GPS systems.*

*"I liked the **mix of past and modern figures** as often we revere scientists from many decades to centuries ago whom we may not feel much connection too, so to **learn about some more modern scientists or mathematicians** was interesting. The **short videos and QR codes on each were a nice addition."***

Student Feedback Responses (n = 214)

(3) What suggestions, if any, do you have for improving these exercises?

*"It would also be helpful to **include discussion questions or reflection prompts** at the end of each section so students can think more deeply about **how these mathematicians' experiences relate to diversity and inclusion** in STEM today.*

*"An **image or equation representing the mathematician's work** could be displayed on their page, e.g. geometric shapes for Kathleen and a PDE for Sofia Kovalevskaya. This would make their contribution **more memorable especially for visual learners."***

*"Have a periodic **newsletter, on Substack or another relevant social media site** that posts regularly about more current strides in STEM diversity. **Inviting female mathematicians for meetings or events with Women in STEM student societies**."*

(4) Would you like such material to be introduced in a classroom setting e.g. in lectures or tutorials?

*"Yes, it would be nice to **mention the contributions from individuals not recognised in history**. For example, if we had a **classical mechanics lesson, Sofia Kovalevskaya's work** on the spinning top could be mentioned."*

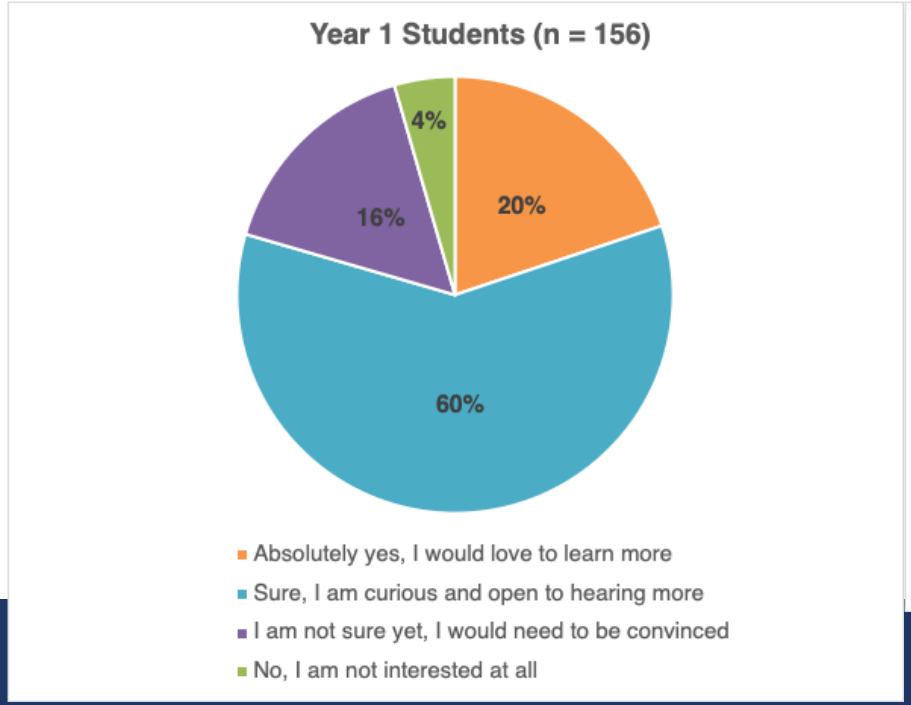
*"I suggest incorporating elements such as **discussion prompts or quizzes** to increase user interaction significantly. Additionally promoting a section dedicated to **STEM projects** could drive community engagement and participation."*

