Nuffield Foundation

"I do and I understand"

Half a century of curriculum development

Contents

Cover image shows two *Nuffield Secondary Science* students measuring lung capacity, and two *Twenty First Century Science* students from St Michael's Roman Catholic School in Stockton-on-Tees (image courtesy of Chris Colclough).

Foreword

It is 50 years since the then Secretary of State for Education, Sir David Eccles, announced in the House of Commons that the Nuffield Foundation would be investing £250,000 towards the cost of a long-term development programme to improve science and mathematics teaching.

Since 1962, the Foundation has supported some 60 major curriculum projects and countless smaller ones. The largest and best known projects have been in science and mathematics, but the story goes much wider, covering languages (ancient and modern), design and technology, economics and business, English, history and more besides.

This booklet tells the story of the Nuffield Foundation's work in curriculum development through the people and projects that have defined its work over the last 50 years.

We look back on the origins of the Foundation's involvement in the school curriculum, examine some of the common themes underpinning its work, and reflect on the lessons learned. We conclude with a look at how the Foundation's current activities are building on past innovations to deliver high quality education research and development.

The projects described in the following pages result from collaborations between very many people and institutions. The Foundation has acted as convenor and funder, and sometimes as instigator, but the work has been done by teachers, academics, scientists, civil servants, examiners, publishers, students, designers and many more. It is their work and their inspiration that we celebrate in this booklet.

Anthony Tomei, Director

Origins

The Nuffield Foundation has played an important part in the development of the science curriculum since the 1960s. Our story begins with innovative individuals who harnessed the desire for reform of science teaching and learning. What inspired and motivated them? What problems did they encounter, and most importantly, what did they achieve?

"It is difficult for me to overstate how important physics A level was to me. We were, or had been, a Nuffield trials school so had masses of wonderful new equipment. I can recall the excitement of measuring the gravitational constant and the charge on an electron as well as being introduced at the end of the course to Schrödinger's equation, a good example of the value of getting learners to 'lift up their eyes' even if the details of what is being taught are well beyond them."

Professor Michael Reiss, Pro-Director: Research and Development, Institute of Education

Inspiration

In the early 1960s there was no statutory, centralised control of the curriculum and government policy was against direct intervention. Yet at the same time, there was a growing consensus among government, leading scientists, Her Majesty's Inspectorate (HMI) and the Science Masters' Association (now the Association for Science Education) that science education was in need of major reform.

In 1961, recognising this desire for change, the Nuffield Foundation convened a meeting attended by government ministers and other key figures in science and education. At the meeting, John Lewis, a physics teacher from Malvern College, spoke about his recent experiences in the Soviet Union, where he had been impressed by science teaching that was supported by a wealth of centrally produced resources. Realising the potential for the Nuffield Foundation's intervention, the Director, Leslie Farrer-Brown, began to explore the possibility of a major education project. He presented his proposal to Trustees at the end of 1961 and was enthusiastically supported by Sir Alexander Todd, a Trustee of the Foundation and a Nobel prize-winning scientist and chair of the government's Advisory Committee on Scientific Policy. Trustees decided not only to fund the project, but to develop it in-house.

Leslie Farrer-Brown's proposal became the Science Teaching Project, which sought to modernise science education for all 5- to 18-year-olds. It began with O level courses in biology, chemistry and physics, followed by mathematics and junior science courses for 5- to 13-year-olds, a science course for teaching in secondary modern and comprehensive schools, and a suite of advanced level science courses. It was the first large-scale attempt to reform both teaching approaches and content in school mathematics and science.

'Spirit of discovery': the Science Teaching Project in context

The case for better science education was first argued in the nineteenth century on the grounds of developing certain faculties in pupils, including the 'spirit of discovery'. This argument was expanded in the early twentieth century to include the importance of science education for national prestige, the economy, defence and welfare. These arguments were brought home during the Second World War, which demonstrated how focused effort could result in rapid advances in science and technology.

The post-war expansion and centralisation of education provision set the backdrop for further scrutiny of science education. In 1955, a study of Soviet scientific and technological training prompted criticism of the UK government's policy, and a White Paper on technical education the following year warned the UK was in danger of 'being left behind'.

