TISME
Researching Science & Mathematics Education

# BRIGHTER FUTURES:

## Five ideas for improving STEM participation in England

# OVERVIEW

**How can we enable more young people to study science, technology, engineering and mathematics (STEM) beyond the age of 16?**

**How do we make STEM curricula more engaging and relevant for more young people? And how do we improve the understanding and attainment of those perhaps worst served by the current system: the low-attainers?**

These are just some of the questions to be addressed in this publication, which aims to present research-informed ideas for potentially useful policy change to improve engagement, attainment and participation in science and maths.

This publication summarises the proceedings of a one-day conference on the future of science and maths education, staged by the TISME (Targeted Initiative on Science and Mathematics Education) research programme on January 28th, 2014 at One Great George Street, Westminster, London. The conference was attended by a range of stakeholders, including STEM professional societies, the Department for Education (DfE), think tanks, STEM educators, academics, researchers and STEM delivery organisations.

TISME, funded by the Economic and Social Research Council in partnership with the Gatsby Charitable Foundation, the Institute of Physics and the Association for Science Education, comprises five constituent research projects (see box opposite).

The five project directors were asked to draw on their research to put forward big, radical and challenging ideas for the future of STEM education. They were encouraged to not necessarily be constrained to ideas that could be easily implemented in the near future. The purpose of the day was to stimulate thinking for the future, not to just 'tinker' with the system in its current form.

The format of the "Five Ideas" event on January 28th saw the director of each TISME research project given five minutes to present a policy initiative emerging from their research. The idea was then subjected to two formal responses from key stakeholders, followed by general discussion.

This report is intended as a useful think piece: it collates the key ideas and challenges that were outlined and discussed at the conference. Our intention is to capture the both the ideas and the challenges that were put forward, in order to enable further debate within the STEM community. We hope that such discussions will be useful for developing a future STEM education policy 'roadmap'.

| The five TISME research projects: | |
| --- | --- |
| **ASPIRES (Science Aspirations and Career Choice: Age 10-14)** | This project, based at King's College London, investigated science aspirations and career choice among 10- to 14-year-olds. This five year, longitudinal project combined large-scale surveys with more than 18,000 students across England and in-depth longitudinal interviews with parents and young people. More information is available from: **www.kcl.ac.uk/aspires** |
| **EISER (Enactment and Impact of Science Education Reform)** | EISER, based at the University of Leeds, examined major reforms to the school science curriculum for 14- to 16-year-olds which have taken place since 2006. This study combined nationally representative data with in-depth school-based case studies. More information available from: **www.education.leeds.ac.uk/research/projects/enactment-and-impact-of-science-education-reform-eiser** |
| **epiSTEMe (Effecting Principled Improvement in STEM Education: Student Engagement and Learning in Early Secondary School Physical Science and Mathematics)** | This project, based at the University of Cambridge, redesigned key aspects of the teaching and learning of physical science and mathematics for students in the early years of secondary school. The intervention was designed for widespread use in schools. More information is available from: **www.educ.cam.ac.uk/research/projects/episteme/** |
| **ICCAMS (Increasing Competence and Confidence in Algebra and Multiplicative Structures)** | ICCAMS, based at King's College London, examined ways of raising students' attainment and engagement by using classroom-based assessment to inform teaching. The study included a large survey of 7,000 students' understandings and attitudes. More information is available from: **www.iccams-maths.org/** |
| **UPMAP (Understanding Participation rates in post-16 Mathematics and Physics)** | This project, based at the Institute of Education, University of London, used a mixture of qualitative and quantitative methods to determine the range of factors that influence post-16 participation in mathematics and physics in the UK. More information is available from: **www.ioe.ac.uk/upmap** |


# 1 IDEA 1: **Replace A-levels with a baccalaureate system**

**Presenter:** Louise Archer, ASPIRES director and lead TISME co-ordinator

"Science is not for me."

Unfortunately, this is the view of most young people when faced with the choice of whether or not to continue with STEM subjects beyond the age of 16.

