ACME

Advisory Committee on Mathematics Education

Mathematically Thinking

2015 ACME conference summary report

On Thursday 9 July ACME held its 2015 conference 'Mathematically Thinking' at the Royal Society in London. Over 130 delegates attended, including teachers, parliamentarians, academics, policymakers and education researchers and discussed key issues in mathematics education policy.

The conference explored the policy changes required to ensure that young people gain the mathematical knowledge and skills needed to move into further education, higher education and employment. Delegates had the opportunity to consider issues such as the assessment of problem solving, the supply, education and development of teachers, and post-16 mathematics pathways.

The conference is a key part of ACME's work – the discussions inform ACME's activities and are used to identify and explore policy priorities in mathematics education. The conference also provides a key opportunity for ACME to engage with the education community and others.

1 Welcome

Professor Alex Halliday FRS
Vice President (Physical Secretary) of the Royal Society

Professor Halliday opened the conference and welcomed everyone to the Royal Society. He highlighted the Royal Society's role in bringing people together to think about important issues in science and mathematics. He noted that the Royal Society supports and hosts ACME and very much appreciates its connection with ACME.

In discussing post-16 mathematics he drew attention to the Royal Society's *Vision for science and mathematics education*[1] which sets out the goal for all young people to study mathematics and science to the age of 18. He welcomed steps towards this goal, such as mathematics being the most popular subject at A level and the development of Core Maths qualifications. He also noted the increase in quantitative elements in other A levels. He drew attention to the need for all of us to consider the types of skills young people need, the qualifications that should be offered to them and the provision for those in further education, apprenticeships and the work place.

In discussing strategic priorities for education he acknowledged the recent general election and emphasised the need for all of us to think about the priorities for education. He went on to state that, from his perspective, we need to encourage a focus on mathematics as a way of life for everyone.

He noted that the support from government for mathematics education offered the community an opportunity to change the education landscape. Professor Halliday also highlighted other priorities in need of attention such as the delivery of Core Maths qualifications and the recruitment of specialist teachers of mathematics.

"Mathematics is critically important to the UK."

"We're all aware of the need for more people to be able to do more maths and to be more confident about using and applying data."

Professor Alex Halliday FRS,
Vice President (Physical Secretary) of the Royal Society

1. https://royalsociety.org/~/media/education/policy/vision/reports/vision-full-report-20140625.pdf.

2 Introduction from the Chair

Professor Philip England FRS
Chair of ACME

Professor England acted as chair for the conference. He began by introducing himself as the new Chair of ACME. He discussed his work in tectonics and highlighted how geologists, such as himself, use mathematical analysis and problem solving in their work. He also noted the use of mathematics and problem solving would be at the heart of some of the discussions later in the day.

For those who were not familiar with ACME he set out a brief history of ACME and its role in mathematics education policy. He noted that the Committee was established in 2002 by the Royal Society and the Joint Mathematical Council of the United Kingdom to provide constructive advice on mathematics education to the Government and others. He then took the opportunity to introduce current Committee members to the audience noting that they would be leading the workshop sessions later in the conference.

In setting out the purpose of the conference he noted that it was an opportunity for the mathematics education community to feed into ACME's work and for ACME to engage with the community about key issues in mathematics education.

He acknowledged the recent reforms in education and noted the conference discussions would consider the next steps needed to implement the some of these reforms. In drawing attention to the conference theme, Mathematically Thinking, he discussed some of the key priorities in mathematics education that would be covered during the day including embedding problem solving in teaching and assessment and the recruitment of teachers of mathematics. He concluded by highlighting the speakers and sessions that delegates could look forward to the during the day.

> "You can use mathematics to lift the veil of nature."
>
> Professor Philip England FRS, Chair of ACME

3 Keynote address

Neil Carmichael MP
Chair of the Commons Education Select Committee

In the first keynote of the day, Neil Carmichael spoke about his personal interest in mathematics and the value to society of understanding problems through the lens of mathematics. He illustrated this with the example of mathematicians studying ocean flows and depth in Antarctica as part of an scientific study. He commented that mathematics is an important subject not only at the beginning of education but throughout all phases and beyond.

As the new Chair of the Education Select Committee he set out the Committee's roles both in scrutinising the performance of government and its role in policy making. He went on to describe his priorities for the Education Select Committee over the next Parliament. In drawing attention to the importance of innovation and productivity he noted his aspiration for the Education Select Committee to undertake a joint inquiry on economic productivity with the Business Innovation and Skills (BIS) Committee looking across both pre- and post-16 education.