"An excellent and most generous action..."

On April 4th 1962, in response to a Parliamentary question, the Minister of Education, Sir David Eccles, announced:

"The Nuffield Foundation has decided to make available £250,000 towards the cost of a long-term development programme to improve teaching in these subjects [science and mathematics]. *This is an excellent and most generous action for which I am very grateful..."*

The accompanying press release stressed the cooperative nature of the venture, which involved the Curriculum Study Group, Her Majesty's Inspectorate, all branches of the educational service, professional scientific institutions, industry, the Science Masters' Association, the Association of Women Science Teachers, the Gulbenkian Foundation, and the American curriculum reform movement.

Themes

The Nuffield Foundation has been involved in many curriculum projects since the 1960s, covering a range of subjects, ages and approaches. But there are a number of underlying themes that are consistent throughout all its work.

"Teaching Nuffield A level biology in the late 60s and early 70s was not just a revelation, it was a revolution: at a stroke the 'mug it up, spew it out' approach to examinations, which tended to make biology a bit like an extended vocabulary test for a foreign language, was swept away - now you had to 'understand' biological principles and do lots of practical work. More to the point, it was the students who were doing the practical work."

Dr Roger Lock, former teacher and Senior Lecturer in Science Education, University of Birmingham

Innovation

The Foundation's independence as a funder enables it to stimulate projects that are innovative or experimental. The early projects encouraged active exploration by students and used practical work as a way of introducing scientific concepts. For example, *"I do and I understand"* was not only the title of the 1960s *Nuffield Mathematics* teachers' guide – it was the central tenet of the project. Similarly, the Nuffield O level physics team wanted students to "be a scientist for the day". Classroom resources from these projects demonstrated an approach based on problem-solving and discussion rather than teacher-lecture.

In more recent years, these early approaches have been criticised for confusing teaching and learning approaches with the methods of the discipline. For example, there was an assumption that students could 'rediscover' scientific theories which took years of research to develop.

Innovation also relies on identifying innovators. The practice of backing talented people combined with the Foundation's 'open door' to proposals of exceptional merit means there is no single 'Nuffield approach'. For the same reason, a focus on science, technology and mathematics education has not excluded work in other areas such as languages, history, economics, and citizenship.

Influencing policy

The Nuffield Foundation has been influential in education policy since Leslie Farrer-Brown convinced the Ministry of Education to start the Science Teaching Project with O level courses rather than A level.

More recently, the 1998 report, *Beyond 2000*, proposed that science education should include 'science for citizenship' as well as preparing scientifically able students for further education in science. This recommendation was endorsed by the House of Lords Science and Technology Committee and had a major influence on the Qualifications and Curriculum Authority (QCA) in its drafting of the 2006 national science curriculum.

Similarly, this influence can be seen in the debate about post-16 mathematics education. The Foundation's 2010 report, *Is the UK an outlier?*, by Dr Jeremy Hodgen, highlighted the comparatively low levels of participation in post-16 mathematics in the UK. This finding was quoted heavily in the 2011 Advisory Committee on Mathematics Education (ACME) report, *Mathematical Needs*, and was referenced in both Carol Vorderman's report on mathematics education and the Wolf Report on Vocational Education. In response to this growing body of evidence, the Secretary of State said in 2011 that a desirable goal would be for the vast majority of pupils to be studying mathematics to the age of 18 within the next decade.

Evidence-informed practice

The move of the Nuffield team to Chelsea College in the 1970s encouraged a two-way exchange of ideas between curriculum developers and researchers. The Foundation continues to support research and its translation into policy and practice today, through grant-making and evidence-informed curriculum development.

This approach can be seen in *Nuffield Primary Science*, which was led by Professor Paul Black in the 1980s. Professor Black's team used research evidence relating to primary school children's ideas about science to provide practical guidance for teachers.