For not only do science A-levels remain a minority option. But ASPIRES surveys of more than 18,000 10- to 14-year-olds found that most see careers in science as not "for them", with science A-levels considered only useful for those wanting to become scientists or doctors. Many young people, then, see current post-16 qualifications as "not relevant for me".

Changing this scenario, with the study of science post-16 rightly being seen as an attractive and useful choice by a far larger group of young people, is central to the thinking behind this idea.

This would see the A-level, now in its seventh decade, replaced with a baccalaureate system in which the norm would be for students to study a broader range of subjects. England is out of step in the narrowness of its focus from 16 to 18; countries with baccalaureate-style post-16 education such as New Zealand have higher post-16 participation rates [1].

Not only would broader post-16 science options enable and encourage more students to study science post-16. They would also lead to improved levels of scientific literacy across each year group; help to reduce popular stereotypical misconceptions about the use and value of STEM qualifications; and help to shift policy discourse away from focusing narrowly on the needs of the science "pipeline" – the next generation of scientists – towards a more prominent valuing of scientific literacy among the general public.

This idea would also help to improve the status, visibility, flexibility and 'connectedness' of post-16 courses that develop students' scientific literacy, which in turn will be useful for a wide range of future pathways and careers. A baccalaureate style system may require a broader (more inclusive) range of post-16 STEM options, which would need to strike a challenging balance: they would need to be open to students with a wide range of attainment, connect to multiple potential further pathways and have a good status with educators and employers, irrespective of whether they are academically or vocationally orientated.

## Rationale and evidence

Improving participation in post-16 science qualifications is important for many reasons, including for social mobility, for equality and to address the predicted "STEM skills gap" in particular aspects of the economy.

In the English system, there is a particular need to provide a much broader set of options for a very large group of students: those who want to study more science outside of biology, physics and chemistry A-level.

Perhaps most notably, there is a missed opportunity to engage those who have achieved a grade B or C in GCSE science. Such students can often seem ignored by a policy discourse which focuses very narrowly on the science "pipeline" – young people going on to science degrees and then STEM careers.

As it is, a student with an interest in science may find it harder to gain entry to A-level biology, physics or chemistry if they lack high GCSE grades than they would in relation to non-science subjects, because of the selective entry policies of many schools and colleges. And many others will simply not want to pursue the A-level route, viewing science as "not for them".

For the evidence is that while many young people are opting not to persist with science, most are generally interested in it. TISME data show that most young people report liking school science from year 6 (at primary school) through to year nine (at the end of key stage 3 in secondary). However, ASPIRES surveys of more than 18,000 10- to 14-year-olds show that the majority consider science A-levels as only useful for those who wish to become scientists or doctors. Many young people, even those in "top sets", but particularly those from female, working class and/or from particular minority ethnic groups, tend to think they are not "brainy" enough to study science at A-level.

TISME evidence also shows that most young people and parents are not aware

*Many young people, even those in "top sets", but particularly those from female, working class and/or from particular minority ethnic groups, tend to think they are not "brainy" enough to study science at A-level.*

that science can lead to diverse post-16 routes. The widespread view – that science qualifications lead primarily to a job either as a scientist, a science teacher or a doctor – is contributing to many young people seeing science qualifications as "not relevant for me".

There are some existing post-16 science qualifications which are supposed to appeal to a wider range of students than those following the traditional academic route, but they currently tend to attract only limited numbers. By contrast, research by Donnelly (2009)[2] shows that GCSE applied science courses have been successful in engaging many learners and producing higher than expected attainment, particularly among less socially advantaged groups. These qualifications offer some hope for similar success with post-16 reform.

A debate about post-16 science routes[3] would also be timely in the light of Department for Education's stated ambition that, by 2020, the "overwhelming majority" of young people in England should study mathematics to at least the age of 18. We suggest the "job" of ensuring appropriate, high and widespread levels of scientific literacy in the next generation is not currently "done" by the end of GCSE.

## Challenges and discussion

Participants in the discussion on January 28th put forward several potential difficulties for this idea.

