Institution: King's College London

Unit of Assessment: UoA25 (Education)

Title of case study: Curriculum and Assessment in Science Education

1. Summary of the impact

The research undertaken by Jonathan Osborne and colleagues in science education at King's has contributed substantially to contemporary curriculum and assessment policy and practice both in the UK and internationally. This programme of research has directly influenced: the Nuffield/OCR 'Twenty First Century Science' curriculum, currently offered by around 1000 schools in England and Wales; the emphasis on 'how science works' in the English and Welsh science curriculum; the US Framework for K-12 science education published in 2012 with its new emphasis on scientific practices; and the framework being used as a basis for the OECD Assessment of Science by the Programme for International Student Achievement (PISA) which will be administered in 70 countries in 2015.

2. Underpinning research [Numbers in brackets refer to references in Section 3.]

The case for change in how science is taught and assessed has been made by a substantial programme of research over a 15 year period, beginning in 1998 with a report for the Nuffield Foundation [11] and an ESRC study undertaken as part of the ESRC's Public Understanding of Science Programme [1], which argued for the importance of understanding basic features of the nature of science in contemporary society. Enduring concerns in the late 1990s about low levels of student engagement with school science led to further research into the factors underlying low levels of participation and engagement in science [2]. This programme of research has demonstrated the importance for all students of understanding basic features of the nature of science in contemporary society [6], has shown how this can be taught and assessed [3, 5, 7, 8] and has provided evidence to support the introduction of new science curricula and assessment practices [4].

The key findings from the programme of work are as follows:

1. Student engagement and participation in science education are strongly influenced by what science is taught, and how it is taught and assessed. Substantial qualitative evidence from students and parents, together with a major review of students' attitudes, demonstrated that the authoritative and content-based nature of the school science curriculum was alienating large numbers of students, in particular girls, and identified the major factors influencing students' attitudes to science [2, 3, 14]. A large-scale quantitative and qualitative study has extended this finding by demonstrating that a critical factor in low levels of student engagement and participation is that students are not taught about what scientists do and what science careers involve [9].
2. Argument is a fundamental feature both of science and of the learning of science. The research of Osborne and his colleagues has provided strong arguments and empirical evidence for the explicit inclusion of argumentation in the school curriculum. [1, 6, 12]
3. Argumentation can be successfully taught in science classrooms. Specifically, the researchers used research-based exemplifications of classroom teaching to show how argumentation can be implemented within the curriculum [3, 7], and they demonstrated the effectiveness of teaching argumentation, showing that the new approaches they developed led to improvements in how students argue and reason scientifically [16].
4. It is possible to assess students' understanding of the nature of science in the curriculum. The research led to the development of a body of innovative questions which were shown to have good discrimination and facility and which could be used for testing students' understanding of

how science works. [5, 10, 13]

5. There is substantial support amongst a wide range of stakeholders for the value of teaching about features of science other than just its content, such as argumentation and how science works. [4,15]

The research has also provided evidence of how argumentation can be implemented in schools through professional development and effective leadership within school science departments [8].

3. References to the research

Supporting grants

[1] Osborne (PI) (1998-1999). *ESRC Fellowship (Public Understanding of Science Programme)*. ESRC (L485274015): £16,743.
[2] Driver (PI), Osborne (1997-2001). *Pupils', parents' and teachers ' views of the school science curriculum and its contribution to the public understanding and appreciation of science*. Wellcome Trust: £89,500.
[3] Osborne (PI), Simon, Monk (1999-2002). *Enhancing the Quality of Argument in Science Lessons*. ESRC (R000237915): £151,096.
[4] Millar (PI), Leach, Osborne, Ratcliffe (2000-2003). *Towards Evidence Based Practice in Science Education*. ESRC Teaching and Learning Programme (L139251003): £450,000.
[5] Osborne (PI), Ratcliffe (2000). *Developing Assessment Methods for Keeping National Curriculum Science in Step with the Changing World of the 21st Century*. Qualifications & Curriculum Authority: £19,200.
[6] Osborne (PI), Ratcliffe (2000). *A Review of the Need to Keep the Science Curriculum up-to-date with the needs of the 21st Century*. Qualifications & Curriculum Authority: £5,800.
[7] Osborne (PI), Simon, Erduran (2002). *IDEAs project: Ideas and Evidence in Science Education*. Nuffield Foundation (EDU / 00302/ G): £62,900.
[8] Osborne, Simon (2008-2010). *Talking to Learn, Learning to Talk*. ESRC (RES-061-25-0090): £484,000.
[9] Archer (PI), Osborne, Dillon (2009-2014). *Science Careers and Aspirations: Age 10-14*. ESRC (RES-179-25-0008): £787,999.
[10] Wilson (PI), Osborne (2010-present). *Learning Progressions in Middle School Science Instruction and Assessment*. Institute for Educational Studies: $352,391.