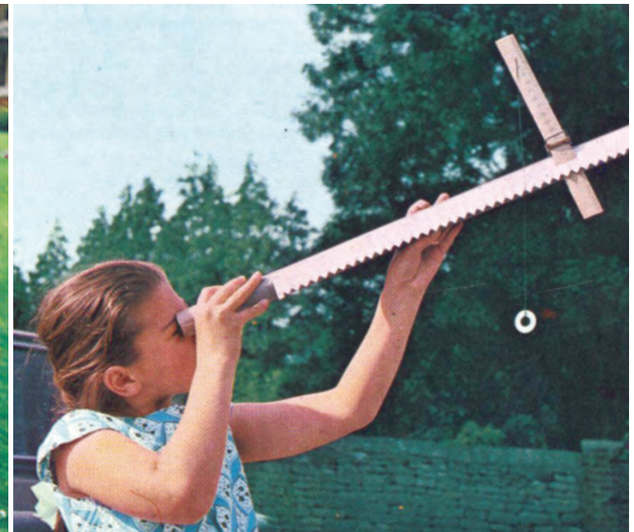
In 2002, the Foundation funded Professor Jonathan Osborne's IDEAS project (Ideas, Evidence and Argument in Science Education), which developed materials designed to support teachers' understanding of the nature and function of argument in science. It was inspired by research evidence suggesting that the opportunity to consider why some ideas are wrong is as important as understanding the justification for accepted ideas.

Quality

The Nuffield name is associated with high quality resources for teaching and learning. Central to this quality assurance is a development process that includes a school-based trial stage and the subsequent opportunity to make revisions in light of feedback from teachers.

Although the Foundation no longer operates a publications group as it did in the 1960s, it has continued to undertake in-house curriculum development in partnership with commercial publishers. This model has enabled the Foundation to utilise the marketing expertise and networks necessary for the widespread trialling and adoption of new courses, as well as the means to invest in the production of books and electronic resources.

In the last decade, increasing use has been made of websites to communicate with teachers and disseminate resources, for example through a suite of websites offering practical activities in biology, chemistry and physics.



Lessons learned

One of the Foundation's early aims in its education projects was to demonstrate the value of curriculum development, and to inspire other organisations to do the same. The expectation was that curriculum development would be carried forward in universities and by the Schools Council, set up in 1964.

"Some projects have had an immediate widespread influence with a large take-up by teachers; some have been a bit too radical for the majority of teachers at their time but have come to significantly influence later developments more indirectly; some have been thwarted by political changes but have nevertheless had a strong influence on national policy."

Professor Margaret Brown, King's College London

The Schools Council was responsible for most curriculum development and examination work between 1964 and 1984. Since then, a succession of public organisations have had responsibility for the school curriculum, but with limited resources to support major innovations in particular subject areas. Universities and professional subject associations have carried out research and development in relation to the school curriculum, but this has often depended on funding from charitable foundations, city livery companies and commercial organisations.

Lessons learned

Wider political context

Experience has revealed a number of key factors in successful curriculum development. The science projects of the 1960s had widespread impact in part because they were developed in response to educational and political consensus for change. This remains true today. In 1995, the Foundation initiated a review of science education in order to have some concrete proposals in place for the end of the government's five-year moratorium on curriculum change. This review began with a seminar series and ended with *Beyond 2000*.

More recently, growing consensus about the inadequacy of post-16 mathematics pathways provided the Foundation with an opportunity to commission research that could provide the evidence base for reform.

Timely evaluation

Significant change in schools takes time. The dissemination and impact of innovations has to be judged over decades, not years. Short-term evaluations tend to give results that are hard to interpret and which may be misleading.

A holistic approach

Curriculum development is most effective when it considers in parallel **content**, **teaching approaches**, **teacher professional development**, and **assessment**.

From the 1960s onward, Nuffield Foundation projects have included the development of questions for use in class, and collaboration with examination boards to reform assessment. In the 1990s, the Foundation funded the Assessment Reform Group, which made recommendations on how assessment policy and practice at all levels could take account of relevant research evidence.

Professional development of teachers has always been important to the adoption of new projects. The 1960s science projects used action research methods, which involved careful briefing of teachers on the underlying philosophy of the development. The 1990s *Nuffield Primary Science* resources included four 'in-service' training modules.