First, **politically** it was argued that there was no realistic prospect of a reform as radical as this within the next five to 10 years, as there was simply no appetite for it within the main parties. The current government had already set about reforming A-levels, while Labour's focus was on "recoupling" AS and A-levels alongside its plans for a vocational/technical baccalaureate. It was pointed out, however, that David Willetts (the then Minister for Universities and Science), has been supportive of the idea of a baccalaureate, while there was an argument that the science education community needed to focus on long-term strategy, building a consensus behind key principles, rather than on short-term political considerations.

Second, this idea would face the perennial argument, which is often mentioned in discussions over introducing baccalaureate systems to replace the A-level, that **depth of study** might be being sacrificed as students pursued greater breadth. Higher education institutions are already complaining, it was argued, that students are not sufficiently prepared for degree study, so they might not welcome this move.

However, it was also pointed out that higher education already welcomes many students who have taken the International Baccalaureate, who tend to do very well. So this might not be a fundamental stumbling block.

Third, a major issue, if more students are to opt for post-16 science, would be where the **additional teachers** would come from. This was raised as a challenge by more than one contributor. Again, it was suggested in the discussion that it was still important to try to get the principles of reform right, and then to address this issue.

Fourth, it was suggested that policy-makers' **reliance on the "pipeline" metaphor** would be hard to shift, given the link between STEM qualifications, degrees and careers with the economy. Broadening policy-making calculations to consider the benefits to individuals and society of those who take science qualifications but do not go on to science careers might thus be difficult. In response, it was argued that a richer economic and societal argument for the benefits of public scientific literacy needed to be made.

Fifth, it was claimed that even the baccalaureate idea ran the risk of concentrating only on students destined for higher education, meaning there was **a need to focus on technical or other routes**, too.

Overall, however, the idea of a baccalaureate system received a broadly positive reaction in the discussions, with it being argued that a broader base of education is good for all. ●

---


1. Hodgen, J., Marks, R., & Pepper, D. (2013). *Towards universal participation in post-16 mathematics: lessons from high performing countries.* London: The Nuffield Foundation.

2. Donnelly, J. (2009). *An invisible revolution? Applied Science in the 14-19 curriculum: A report to the Nuffield Foundation.* London: The Nuffield Foundation.

3. See Department for Education (2013) *Introduction of 16 to 18 core maths qualifications Policy Statement* http://bit.ly/1jBNgrf

# 2 IDEA 2: **Embedded STEM careers education**

**Presenter:** Michael Reiss, UPMAP director

## Imagine a future in which science and maths lessons provide insights to young people not just into the theories and techniques being studied, but into how the subject matter could help them in their careers.

This is the second idea: science, technology and mathematics lessons should feature "embedded" careers education to a far greater extent than at present. This would mean a consistent and integrated approach within the curriculum that highlights the real world relevance of the subject. This approach would include linking STEM subject content to a wide range of occupations and applications at a variety of levels (e.g. degree level and vocational/ technical levels).

Careers education needs to help broaden students' awareness of the transferability of STEM qualifications for a wide range of careers both in and beyond science and mathematics, it was argued.

Evidence[4] from a randomised control trial in the United States suggests that systematically highlighting the real world relevance of a subject and embedding links within the curriculum to a wide range of jobs can raise student attainment and improve engagement. Ongoing evaluation of CareerStart, a school intervention in the US middle grades designed to advance the occupational relevance of what students are being taught in the core subjects, shows a significant treatment effect for performance in mathematics. This is an encouraging finding for those open to the idea of "embedding" STEM careers education in the UK.

*Careers education is currently not strong in most schools and colleges. A range of reasons help to explain this, principal among them its low status and shifts in government policy and funding.*

### Rationale and evidence

Careers education is currently not strong in most schools and colleges. A range of reasons help to explain this, principal among them its low status and shifts in government policy and funding.

As a result, too many young people make subject choices for post-16 study that they subsequently regret. In particular, fewer young people in the UK choose post-16 STEM subjects than would if they were more aware of the potential benefits following from the range of post-16 STEM options. STEM graduates are especially valued by employers; are more likely than other graduates to be in employment soon after graduating; report being more positive about their degrees than do other graduates; and have higher lifetime earnings.