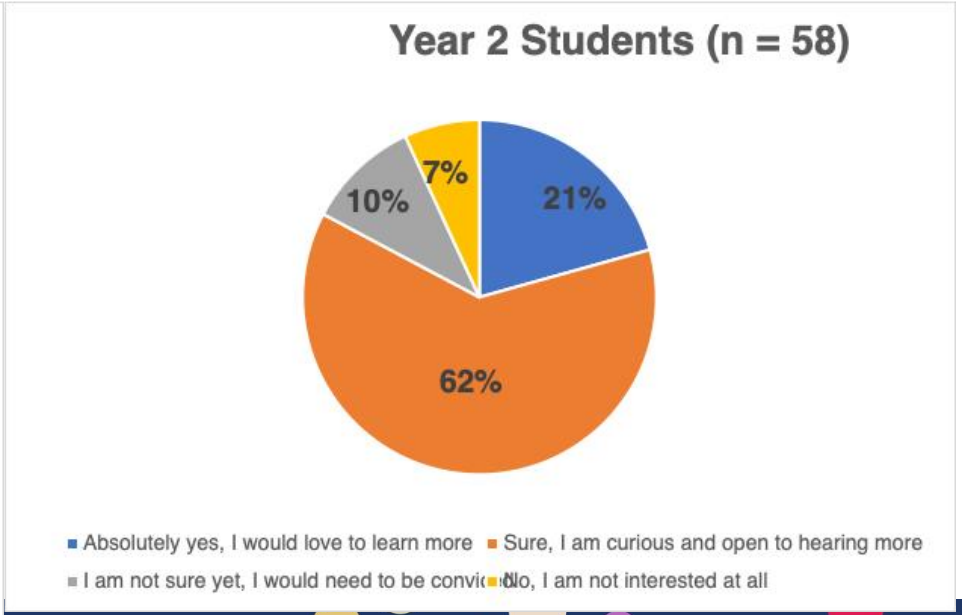
*"A **quick mention and short introduction** would be enough and students can **use their own time** to check out the resources available."*

Student Feedback Responses (n = 214)

(5) Did these resources makes you want to learn more about diverse individuals in mathematics and STEM disciplines?

*Majority (80%) open to learning more, with only 20% not very sure, **highlighting strong engagement and uptake overall**.*





Formative Practice Quiz

- Introduced in 2025-26 implementation in **response to student feedback** from previous years
- Designed to **capture students' understanding** of diversity and inclusivity in mathematics.

Nalini Joshi became the first woman in Australia who

- ☐ a. continued a PhD in Mathematics focusing non-linear differential equations
- ☐ b. become the president of Australian Mathematics Society
- ☐ c. was appointed as a Professor of Mathematics at the University of Sydney
- ☐ d. joined the Australian Mathematics Trust

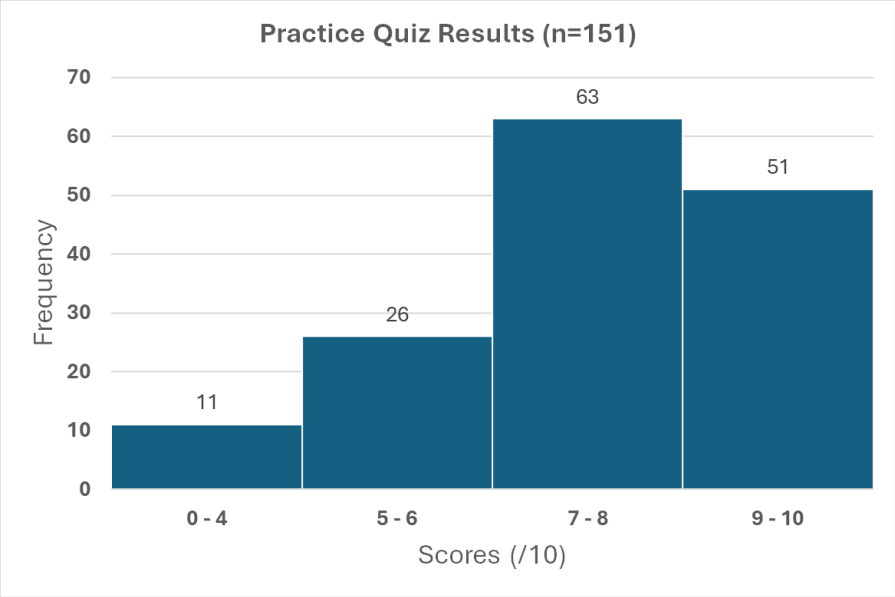
Who was the first female mathematics professor in the world?