More recently, the potential for professional development has been challenged by the difficulties teachers experience in putting aside the necessary time.

Timing

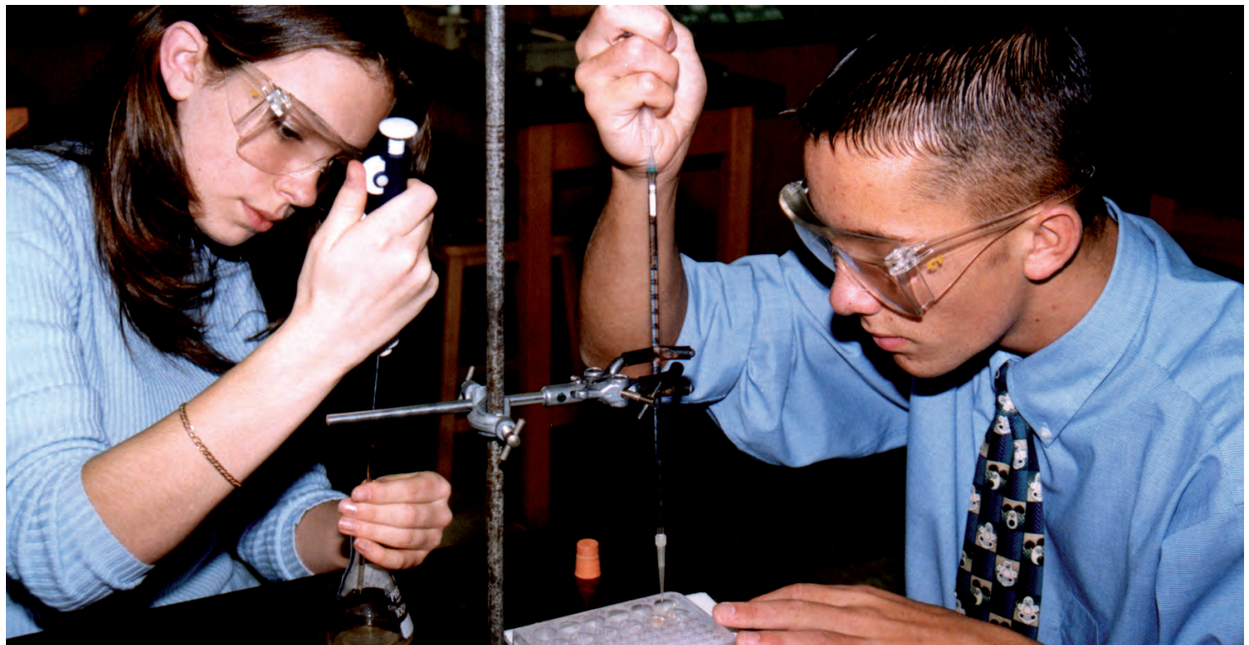
There is an inevitable element of risk in supporting new initiatives and not all of them are successful, particularly if the timing is wrong. For example the *Advanced Mathematics* project featured modern mathematics, including its applications in art and music, to promote independent study and exploit the power of programmable calculators and computers.

The project was launched in 1994 just as league tables began to have a major influence on school decision-making. As a result, this innovative and challenging course was adopted by very few schools and colleges and was short lived.

Assessment for Learning

In 1996 the Foundation funded Paul Black and Dylan Wiliam to carry out a literature review on the use of assessment to help with learning. They found decisive evidence that 'formative assessment' could improve learning, and published a booklet for practitioners called *Inside the Black Box*. A further project, also funded by the Foundation, showed teachers how to apply the principles in practice. The underlying idea, now widely known as 'assessment for learning', is quoted in the research and policy literature in many countries.

Reflecting on the project, Professor Paul Black quotes a student who said of her teacher, a participant in the development project: *"Now I know she is interested in what I think, not in whether I've got the right answer"*.



The 21st Century

The last 50 years have seen significant shifts in the responsibility for, and the development of, the school curriculum. The Foundation's role has also changed, but its presence has endured because its flexibility and independence enable it to adapt to changing contexts.