However, many students have little idea of the doors that will be opened to them if they study STEM subjects after the age of 16. In particular, most young people are not aware that science can lead to diverse post-16 routes. The widespread view – that science qualifications lead primarily to a job as a scientist, science teacher or doctor – is contributing to many young people seeing science qualifications as "not relevant to me".

A related issue is that there are marked inequalities in terms of who undertakes STEM subjects post-16 and at university and who goes on to have STEM careers. The UK has one of the worst gender disparities in engineering and the physical sciences and there is marked under-representation for those from lower socio-economic status backgrounds and for certain minority ethnic groups as well as for disabled people.

Underlining these statistics, evidence from ASPIRES shows that families are the main influence on 10 to 14 year-olds' aspirations. Children from families familiar with the world of science – those that have "science capital" – are much more likely than their peers to want to study science post-16 and/or work in science. Improving careers education in the classroom could help to address this disparity.

The UPMAP project showed that the three strongest factors that predicted whether year 10 students would study physics at advanced level (about which schools can do something, as opposed to student gender) was the extent to which they felt that studying physics would help them materially, followed by their attainment in physics, followed by the advice or pressure they reported receiving to study post-16 physics. Both the first and third of those factors could be influenced by enhanced science careers teaching in lessons. The findings for mathematics were similar.

There are some promising initiatives in this field. In particular, The Future Morph website (**www.futuremorph.org**) helps young people engage with science and mathematics study by demonstrating the huge range of career opportunities the subjects open up. However, resources have been withdrawn both from STEM careers education in particular – for instance, there is no longer a National STEM Careers Co-ordinator – and from careers education more generally.

## Challenges and discussion

A first challenge for this idea, raised by several people in the discussion, was that **teachers would need to be well-trained** if good advice on STEM careers was really to be embedded effectively in lessons. Training would need to be of high quality, especially as it was felt that many teachers needed a better understanding of the range of possible STEM careers, while most careers specialists were said to have an arts background. It was suggested that the professional societies might be well-placed to provide this professional development.

A second challenge was the **need for good evidence** that such an approach would work. Several participants were interested in the CareerStart study but it was argued that evidence would be needed from the UK of the impact on young people's study choices before it could be implemented at scale here. It was suggested that thought be given as to how a UK randomised control trial could be undertaken.

Several contributors made the point that the notion of "embedding" careers advice in lessons **needed to extend beyond STEM subjects**, across the curriculum. It was also argued that this should not be seen as replacing existing advice and guidance, but as part of a broader structure of careers education.

One participant argued that the **terminology of "embedding" was a problem**: it should not be called something which sounded as radical as this, when in fact it was simply an extension of how science used to be taught: grounding the subject in real-life contexts.

One aspect would not be a problem: this idea would not be rejected by specialist careers staff, who would welcome it, it was claimed. ●


4. Woolley, M. E. et al. (2013) Advancing academic achievement through career relevance in the middle grades: a longitudinal evaluation of CareerStart, *American Educational Research Journal*

# 3

# IDEA 3: **Creating a national science curriculum group to improve the involvement of stakeholders in curriculum reform**

**Presenter:** Jim Ryder, director of EISER

Teachers who are dismayed at having repeatedly to respond to seemingly constant curriculum and qualifications changes may welcome this third idea, which seeks to provide some non-political stability around the process of reform.

The National Science Curriculum Group (NSCG), representing a broad range of stakeholders, would oversee national school science curriculum reform. It would include representation from teachers, students, parents, scientists, employment organisations, science education researchers, representatives of charitable organisations (such as the Nuffield Foundation), awarding bodies and government policy-makers.

The NSCG would: pro-actively advise the government on curriculum reform policy; be consulted on government curriculum reform proposals; have responsibility for the ongoing evaluation of the current curriculum; have responsibility for the piloting and evaluation of proposed reforms; design an implementation plan for curriculum reforms; and consider how proposed science curriculum reform policies might interact with other current and planned education policy reforms, to ensure "curriculum coherence".

The NSCG would represent the "collective memory" and research-based insights of the community. An allocation of funds to support the work of the group, including piloting and associated evaluation, would be needed.