He outlined some of the key issues in mathematics education. The first was about the need to recruit and retain more teachers of mathematics. He signalled that it was something that the Education Select Committee could prioritise. The second issue to which he referred pertained to those young people who do not gain a C in mathematics at GCSE and are required to retake it post-16. He questioned whether this is the appropriate pathway to a mathematics qualification for some students.

The third issue he highlighted was about the skills needed by young people in different industries and the value of mathematical and problem solving skills to all. Coming back to post-16 education he noted that compared to some other countries more young people in England stop studying mathematics at 16. He argued there is a case to investigate a Baccalaureate model, with a mathematical element, for post-16 education in England.

Concluding his speech Neil reiterated the importance of everyone understanding mathematics and the need to make sure everybody is equipped to use mathematics in their everyday lives. He also discussed the different needs of individuals, including those undertaking university study and apprenticeships, emphasising that various educational pathways need to equip every person to be a problem solver. He also reflected on his own experience with mathematics – he stopped studying it at 16 he but was later reminded of the importance of mathematics whilst doing industrial economics. He noted that he was still benefitting from his mathematical experience.

> "Maths is an important subject and we do have to recognise that. Not just at the beginning of our time in education but throughout it and beyond."
>
> Neil Carmichael MP, Chair of the Commons Education Select Committee

4 Workshop sessions

ACME members led four parallel workshop sessions, which explored mathematical thinking across the different phases of education.

The discussions during the workshops will contribute to ACME's work. In particular, they will feed into ACME's work on the assessment, teaching and learning of mathematical thinking and ACME's thinking on the assessment of problem solving and reasoning.

The discussions will also inform scoping work on early years mathematics and build on ACME's work on *Mathematical Needs*[2] and *Raising the bar*[3].

2. http://www.acme-uk.org/media/7630/acme_4pp_overarching_report_summary.pdf.
3. http://www.acme-uk.org/media/10498/raisingthebar.pdf.

GROUP 1: Assessing problem solving and reasoning

WORKSHOP LEADS

Richard Browne and Jennie Pennant

Richard Browne and Jennie Pennant opened the session by explaining the discussions would feed into ACME's work on the assessment of problem solving and reasoning. It was highlighted that the focus of the session would be on early years to Key Stage 4. Richard and Jennie noted the aims of the session were to consider official expectations around problem solving set out in assessment criteria, to review a selection of problem solving tasks and to identify, strengths, concerns and possible innovations in the assessment of mathematical problem solving.

The reform of the National Curriculum has placed an increased emphasis on problem solving, reasoning and fluency. During the first part of the session delegates considered a range of official expectations around problem solving from the National Curriculum and in assessment materials. Discussion points included the issues around defining problem solving and the different interpretations that are held, as well as the challenges there will be in teaching and assessing it. It was noted that a step change would be required in classrooms across England.

For much of the session delegates worked in groups. Delegates examined a selection of questions from early years to Key Stage 4 in groups. When discussing the questions delegates were asked to reflect on what makes a good problem solving question from their perspective. Delegates were also invited to examine mark schemes for different questions and consider the differences between the marks awarded for similar skills across different key stages. Some points raised were:

- the importance of assessment as it impacts on what teachers deliver in the classroom;
- the benefits of using questions presented in innovative formats and creating opportunities for thoughtful responses to the questions.

Delegates discussed the use of 'scaffolding' in questions. Over the years questions in examinations have become more scaffolded, that is, more prompts are given to students to guide them towards an answer. It was noted that the best problem solving questions are those that use little scaffolding as these encourage a deeper level of mathematical thinking by the students. However, the delegates acknowledged that scaffolding has been used in examinations as it can be seen to reduce the risk that questions are found to be insufficiently accessible by candidates.

GROUP 2: Mathematical Thinking post-16: A level and Core Maths

WORKSHOP LEADS
Dr Mary McAlinden and Professor Andy Noyes
Mary McAlinden and Andy Noyes led this session which focused on post-16 mathematics. The aims of the session were to review a range of problems solving tasks, consider the connections between assessment objectives and approaches and to identify innovations, strengths and concerns in the assessment of post-16 mathematical problem solving.

The recent reforms to post-16 level 3 mathematics were highlighted at the start of the session including the new mathematics A levels and the introduction of Core Maths qualifications. ACME's work in this area was highlighted, such as ACME advocating the development of an alternative level 3 mathematics qualification to AS/A level Mathematics for post-16 students.

In groups delegates were invited to analyse different Core Maths problems from the sample assessment materials and discuss their reflections on the problems. A range of points were raised including:

- the variation in the amount of context provided with the questions;
- the high levels of literacy needed to understand some of the questions;
- the capacity needed to assess longer questions.