"I was really nervous about starting the placement. Chucked in at the deep end with all these scientists that have PhDs and all the rest, and you're just an AS-level student! But they're really supportive, take you under their wing and don't expect you to know everything when you start... I know science is for me now."

Senel Hazal, 17, on her Nuffield Science Bursary experience

There has been an increasing government role in the development and regulation of the curriculum, for example, in the introduction of the National Curriculum in 1988 and subsequent rationalisation of the awarding bodies. In recent years, government control has receded slightly, as successive governments have given greater autonomy over the curriculum to free schools and academies. Commercial publishers have also played an increasing part in curriculum development, and there has been a changing emphasis on teacher professional development.

The Nuffield Foundation works within this changing social and political context, requiring a flexible approach. Many curriculum projects have been developed in-house. Others have been commissioned, or supported through responsive grant-making. But underpinning all this work is a commitment to support an evidence-informed approach, at both policy and classroom level.

Current focus

In the last two years, there has been a change in government for the first time in 13 years, a review of the National Curriculum (currently underway), and a wider debate about the role of various education agencies. As a result, the Foundation's focus has shifted to supporting smaller scale development and interventions rather than large, in-house projects. Trustees are keen to strengthen the links between strong research evidence and the resources and teaching approaches that exemplify it.

Our work in science and mathematics education is part of a wider education programme. Other priority areas for us include *Foundations for learning*, focusing on the early years; *Secondary education transitions*, examining the significance and impact of transitions into, through and out of secondary education; and *Women's education and student parents*, aimed at improving opportunities for access and support to education.

Science and mathematics for all

The Foundation is committed to supporting education projects that ensure all young people develop the understanding and skills required to play an informed role in society. This commitment is evident in the philosophy of projects such as *Twenty First Century Science*. It is an approach that requires the provision of different pathways appropriate for different students' needs.

Similarly, the Foundation is currently advancing the case for wider participation in post-16 mathematics. Trustees have awarded a grant to Dr Jeremy Hodgen for a follow-up study to *Is the UK an outlier?*, and we have recently published findings from a project to examine the mathematical content of A level assessments in six subjects (alongside a similar project by SCORE). Trustees are also keen to promote mathematical and statistical thinking in social sciences and in the wider world, for example, through support of projects such as the Royal Statistical Society's *getstats* campaign.

Working in partnership

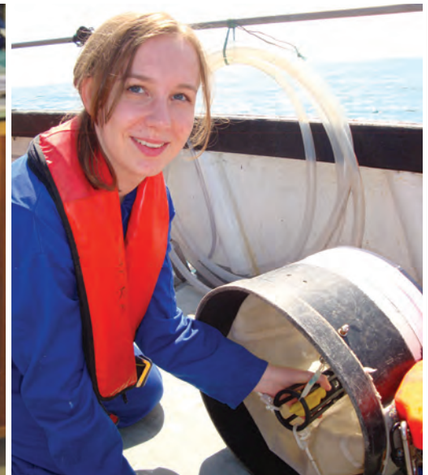
From the roll-out of the Science Teaching Project, to the development of three practical science websites, the Foundation has always sought to increase its expertise and impact through collaboration with others. A recent drive to disseminate and embed our education projects in schools and colleges has involved forming partnerships with the Science Learning Centres, Teach First, the National Centre for Excellence in the Teaching of Mathematics, and the Centre for the Use of Research and Evidence in Education.

Widening participation in STEM:
Science Bursaries for Schools & Colleges

Nuffield Science Bursaries provide opportunities for school and college students to take part in STEM-related research in their summer holidays. We offer about 1,000 bursaries a year, for students to work alongside professional scientists, technologists, engineers and mathematicians. Placements are provided across the UK by universities, research institutions, commercial companies and charities.

The programme actively encourages a wider uptake of science and mathematics in higher education, working with partners to reach students from groups that have previously been under-represented. Our aim is to provide students from less advantaged backgrounds with appropriate support to compete for a bursary placement and to take full advantage of the opportunity.