## Rationale and evidence

Previous systemic curriculum reform initiatives have often proved unsuccessful in the long term. Many teachers resent being asked to respond to seemingly constant curriculum change, without either sufficient time or resources, or a clear sense of how the reform can support their goals as education professionals.

*Many teachers resent being asked to respond to seemingly constant curriculum change, without either sufficient time or resources, or a clear sense of how the reform can support their goals as education professionals.*

On the other hand, curriculum policy-makers complain that teachers do not implement curriculum reforms as intended.

Inevitably, the school science curriculum is contested terrain, with many distinct aims ascribed to it. For example: the development of "scientific literacy" for all students; the starting point for further study and potentially a career in science; an opportunity to be fascinated by science and technology. It is unlikely that all such demands on school science curricula can be fully catered for. However, without an explicit identification and consideration of multiple aims, and associated tensions, we know that successful long-term curriculum reform is unlikely. The NSCG would be the mechanism for doing so.

Much has been written about the "failures" of successive school curriculum reform efforts internationally. Studies provide numerous examples of unsuccessful reforms. Underlying these reforms is a failure to recognise: the long timescales involved in systemic educational reform (three to five years); the multiple aims of school science education; the diversity of school contexts; the need for coherence across multiple education reform policies; and the diverse professional identities and goals of teachers.

The EISER study, which considered the 2006 reforms to the key stage 4 science curriculum, found that while the development phase showed many positive features, the implementation phase was rushed, paid insufficient attention to the outcomes of ongoing pilot studies and did not develop robust assessment items for innovative areas of the reformed curriculum. Teacher experiences showed that a negative response to an externally-driven curriculum reform was often the result of a professional judgement that aspects of the reform did not meet the needs of their students.

Awareness of evidence such as this would be part of the remit of the NSCG. There are successful precedents in other countries, such as the Netherlands Institute for Curriculum Development (SLO) (**www.international.slo.nl/downloads/SLO-in-brief.pdf/**).

## Challenges and discussion

There was broad agreement that there needs to be a long-term planning structure for curriculum change, and that party politics needs to be removed, so far as possible, from curriculum development.

Discussion centred not so much around challenges but around potential aspects of this group's work.

There were several comments that the group needed to have a **remit to cover assessment, and possibly accountability**, as well as curriculum, as these aspects of education were very closely linked.

There was a question as to whether the group would be **"pro-active"** – initiating policy – **or reactive**: responding to ideas put forward by others.

The questions as to **whether there should just be one group for science, or several, and whether to restrict this development only to the sciences** were also raised.

**Stakeholders needed to be seen as an integral part of the development process,** rather than as an end-point of policy advice, as currently happened.

One inevitable issue would be: **who would be the members of this group?** And there would also be **disagreements about its possible remit**, it was argued, but the community would have to unite and not see the group as a threat. One participant commented that a similar idea had foundered because of differences of opinion as to who would be on the group.

Comparisons were also made to **seemingly successful developments** in healthcare – the National Institute for Clinical Excellence (NICE) – and a specific initiative in education – the adoption of Assessment for Learning policies in schools, especially in Scotland – which had achieved widespread backing from professionals.

But one participant wanted to know: **what would the politicians say?** ●

4

# IDEA 4: **Realistic continuing professional development for change**

**Presenter:** Kenneth Ruthven, director of epiSTEMe

The ongoing development of teachers is a concept which many would agree is centrally important in education. Indeed, it emerges as a key issue in any analysis of how to improve the quality of school mathematics and science education. However, it is often marginalised in schools and colleges.

© Philip Wolmuth

This idea would seek to make it more high profile at an institutional level, by making continuing professional development a central and directly evaluated component of accountability for schools.

## Rationale and evidence

Research points to the kinds of capacity which schools themselves, or groups of schools, need to build if they are to become effective sites for the professional learning of their workforce.

Schools need regularly to schedule time for collaboration, and to ensure that such time is used to foster in-depth interaction between teachers doing subject activities together and discussing strategies; at least some of the teachers taking part need to be relatively accomplished at their jobs; successful implementation of changes in practice depends on coaching support through co-teaching, observation and joint planning and analysis; and the school leadership must be supportive and comprehending of developmental aims in subject teaching and give them priority.