In the next part of the session delegates conducted an analysis of the strengths, weaknesses, opportunities and threats in the teaching, learning and assessment of problem solving. Some of the points raised by delegates included:

- in the past problem solving has not been assessed well;
- alternatives methods to summative assessment, such as coursework, could be considered to assess problem solving;
- there is an opportunity to build mathematical resilience in young people by integrating problem solving into the curriculum;
- there are concerns about teacher supply for the various post-16 pathways;
- there is need to look at the balance of funding and provision of teacher professional development across different qualifications.

The session concluded by discussing issues to be addressed in order for problem solving to be successfully embedded in assessment. These included the need for examiners to have a shared understanding of what is being assessed and the importance of using the expertise in other subject areas to apply mathematical problem solving to other contextual fields.

GROUP 3: Encouraging depth of mathematical thinking

WORKSHOP LEAD
Anne White

ACME continually highlighted throughout the reform of the National Curriculum that students should be encouraged to develop their depth of mathematical thinking. The aims of this session, led by Anne White, were to consider the importance of the depth of mathematical thinking and learning, to explore how to encourage depth of learning in the classroom and to act as a scoping process to inform ACME's work on problem solving and mathematical thinking.

In the first part of the session delegates considered how a strategy called 'Learning for Mastery' set out by Benjamin Bloom in 1968 could be used to encourage mathematical thinking.[4, 5] Delegates conducted an analysis of the strengths, weaknesses, opportunities and threats of this approach to consider how useful a strategy such as this could be for encouraging death of learning.

They went on to discuss this in the current education landscape. Key points raised included:

- the importance of having time for students to work at their own pace and to think mathematically;
- the need to have rich resources for learning;
- the need for support and professional development for teachers to help them identify the best resources for themselves and their students;
- the benefit of having an extended interpretation of the curriculum for some young people.

The workshop concluded by exploring potential policy implications of the discussion points raised earlier in the session. These included the need for:

- professional development courses;
- time for teachers to collaborate and do mathematics together;
- rich and extensive resources for problem solving to support the understanding of how problem solving progresses.

4. Bloom, B. S. (1968). *Learning for mastery*, Evaluation Comment, Vol. 1, No.2, pp.1 – 12.
5. This strategy is one of many strategies that exist for learning and was selected to stimulate discussions.

GROUP 4: Early years and early primary mathematical thinking

WORKSHOP LEADS
Robert Barbour and Dr Sue Gifford

This session explored mathematical thinking in the early years and early primary education. The aims of the session were to discuss what mathematical thinking looks like for young children and to consider how mathematical thinking can be fostered in the early years. It was noted that the discussions would also contribute to ACME's work on assessing problem solving and its scoping work in early years mathematics.

Sue Gifford and Robert Barbour led delegates in a discussion about what mathematical thinking looks like for young children and how it can be fostered in the early years. Three main questions framed the group work and discussions:

- What does mathematical thinking look like in the early years and reception?
- How can mathematical thinking be fostered?
- What policy changes are required to ensure that mathematical thinking is embedded in early years education?

It was noted that mathematical thinking is about children making connections, exploring and asking questions. To foster this, delegates acknowledged that children need time to work out problems and a rich environment where children are exposed to questions and prompts. Enthusiasm and excitement were noted as key components of fostering mathematical thinking, as well as children seeing mathematics as important.

The sessions also explored the key policy actions that are needed in early years mathematics and ACME's place in the early years policy landscape. Key points raised included the importance of:

- stability in the early years curriculum;
- increased professional development and subject knowledge training for early years professionals;
- input from parents in their child's mathematical learning though methods such as games;
- mathematical play during Key Stage 1.

5 Keynote address

Nicola Blackwood MP
Chair of the Commons Science and Technology Committee

Nicola Blackwood opened her speech by discussing the value of data-driven skills to the UK. In speaking about research she noted that the UK has one of the strongest science and research communities in the world and that research and development is vital to the future of the UK. In her capacity as Chair of the Science and Technology Select Committee she highlighted its role in scrutinising government departments and policies.

She welcomed that mathematics was the most popular A level subject. However, she also highlighted that more young people still need to study mathematics and science at this level and made a similar observation to Neil Carmichael that the uptake of mathematics post-16 was much lower than in other countries.

Discussing this further she noted her concern that mathematics and science are viewed as elite subjects reserved for 'geeks'. She stated that this view not only damages the prospects of young people opting out of STEM subjects but also damages the economic competiveness of the UK. She also articulated the need to communicate to young people that STEM subjects can be undertaken by all. She spoke about some of measures the Government has taken to increase the study of STEM subjects such as the Your Life campaign.[6] She also noted that many of the conference delegates have also been focusing on communicating the importance of STEM in their fields.