We are working with *Teach First Higher Education Access Programme for Schools*, which links mentors with sixth form students, and the *Realising Opportunities* programme, run by a group of research intensive universities. We are also working with the Brightside Trust to develop a mentoring programme combining face-to-face and web-based support.



Timeline

More information about all these projects, including details of their development and links to available resources, can be found in our online archive at **www.nuffieldfoundation.org**

1962 Minister of Education, Sir David Eccles, announces the Nuffield Foundation will grant £250,000 towards a programme to improve science and mathematics teaching.

Nuffield Primary Mathematics applies the philosophy of 'I do and I understand.' First edition sells over one million copies.

1963 O level courses in *Biology*, *Chemistry* and *Physics*.

Nuffield Junior Science advocates practical experiences in science.

1964 Teaching methods from the *Science Teaching Project* are applied to modern languages and the *Cambridge School Classics Project*.

1965 The *Humanities Curriculum Project*, funded jointly with the Schools Council.

Nuffield Combined Science provides comprehensive science education for 11- to 13-year-olds.

1966 First German publications from the *Nuffield Languages Project*.

1967 Publication of the French course, *Tricolore*. Its descendent, *Encore Tricolore*, lives on today.

1968 *Nuffield Secondary Science* provides ideas and materials for teachers to construct their own CSE courses.

1969 A levels in *Biology*, *Chemistry* and *Physics* enable different examining groups to determine the form and content of the assessment scheme. Revised editions were published between 1985 and 2000.

1970 A level *Physical Science* combines common areas of chemistry and physics but fails to convince medical schools that it offers a viable alternative to pure chemistry.

1971 *Teaching Primary Science* is designed for teachers with little background knowledge in science.

1972 Launch of the Russian course, *Novaya Iskra*, which is still in use today.

1973 *Nuffield Working with Science* offers a series of applied science resources in response to the raising of the school leaving age in 1972.

1974 *Nuffield Science 13-16* provides a modular, integrated science course for comprehensive schools.

1975 *Nuffield Mathematics 5 -11* succeeds *Nuffield Primary Mathematics*.

1976 *Nuffield Home Economics* encourages a scientific, investigative approach to technology education.

1977 *Nuffield Co-ordinated Sciences* meets new requirements for all pupils to spend 20 per cent of their curriculum time doing science.

1978 *Nuffield 11-13* succeeds *Nuffield Combined Science* and is revised as *Nuffield Science for Key Stage 3* in 1990.

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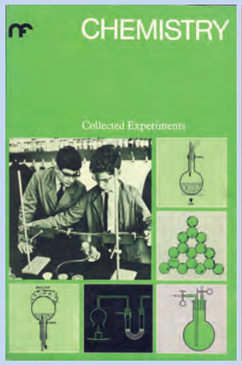
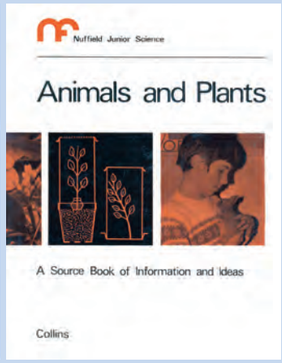
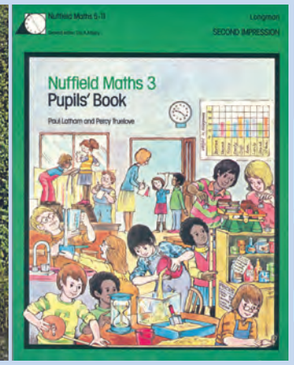
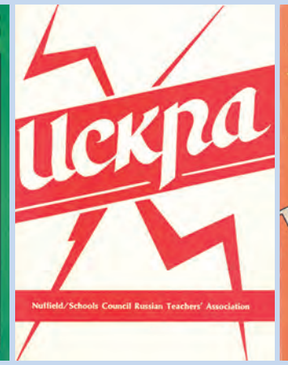








Timeline continued...

Pathways through Science offers differentiation in a double-award GCSE science course.

Nuffield Advanced Mathematics exploits the power of programmable calculators and computers, but few schools adopt the course.

Nuffield Science in Practice resources support GNVQ courses in schools and colleges.

