Institution: University of York

Unit of Assessment: 25, Education

Title of case study: Improving scientific literacy and engagement with science

1. Summary of the impact (indicative maximum 100 words)

Twenty First Century Science (OCR Science A) is a research evidence-informed suite of GCSE courses developed by the Science Education Group at York from 2001-6. Following pilot trials and evaluation in 2003-6, it was adopted and continues to be used by over 1200 centres (schools and colleges) in England, thus having significant impact on the day-to-day practice of several thousand teachers and on over 120,000 students annually from 2006 to date. A survey of centres in 2008 (Millar, 2010), after the first post-pilot cohort completed their GCSE courses, indicated increases of between 25 and 38 percent in uptake of the three main sciences at AS-level, over three times the national increase observed that year. The core GCSE Science course is unique internationally in addressing explicitly the widely accepted policy objective of improving 'scientific literacy'. As a result, *Twenty First Century Science* has influenced science curriculum policy discussions and debates in the UK and internationally.

2. Underpinning research (indicative maximum 500 words)

A series of studies (including refs. 1 and 3 below) was undertaken from 1993 onwards by staff at York (Bennett (formerly Ramsden) (Lecturer, SL, Professor: 1988-to date); Campbell (SL: 1978-2005); Holman (Professor: 2002-5); Lazonby (SL: 1972-8); Millar (SL, Professor: 1982-to date)), investigating the impact on student learning, and on students' and teachers' attitudes and views, of context-led (or context-based) approaches to the teaching of science at secondary school level. This research programme built upon formative evaluation studies of a series of innovative science curricula previously developed by the University of York Science Education Group, with funding from the Salters' Institute and other sponsors. These studies, in line with similar work carried out internationally, provided a body of evidence showing that a context-led approach to the teaching of science increased the interest and engagement of many students, improved understanding of applications of science, and achieved a level of understanding of fundamental science concepts similar to more conventional courses.

A series of research seminars funded by the Nuffield Foundation in 1996-8, co-directed by Millar, led to the influential *Beyond 2000* report (ref. 2 below), which made the case for a stronger emphasis in the 5-16 curriculum on the 'scientific literacy' of all students, and a more flexible 'Core-plus-Additional science' curriculum structure to provide this core element whilst also improving progression routes to more advanced academic and applied courses in the sciences.

The development of *Twenty First Century Science* from 2002-6, with funding from the Nuffield Foundation, the Wellcome Trust and the Salters' Institute, involved the transformation of knowledge obtained from research into forms that can impact directly on practice: research-informed courses and teaching materials, and their trialling and formative evaluation (ref. 5 below). The content of these courses was also informed by research on stakeholders' views on what should be taught 'about science' (ref. 4) and by systematic reviews (carried out by Bennett (details above); Hogarth (Research Fellow: 2001-2009); Lubben (Research Fellow, 1991-to date); Torgerson (Research Fellow, Reader 2001-2010)) of the evidence of impact of context-based science courses and small-group discussion (ref. 6 below). The implementation and research evaluation of the pilot trial of the *Twenty First Century Science* suite of GCSE courses provided evidence that led the Qualifications and Curriculum Authority (QCA) to require that all GCSE science courses from 2006 have a Core-plus-Additional Science structure.

3. References to the research (indicative maximum of six references)

Underpinning research:
1 Ramsden, J.M. (1997). How does a context-based approach influence understanding of key

chemical ideas at 16+? International Journal of Science Education, 19 (6), 697-710. DOI:10.1080/0950069970190606
2 Millar, R., & Osborne, J. (1998). *Beyond 2000. Science education for the future.* London: School of Education, King's College London. http://www.nuffieldfoundation.org/sites/default/files/Beyond%202000.pdf
3 Bennett, J., & Holman, J. (2002). Context-based approaches to the teaching of chemistry: What are they and what are their effects? In J. Gilbert (Ed.), *Chemical education research-based practice.* Dordrecht: Kluwer Academic Publishers. *Available on request.*
4 Osborne, J., Ratcliffe, M., Collins, S., Millar, R., & Duschl, R. (2003). What 'ideas-about-science' should be taught in school science? A Delphi study of the 'expert' community. *Journal of Research in Science Teaching,* 40 (7), 692-720. DOI: 10.1002/tea.10105
5 Millar, R. (2006). *Twenty First Century Science*: Insights from the design and implementation of a scientific literacy approach in school science. *International Journal of Science Education*, 28 (13), 1499-1521. DOI: 10.1080/09500690600718344
6 Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, 91 (3), 347-370. DOI: 10.1002/sce.20186

Evidence of the quality of the research:
The research reported in outputs 1 and 3 is original in that it explores the effects of the first context-led course in science to have been developed and implemented at national level in any country. One was published in a leading international peer reviewed research journal, the other in a peer-reviewed international collection of research articles.