To motivate such capacity building in the current context of English education, it must become a central and directly evaluated component of accountability for schools.

Studies carried out both in the United States and through TISME in England offer evidence on the initiation of professional development programmes. In two of the TISME projects, research-based pedagogical design played a central part: epiSTEMe and ICCAMS.

Both projects have developed topic-focused, early secondary interventions, designed to be amenable to implementation at scale. Both are designed to be “educative” for teachers, and are based on research on helping students develop fundamental aspects of mathematical and scientific reasoning. Both projects followed an alpha phase in which the researchers worked with small numbers of teachers to develop and pilot the intervention, then a beta phase involving larger numbers of teachers conducting field trialling.

epiSTEMe involved teachers spending only two days out of school on training,

while ICCAMS had six out-of-school days. In practice, both projects underestimated the shifts in practice that the interventions implied, and the corresponding demands on teachers, and found that they needed to provide more support to teachers than expected.

During both phases, and in continuing work to build use of the interventions into departmental schemes of work, it became clear that there were a number of institutional challenges to producing substantial and sustainable changes to teaching and learning.

These included many secondary schools giving low priority to the early secondary phase in matters of staffing; extensive teacher turnover, notably within-year, resulting not just from external movement of teachers to other schools but from internal reallocation of teachers to examination classes in the face of staffing shortages; and an inhibiting influence from accountability measures which produced an overemphasis on shorter-term markers of compliance and success. As found in earlier evaluations of the implementation of the National Strategies, school and departmental cohesion on matters of pedagogy was often weak.

The issue of realistic continuing professional development has been studied more directly in the United States, in a similar context of high-stakes accountability and schools under pressure. The TISME projects were well-aligned with the first two criteria for successful professional development from the US research: focus on key pedagogical issues and high leverage practices; and organised around records of practice and instructional materials. What was generally lacking was the third: these initiatives needed to take place in a stable collaborative community over a sustained period of time.

The research[5] in the United States also relates to two other institutional factors which the relatively short-duration TISME interventions did not seek to change, but which need to be addressed in order to promote their success: additional support for struggling students and aligned assessment which matches goals for student learning and informs ongoing improvement of instruction.

## Challenges and discussion

It was acknowledged that the idea of **creating sustainable, successful professional development programmes on a large scale** was challenging terrain.

There were challenges in **creating sustainable, collaborative teaching communities over time** because of high teacher turnover.

This idea, though, would seek to make professional development more of a priority within schools by making it an institutional indicator within the accountability framework. In other words, it would be as important for schools to be fostering professional development as to be improving the attainment of their students, within the accountability structure.

There was some dissent about that during the discussions, with one contributor arguing that **new accountability measures "will not be the solution to too much accountability"**, while another said that **successful professional development was too subtle to measure through league tables**. However, another contributor said there was recent evidence of the potential power of the accountability system to drive behaviour in ways that perhaps purely professional considerations by teachers did not: Ofsted asking schools how they were spending their pupil premium money seemed to influence them more than did evidence from the Education Endowment Foundation as to which intervention worked.

The ability of schools even to provide a modest amount of **time** – the two days of the epiSTEMe study – for teachers in training was questioned.

Scepticism about the government's move to **schools rather than universities leading on initial teacher education** was also expressed, with the risk being, it was claimed, that research would be given less emphasis.

There was support for the concept of a **Royal College of Teachers**, which would back professional development. It could provide professional accreditation for institutions as well as individuals. There would need to be reflection on where the General Teaching Council for England went wrong. One contributor said either too little, or too much, support from the government and unions could prove fatal for a Royal College of Teachers. ●


5. Bryk, A. S., Sebring, P. B., Allensworth, E., Luppesco, S., & Easton, J. Q. (2010). *Organizing schools for improvement: Lessons from Chicago.* Chicago: University of Chicago Press.

Jackson, K., & Cobb, P. (2013). Coordinating professional development across contexts and role groups. In M. Evans (Ed.), *Teacher education and pedagogy: Theory, policy and practice* (pp. 80-99). Cambridge, UK: Cambridge University Press.