Key peer-reviewed publications: [hard copies are available on request]

[11] Millar, R., & Osborne, J. F. (Eds.). (1998). *Beyond 2000: Science Education for the Future*. London: King's College London.
[12] Driver, R., Newton, P., & Osborne, J. F. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84* (3), 287-312. Doi: 10.1002/(SICI)1098-237X(200005)
[13] Osborne, J. F., & Ratcliffe, M. (2002). Developing effective methods of assessing ideas and evidence. *School Science Review, 83* (305), 113-123.
[14] Osborne, J. F., Simon, S., & Collins, S. (2003). Attitudes towards Science: A Review of the Literature and its Implications. *International Journal of Science Education, 25* (9), 1049–1079. Doi: 10.1080/0950069032000032199
[15] Osborne, J. F., 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
[16] Osborne, J. F., Erduran, S., & Simon, S. (2004). Enhancing the Quality of Argument in School Science. *Journal of Research in Science Teaching, 41* (10), 994-1020.

4. Details of the impact [Numbers in brackets refer to references and sources in Sections 3 & 5.]

The research underpinning this case study has had a direct and significant impact on what science is taught, how it is taught and how it is assessed, and specifically on curriculum development and delivery in England and Wales; on curriculum standards in the US; and on international assessment in science by the OECD. These developments have resulted in a greater emphasis on teaching the nature of the discipline and how science works than was previously the case and have helped to shift the terms of the international 'policy conversation' on science education about what it means to offer a challenging and engaging science education which meets the needs of all learners.

In England and Wales the Nuffield *Beyond 2000* report [11] laid the foundation for a new curriculum course, funded by the OCR examination board and supported by the Nuffield Curriculum Centre, called 'Twenty First Century Science' [23]. Twenty First Century Science is a suite of GCSE courses that consists of six inter-related GCSE courses: GCSE Science, GCSE Additional Science, GCSE Additional Applied Science, GCSE Biology, GCSE Chemistry and GCSE Physics. Around 1,000 schools (more than 25% or all secondary schools) in England and Wales now offer this course. In line with the recommendations of *Beyond 2000*, the course resolves the tension between educating the future citizen and the future scientist by providing a broad overview of what we know and how science works. Additional courses are offered for those wanting to specialise in science. The course was developed by a project team based at York University, which was led by Robin Millar, co-author of *Beyond 2000* [11]. Originally published by OUP in 2006-7, second editions of the course materials were produced in 2011. The success of the trials of this program contributed to changes in the national curriculum for science, with an innovative element called 'How science works', supported by video materials for teachers' professional development produced by Osborne and colleagues [18], becoming a prominent feature of the curriculum from 2006 onwards. This included new requirements, introduced on the advice of Osborne and colleagues, that students be taught about 'data, theories and explanations', 'communication skills' and 'applications and implications of science', as a result of which students in classrooms throughout the period from 2006/7 to 2013/14 have been exposed to a science curriculum that is very different from that experienced by previous cohorts.

The program of work on argumentation has also had an impact on the US National Academies 'Framework for K-12 science education' published in 2012. This document forms the basis of the US Next Generation Science Standards which were released in May 2013. Osborne was responsible for leading on the chapter on the need to teach students about scientific practices [21], which placed the role of argumentation and evidence very much at the core of the framework's vision and model of good practice in science education. Consequently, the new US standards for the science curriculum now require students to be taught how to engage in argument from evidence in science and it will be a feature of their assessment [25]. These standards are currently being adopted for all stages of K-12 education in 26 states and another 14 are considering their adoption [25]. 51 businesses including Bayer, IBM and Hitachi, have signed a statement that says: 'We support the Next Generation Science Standards…These standards will provide all students with a coherent and content-rich science education that will prepare them for college and careers' [26].