Output 2 has been widely cited in the UK and in other countries by researchers, curriculum developers and policymakers. As of August 2013 it has over 900 citations on Google Scholar.

Output 4 was awarded the 2003 prize of the US National Association for Research in Science Teaching (NARST) for the 'most significant contribution' in that year to the *Journal of Research in Science Teaching*, the science education journal with the highest impact factor. It currently (August 2013) has over 400 citations on Google Scholar.

Output 5 is published in a leading international peer-reviewed research journal. It is original in setting out the design rationale for a science course with a distinctive scientific literacy emphasis. It also reports on the development and implementation of a course based on this design.

Output 6 is published in a leading international peer-reviewed research journal. It was the first article published in a science education journal reporting the findings of an EPPI-style systematic review.

4. Details of the impact (indicative maximum 750 words)

The research outlined above was used to underpin and inform the development of an inter-related suite of GCSE courses. This development work involved the transformation of knowledge from the series of research studies summarised in section 2 above, and from syntheses and evaluations by York staff of relevant research carried out by science educators internationally, into the form of a fully documented curriculum package with a supporting in-service training programme for users. This was published by Oxford University Press. These new and significantly improved teaching materials included the first example (internationally) of a mainstream science course for the 14-16 age range with a clear scientific literacy emphasis, based on a clear and explicit rationale. Making this a component of a suite of inter-related GCSE courses showed how 'science for all' could be provided alongside 'science for future specialisation'. This had not previously been implemented in any other country. The development work was carried out by staff in the Centre for Research and Innovation in Science Education (CIRSE) at York, in collaboration with the Nuffield Curriculum Centre. It involved close collaboration with practising teachers, and with scientists. The work was made possible by grants from the Nuffield Foundation (£600k), Wellcome Trust (£330k) and Salters' Institute (£200k). The first was held jointly (50:50) with the Nuffield Curriculum Centre, the

others entirely by CIRSE.

Following pilot trials in 2003-6, *Twenty First Century Science* (OCR Science A) was one of four suites of GCSE science specifications offered to schools following the regulatory changes implemented in 2006, and still in use. It was adopted by 23% of maintained schools in England (1200 centres; over 120,000 students each year), which is the highest market share ever achieved by any 'project' specification at GCSE or A-level, in competition with more 'traditional' alternatives. The principal impact since 2008 of the research and development programme that led to *Twenty First Century Science* has therefore been on the experience of school science of over half a million young people, and their teachers. Evaluation studies during the pilot trial (2003-6) (including ref. 5 above) provided clear evidence of increased engagement of students with science in many pilot centres, which was attributed by teachers to the clearer and stronger links between course content and science issues that students hear about outside school, and the greater emphasis on evaluation of knowledge claims and discussion of science-related issues throughout the courses. Teachers using *Twenty First Century Science* continue to report enhanced student engagement and interest in science (see, for example, Reynolds, section 5).

The teaching materials for *Twenty First Century Science* consist of 10 textbooks, 8 teacher and technician resource packs, and over 20 workbooks and revision guides, all with separate ISBNs, supported by dedicated computer-based materials. From 2008 to date, over 600,000 copies of these publications have been purchased, including 234,427 student textbooks.