- ☐ a. Emmy Noether
- ☐ b. Sofia Kovalevskaya
- ☐ c. Kathleen Ollerenshaw
- ☐ d. Nalini Joshi

Which invention by Taqi ad-Din was an early version of the steam turbine?

- ☐ a. Condenser
- ☐ b. Self-rotating spit
- ☐ c. The Aeolipile
- ☐ d. Water pump

Quiz Performance (n = 151)



Score	0	1	2	3	4	5	6	7	8	9	10
Frequency	0	1	4	2	4	13	13	29	34	24	27
Relative Frequency	0%	1%	3%	1%	3%	9%	9%	19%	23%	16%	18%

- Quiz results **indicated a strong overall understanding** of the poster material.
- Out of 151 students, approximately **76%** achieved a score of 7 out of 10 and more.
- High scores **suggest students read the posters and content thoroughly** and engaged meaningfully.
- Overall, the practice quiz successfully **increased engagement** and **reduced superficial interaction.**

Student Focus Group Findings (n = 18)

(1) In what ways would you like to see diversity emphasised?

- potentially **expand coverage of individuals chosen** for posters (only selected snapshot shown)
- **organic integration of an individual's life story and their mathematical work**
- make use of **gamification by incorporating interactive elements** to present content (e.g. videos, quizzes)

(2) Are there ways in which emphasis on diversity is unhelpful?

- present **individuals as humans**, in a **celebratory, yet realistic** manner
- mention **challenges** faced to give students a **sense of identity**, avoid controversial parts as taglines,
- **Little and often** could be the better approach (**gradual changes vs. aggressive pushes**)

(3) How can these resources help you be a better mathematician?

- **inclusivity very important for group dynamics and teamwork** at university and in workplace
- **current political climate makes discussion of such resources inspiring**
- important for **young students to get interested in STEM**

(4) Should these resources form part of any summative assessment?

- **no, as becomes a 'one-time thing'** rather than an ongoing discussion (**formative > summative)**
- **certificate of completion** for CV from a **pass/fail module, integrating in existing coursework assignments**

Findings from Student Feedback

- Most students **had not previously heard** of diverse STEM individuals (if at all, only in a secondary school setting, **not at university** – usually also **through films and books**)

- **Minority and female students resonated more** strongly and motivated by materials

- Suggestions to increase engagement through **discussion forums, quizzes and videos**

- Most students **highlighted strong need** for such resources, enjoyed **integration of biographical life stories** of individuals **with technical details** of mathematical contributions

- Would like **embedded in lectures/formative assignments in a relevant manner**

Impact Highlights of Project

- **Increase in module student satisfaction results** over 3 years (from 67% to 82%)
- Students presented findings at **QMUL Festival of Education (received 'Best Innovation Poster' Award)** and represented QMUL to showcase work at **Posters in Parliament** at House of Commons
- Student **co-creators awarded QMUL Student Enhanced Engagement and Development (SEED) Award** for contributions to project
- Work featured in **UK History for Diversity in Mathematics Network's online repository** to share resources with colleagues externally
- Practice-based case study **journal article** (co-authored with student) published in *New Directions in the Teaching of Natural Sciences* (a second paper also submitted to *MSOR Connections*)
- Work **nominated twice for QMUL Education Excellence Awards** and **among top 20 global finalists for QS Reimagine Education Award 2025** in *Access, Diversity and Inclusion* category

Conclusion and Next Steps

- **Complete analysis** of **second round of student** focus groups
- Submission of a mathematics education **journal research paper** documenting findings
- **Iterate toolkits** based on feedback, explore possibility of featuring **video interviews**
- Opportunities for **in-person discussion sessions** with students in reading/skills week
- Expansion and integration of resources to **global** transnational context (campus in China)

Thank you for listening!

Please feel to get in touch with me at rehan.shah@qmul.ac.uk

Toolkit resources (Project 1)

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