Newmann, F. M., Smith, B., Allensworth, E., & Bryk, A. S. (2001). Instructional program coherence: What it is and why it should guide school improvement policy. *Educational Evaluation and Policy Analysis,* 23(4), 297-321.

# 5

# IDEA 5: **Addressing low attainment**

**Presenter:** Jeremy Hodgen, director of ICCAMS

## The majority of low-attaining students are currently offered the very antithesis of what should surely be their right: an engaging and challenging mathematics curriculum tailored to their learning needs.

In fact, too often, what they receive is uninteresting, repetitive and remedial mathematics that discourages further participation and does little to raise mathematical attainment and understanding.

This may be reflected in very disappointing findings on levels of mathematical understanding (see below) within ICCAMS, which show the proportion of students failing to reach even the lowest defined levels of performance has grown sharply since the 1970s.

This idea, then, proposes to improve the evidence base on "what works" for low-attaining students in secondary mathematics and in particular to provide convincing evidence, for use by schools and teachers, of the efficacy of such an approach; and to develop resources to support teachers and schools in this endeavour.

### Rationale and evidence

The ESRC-funded ICCAMS study indicates that the problem of low attainment in England has got significantly worse since the 1970s, despite a plethora of initiatives designed to address it.

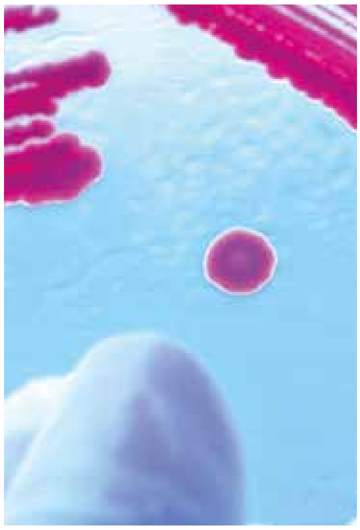
In Phase 1 of ICCAMS, the team conducted a representative national survey of mathematical understanding in algebra and multiplicative thinking in Key Stage 3 in England. The survey was undertaken in 2008/9 and used tests of Algebra, Decimals and Ratio developed in an earlier study, thus allowing a unique comparison of students' understanding over time.

The results show that, in comparison to the original survey in 1976/7, at the end of Year 9, students' average results in algebra and ratio had declined. This evidence of a decline in mathematical understandings is supported by recent studies of secondary-age students and of 16-18 year-olds[6]. In relation to low-attaining students, ICCAMS found:

- At the end of year nine, the proportion of students whose responses failed to reach even the lowest defined level of performance appeared to have doubled in Algebra and Ratio to more than 15 per cent of the cohort. The increase in the very lowest attaining group in the Decimals test is lower, but nevertheless the proportion is more than 10 per cent of the cohort. These secondary students have difficulty answering even basic questions about core ideas from primary mathematics.
- Looking beyond the very lowest attaining group, the proportion of students who do not appear to have mastered the most basic mathematical ideas in the secondary curriculum by the end of Key Stage 3 is also worryingly high. For example, almost two thirds of the cohort has difficulty with ratios involving simple non-integer multipliers.
- The attainment gap appears to widen considerably during Key Stage 3.

Turning to other evidence, studies of setting show that lower sets in

*The ESRC-funded ICCAMS study indicates that the problem of low attainment in England has got significantly worse since the 1970s, despite a plethora of initiatives designed to address it.*



mathematics are characterised by low expectation, a restricted and fragmentary curriculum and a slow pace. The research evidence base on low attainment in secondary mathematics is limited, but there is little evidence to support this remedial approach. Indeed, this approach appears to discourage students continuing with mathematics (and other STEM subjects) post-16.

Currently, a great deal of policy attention is focused on increasing mathematics provision in 16-to-19 education. However, for this supply-side policy to be successful, we also need to increase the demand for mathematics from young people by convincing them of the value of studying mathematics. There is a danger that the revised national curriculum will further entrench a remedial approach to low attainment in mathematics and that, contrary to the intentions of policy-makers and politicians, low attainment and participation in mathematics may get worse.