The regulatory requirement that the distribution of GCSE grades awarded for any specification is normalised against baseline data on the prior attainment at Key Stage 3 of the cohort of students taking that specification means that any overall enhancement of student learning as a result of using *Twenty First Century Science* will not be reflected in the distribution of grades awarded. Students' subsequent subject choices are therefore a better indicator of impact. A survey of centres using *Twenty First Century Science* carried out in 2008 just after the first post-pilot cohort had completed the *Twenty First Century Science* courses found increases of between 25 and 38 percent in uptake of the three main sciences at AS-level, as compared to national increases of 8-10% in the same school year (reported in: Millar, R. (2010). Increasing participation in science beyond GCSE: The impact of *Twenty First Century Science*. *School Science Review*, 91 (337), 41-47). These findings are corroborated by an independent study by Homer, Ryder and Donnelly (2010) of the impact of the 2006 curriculum changes on students' science subject choices. Increasing uptake of post-GCSE science courses is widely seen (for example, by government and by the professional organisations representing the science community) as a key policy objective in the UK. These studies provide clear evidence that this research and development work has had a significant impact on post-GCSE student participation in the sciences.

The success of the *Twenty First Century Science* curriculum model during the pilot led QCA to require that all science GCSEs from 2006 should be structured on the 'core + additional' model, replacing the previous 'double award science' model. This was a clear and distinctive impact on national policy regarding the structure of the science curriculum at Key Stage 4, which arose primarily from this research and development work.

The successful implementation of a school science course with a scientific literacy emphasis has stimulated discussion of science curriculum policy in the UK and more widely. Millar was listed in 2010 in *The Times* Eureka 100 list of influential figures in UK science, the citation highlighting his role in implementing the recommendations of the *Beyond 2000* report through the *Twenty First Century Science* project.

The assessment framework for the Organisation for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA) science assessments in 2006, 2009 and 2012 (OECD, 2009: 130 (Figure 3.1)) was initially proposed by Millar at a PISA Forum meeting in 2002, and is based directly on the design framework of the scientific literacy course in *Twenty First Century Science*.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Impact on classroom practice and students' experience of school science:

OCR (2013). *Science A (Twenty First Century Science suite). Specifications for Science, Additional Science, Additional Applied Science, Biology, Chemistry, Physics.* Retrieved August 29, 2013 from: www.ocr.org.uk/qualifications/by-subject/science/

OCR (2013). Provisional Examination Statistics, June 2013. Retrieved August 29, 2013 from www.ocr.org.uk/Images/142194-provisional-exam-statistics-june-2013.pdf
Candidate numbers for the components of the *Twenty First Century Science* GCSE suite are shown under: Additional Applied Science, Additional Science A, Biology A, Chemistry A, Physics A, and Science A.
Similar data for previous years (back to 2010) are available from: www.ocr.org.uk/ocr-for/exams-officers/results/results-statistics/

A report corroborating the sales data for *Twenty First Century Science* textbooks is available, along with user feedback collected by Oxford University Press. Further information on sales can be provided by: Oxford University Press, Education Division

Reynolds, H. (2008). Some positive thoughts on the new KS4 curriculum. Teaching the physics in 21C Science. *Institute of Physics Education Group Newsletter,* 1, 6-8.
[An example of an unsolicited account by a teacher of the impact of a *Twenty First Century Science* module on her students' understanding and engagement with science.]

Impact on students' subsequent subject choices:

Homer, M., Ryder, J., & Donnelly, J. (2010). *The progression of Twenty First Century Science students to AS-level science qualifications.* Research report for the Nuffield Foundation. Leeds: Centre for Studies in Science and Mathematics Education.
[Analysis of progression to AS-level sciences, using the National Pupil Database.]

Impact on discussion and debates about science curriculum policy:

Corroboration of claims of impact on science curriculum discussions and policy in the UK can be provided by:

- Chief Executive, Association for Science Education;
- Director (former) of the Nuffield Foundation.

OECD (2009). *Programme for International Student Assessment. PISA 2009 Assessment Framework. Key competencies in reading, mathematics and science.* Paris: OECD. Retrieved August 29, 2013 from: www.oecd.org/pisa/pisaproducts/44455820.pdf

Bybee, R., & McCrae, B. (2009). Scientific literacy: Implications of PISA Science 2006 for teachers and teaching. In R. Bybee & B. McCrae (Eds.) *PISA Science 2006. Implications for science teachers and teaching* (pp. 227-247). Arlington, VA: NSTA Press.
[On p. 229, the authors (the Chair of the PISA Science Expert Group from 2003-12 and the PISA Project Manager for the 2003-2012 surveys) acknowledge and discuss the relationship between *Twenty First Century Science* and the PISA assessment framework.]