To increase the uptake of STEM subjects she noted that interventions need to start in primary school. To illustrate this she told an anecdote about a primary school in a school previously in special measures that now has children going into secondary education with the aspiration to be teachers and doctors. Drawing on this she noted the need to start democratising STEM subjects by starting early. She highlighted her view that the UK's STEM ecosystem needs to be the most agile and responsive in the world because it underpins the rest of the economy and that in the future most industries will be shaped by it. She concluded by stating that this means there will be a fast growing demand for the skills acquired through mathematics and physics, noting that these subjects will become the twin pillars of the future success of the UK economy.

6. http://yourlife.org.uk/.

6 Panel discussion

Key opportunities in mathematics education in the next five years

The panel discussion followed a 'Question Time' approach. Questions were submitted by delegates in advance of the conference. Further questions were also asked from the floor.

Chair
Warwick Mansell, freelance education journalist.

Panel

- Professor Margaret Brown, Emeritus Professor of Mathematics Education, King's College London; Education Committee, Royal Society;
- Professor Richard Craster, Head of Department of Mathematics, Imperial College London and Former Chair of the A level Content Advisory Board (ALCAB);
- Mike Warriner, Director of Engineering, Google;
- Sue Johnston-Wilder, Associate Professor of Mathematics Education, University of Warwick.

This section is a summary of some of the points discussed during the panel session. The ideas explored should not be considered the view of all panellists but rather an overview of some of the points raised in the discussion.

Priorities in mathematics education	**Teachers** **Points discussed included:** • the need for teachers who are knowledgeable about how to teach mathematics; • potential benefits of building a teaching workforce made up of users of mathematics; • the need to invest in non-specialist teachers to upskill them to teach mathematics. **Learners** **Points discussed included:** • the importance of developing mathematical resilience and combating mathematics anxiety; • the need for all young people to understand that mathematics is a fundamental part of everything; • the importance of role models, career advice and support from parents; • the importance of teaching young people to think and to explore new problems. **Education system** **Points discussed included:** • the need for one a single not-for-profit awarding organisation; • the need to have a period of stability in the education system.
Developing the mathematical skills desired by employers	**Points discussed included:** • the need to understand what employers are looking for, such as problem solving skills and the ability to learn new things; • the need for flexibility in the curriculum to allow different skills to be incorporated in order to meet the changing needs of employers over time; • the need for young people to feel confident in mathematics.
Increasing participation in mathematics post-16 and delivering the current post-16 qualifications	**Factors suggested for increasing the participation of post-16 mathematics included:** • the need for teaching staff to have qualifications specific to what they teach; • the need for Core Maths to become a valued and demanded qualification; • the need to ensure that problem solving is embedded at A level; • the benefit of exploring the way post-16 qualifications are delivered in other systems, such as through a Baccalaureate model.
Addressing the recruitment and retention of teachers of mathematics	**Points discussed included:** • the need to recruit good non-specialists to teaching and to develop their capability to teach mathematics; • the need for clear information about the routes into teaching; • the need for consistent data on the supply of mathematics teachers; • the possibility of investigating whether to offer more undergraduate degrees which combine mathematics and teacher education.
Mathematical thinking and the curriculum	**Point discussed included:** • the differences in the development and assessment of mathematical thinking at primary and secondary level; • the importance of encouraging depth of learning rather than acceleration through the curriculum; • the idea of setting aside one lesson per week during primary education to look specifically at problem solving questions.

7 Keynote address

Professor Kevin Buzzard

Professor of Pure Mathematics, Imperial College London

Structure and randomness in mathematics

Professor Buzzard rounded off the conference with his high-energy talk on structure and randomness in mathematics. He discussed his work on number theory in what he descried as the 'abstract' universe of pure mathematics. He noted that his work on elliptical curves was an example of this type of thinking.

The audience was led through a series of mathematical problems that exhibited either structure or randomness. He went on to explore how structure and randomness can co-exist in mathematics noting that the answers to some mathematical problems can exhibit both. To demonstrate one of his points he gave all delegates a glimpse of the pattern of his bathroom tiles.

When working through each of the mathematical problems he discussed some of the methods for solving them that he had explored with school students.

He also spoke about how mathematics can be used to model real-world systems and how it is used in computer science. One example he gave of this was him using the Global Positioning System on his phone earlier in the day to work out the quickest route from his location to the conference, something that people use in their daily life without considering the mathematics behind it.

For further information about the Advisory Committee on Mathematics Education:

The Royal Society,
6 – 9 Carlton House Terrace, London SW1Y 5AG

T +44 (0)20 7451 2575
E acme@royalsociety.org
@ACMEmaths

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JMC