On the international stage Osborne is chair of the expert group that has been responsible for drafting the now agreed framework for the 2015 OECD PISA assessment in science for 15-year old students. Science will be the major focus of PISA in 2015 and, given the policy importance of the PISA tests, the influence of this framework on the national science curricula in the 76 participating countries is expected to be substantial. The 2015 framework, which defines what the 2015 PISA exercise will assess in science, is significantly different from the framework used in 2006 (when science was last the major focus of PISA). The 2015 framework takes a 'literacy-based' view of science education that – analogous to the teaching of English literacy – balances the importance of knowing the content of science with developing students' competency to evaluate scientific evidence, claims and arguments. PISA sees the latter as dependent on knowledge of the procedures and epistemic features of science which Osborne's research [11, 14] (cited in the framework document [22]) has contributed to describing and assessing. The focus on scientific literacy and the teaching of the epistemic and procedural features of science which promotes the understanding of science as a distinct discipline is a significant departure from the authoritative and content-focused way science has been taught to date in most countries.

The impact described in this section has been achieved in several ways. First, Osborne and colleagues have not only addressed an enduring and substantive research problem of concern to science education, but they have also investigated how change could be effected [e.g., 4] and to do so collaborated with policy-makers and practitioners [e.g., 11]. Second, Osborne has directly engaged in the development of curriculum and assessment policy and practice in the UK, in the US and internationally. His contributions include leading on the development of policy (e.g., as Chair of PISA's expert group), producing commissioned and focused guidance [e.g., 17], providing ad-hoc and ongoing advice (e.g. on the development and implementation of the National Curriculum in England) and leading seminars bringing together academics and users. Third, Osborne and colleagues have produced exemplars of classroom practice [e.g., 18], of innovative assessment items [e.g. 5], and shown how argumentation can be implemented in the classroom [e.g., 16, 18]. Fourth, building on research on the nature of evidence-based practice [e.g., 4], Osborne and colleagues have 'translated' the research for a range of stakeholder audiences, making the case for change and showing how the change could be implemented at national and local levels. These stakeholder audiences include policy-makers [e.g., 11], scientists [e.g., 20], and teachers [e.g., 18].

5. Sources to corroborate the impact

Documents and webpages: [hard copies are available on request]

[17] Osborne, J & Ratcliffe, M (2002). *Feasibility study: Assessment*. Commissioned by QCA, Unpublished.
[18] Osborne, J. F., Erduran, S., & Simon, S. (2004). *Ideas, Evidence & Argument in Science Education: A CPD Pack*. London: King's College London.
[19] *Science National Curriculum for England and Wales: 2004 Revision*. [Implemented 2006.]
[20] Osborne, J. F. (2010). Arguing to Learn in Science: The Role of Collaborative, Critical Discourse. *Science, 328*, 463-466.
[21] US National Academies of Science: Committee on a Conceptual Framework for New K-12 Science Education Standards. (2012). *A framework for K-12 Science Education*. Washington, DC: National Academies Press. Chapter 3 Dimension 1: Scientific and Engineering Practices: http://www.nap.edu/openbook.php?record_id=13165&page=41
[22] PISA 2015 Draft Science Framework: http://www.oecd.org/pisa/pisaproducts/pisa2015draftframeworks.htm
[23] http://www.nuffieldfoundation.org/twenty-first-century-science/rationale
[24] http://www.azteachscience.co.uk/ext/cpd/argumentation/index.php
[25] http://www.nextgenscience.org/search-performance-expectations?tid%5B%5D=32
[26] http://www.nextgenscience.org/business-community-support

Individuals:

Former Curriculum Officer for Science with the Qualifications and Curriculum Authority in England and Wales. [Curriculum and qualifications in England and Wales.]
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