The ICCAMS study may contain some hope, however. As part of ICCAMS, the team developed an approach to mathematics that provided appropriate challenge using formative assessment. This was piloted with a group of 20 teachers and year eight mathematics classes from 10 schools. The results show that students who received ICCAMS made greater progress than a matched control group. Although students across the attainment range made significant learning gains in ICCAMS, many teachers were reluctant fully to implement the approach with their low-attaining classes. This suggests that a similar, but more complete and better-targeted, implementation would result in greater learning gains for low-attainers.

## Challenges and discussion

There was a wide-ranging discussion.

First, it was re-iterated that there was a **general lack of evidence concerning how to address low attainment**. However, ICCAMS had added further weight to the evidence that feedback, peer tutoring and explicit teaching tended to improve attainment[7].

Second, there was some discussion about the **difference of views among teachers** as to the best approach with lower attainers. Some teachers had thought that the ICCAMS approach would motivate these students, but others felt strongly that they needed basic numeracy. It was suggested that a randomised control trial of ICCAMS might be needed next. More generally, there was a need to engage with the question as to why many teachers were resistant to implementing it with lower attainers. Were they, for instance, worried about a possible trade-off between short-term test score improvements and longer-term gains, or did they have other concerns?

Third, there was a suggestion that the **ICCAMS approach might contrast with the simple rhetoric of "aiming high, no excuses, high expectations"** which often seemed to work for politicians.

Fourth, while ICCAMS had focused on secondary education, there were some suggestions that **work with pupils needed to start earlier**, in primary schools, so that fewer children became lower attainers in the first place.

Fifth, the question was asked as to whether what ICCAMS demonstrated was the **need for a better maths curriculum or simply that there was a need to put the best teachers in the bottom sets.**

Finally, the question of **teacher supply** was raised again. A maths teacher shortage was developing, with the advent of the new "Core Maths" qualification post-16 about to put new pressure on recruitment and retention numbers. Innovative approaches were needed, it was suggested. ●


6. Shayer, M., Ginsberg, D., & Coe, R. (2007). Thirty years on – a large anti-Flynn effect? The Piagetian test volume & heaviness norms 1975-2003. *British Journal of Educational Psychology*, 77(1), 25-41.

   Shayer, M., & Ginsburg, D. (2009). Thirty years on – a large anti-Flynn effect? (II): 13- and 14-year-olds. Piagetian tests of formal operations norms 1976-2006/7. *British Journal of Educational Psychology, 79,* 409-418.

   OECD. (2013). *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills.* Paris: OECD Publishing.

7. Baker, S., Gersten, R., & Lee, D.-S. (2002). A Synthesis of Empirical Research on Teaching Mathematics to Low-Achieving Students. *The Elementary School Journal, 103*(1), 51-73.


# CONCLUSION


© Philip Wolmuth

There was a clear consensus at the conference that all five ideas that had been presented were important and worthy of further consideration. It was agreed that the scale and persistence of STEM participation issues are such that significant and substantive change will be required if we are to significantly improve STEM participation. Small-scale and piecemeal interventions are unlikely to deliver change at scale. TISME urges the sector to be bold in its thinking – and collaborative in approach – when considering how we might improve STEM participation. Indeed, we hope that one potential legacy from the TISME initiative is to highlight the value of bringing together policy, practice and research communities to jointly explore ideas for improving science and mathematics education and participation.

For further information about the TISME programme, please see our final report (Autumn 2014).

**Acknowledgements:**
We express our thanks to all the participants and speakers who attended the 'Five Ideas' conference and whose views and discussion contributed to this report. The report was written by Warwick Mansell on behalf of TISME.

**TISME**

King's College London
Room 1/1 FW Building
Waterloo Bridge Wing
London, SE1 9NH

Tel +44 (0)207 848 3139
Fax +44 (0)207 848 3182

@TISMESciMaths

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

IOP Institute of Physics

GATSBY

The Association for Science Education — Promoting Excellence in Science Teaching and Learning

UNIVERSITY OF CAMBRIDGE

IOE LONDON — Leading education and social research — Institute of Education University of London

UNIVERSITY OF LEEDS

KING'S College LONDON