Nuffield Advanced Economics and Business aims to make the subject accessible, and rooted in practice.

Nuffield Primary History offers resources based on seven key principles for teaching and learning history.

Science for Public Understanding AS level course applies the principles of *Beyond 2000*.

www.practicalphysics.org, developed in partnership with the Institute of Physics, provides practical protocols and guidance for teachers and technicians.

Twenty First Century Science GCSE post-pilot resources published, exemplifying the multi-pathway approach recommended in *Beyond 2000*.

www.practicalchemistry.org launched in partnership with the Royal Society of Chemistry (RSC).

Publication of resources to support A level *Extended Project Qualifications* (EPQs) in partnership with Gatsby Technical Education Projects.

Two Nuffield STEM projects, *Games* and *Futures*, enable 11- to 14-year-olds to apply STEM knowledge and skills to solve topical problems.

Evidence-informed approaches to science practical work are piloted.

A report on the mathematical content of A level assessments in six subjects shows significant variation in their quantitative content, even within the same subject.

1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Nuffield Secondary Mathematics provides a step-by-step ladder of achievement from any starting point.

Nuffield Primary Science provides materials based on research into children's ideas about science.

Nuffield Secondary Design and Technology offers a new approach, which is subsequently incorporated into the National Curriculum.

Beyond 2000: Science education for the future, argues that the science curriculum should be designed to develop the scientific literacy of future citizens.

Free-Standing Mathematics Qualifications and AS level *Use of Mathematics* provide post-16 mathematics to support study in other subjects.

Nuffield Design and Technology is extended to primary schools.

Salters-Nuffield Advanced Biology uses realistic contexts to engage students with biological principles.

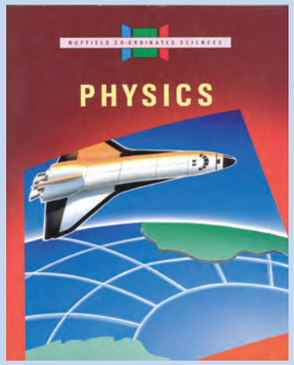
www.practicalbiology.org launched in partnership with the Society of Biology.

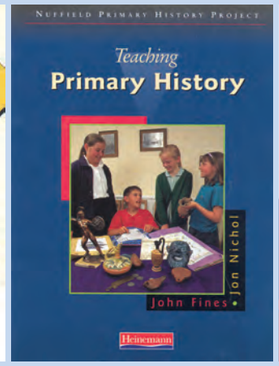
The former *Science for Public Understanding* is launched as a full A level course, *Science in Society*.

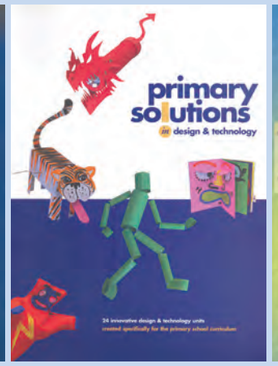
Learning Skills for Science is adapted for post-16 courses following collaboration with the Gatsby Science Enhancement Programme (SEP).

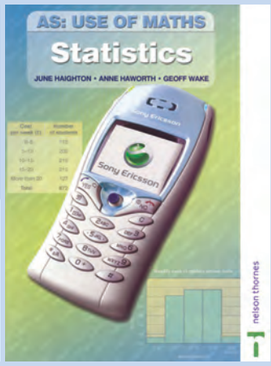
Applying Mathematical Processes (AMP) provides resources to support teachers in their teaching and assessment of key processes in secondary mathematics.

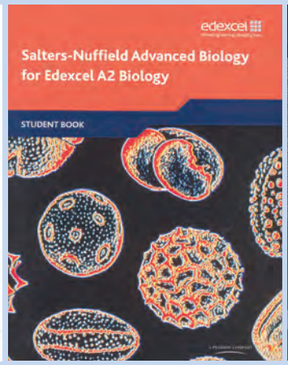
Is the UK an Outlier? An international comparison of upper secondary mathematics education shows that England, Wales and Northern Ireland have the lowest levels of participation in post-16 mathematics out of 24 countries surveyed.











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