Institution: University of Leeds

Unit of Assessment: 25

Title of case study: Case Study 2: Improving the teaching and learning of conceptual scientific content in schools.

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

This longstanding research and development programme on teaching and learning conceptual scientific content has resulted in beneficial impacts on the day-to-day teaching practices of secondary school science teachers within and beyond the UK. The programme has resulted in three broad areas of impact:

1. the content of curriculum materials used by teachers of physics, chemistry and biology in their practice;
2. the initial training of science teachers;
3. professional development programmes for science teachers.

2. Underpinning research (indicative maximum 500 words)

The underpinning research has three components: (a) empirical evidence about science learners' characteristic ways of understanding newly-introduced conceptual content; (b) a theoretical perspective on designing teaching to promote conceptual learning in science in classrooms; and (c) a perspective on teacher-student interaction that is underpinned by empirical studies of science classrooms.

Since the 1970s there has been an international research programme to document science learners' characteristic ways of thinking about natural phenomena. The University of Leeds has pioneered several studies to provide evidence about learners' explanations of the phenomena typically encountered in science classrooms, and how these change as a result of teaching. Areas of curriculum content that are particularly difficult to teach and learn were thereby identified (component a). Drawing upon this empirical evidence, a social constructivist perspective on teaching and learning science content in classrooms was developed. 'Learning demand' was proposed as a design tool to characterise the precise difficulties of teaching and learning specific conceptual content in science (component b). Work from components (a) and (b) are presented in the position paper **[1]**, review article **[2]** and book **[3]**.

Within component (c) the focus is on the ways in which teacher talk in the school science classroom can support students in developing understandings consistent with the accepted scientific viewpoint. This work is presented in a book **[4]**. This book provides a theoretically-grounded characterisation of the goals and structures of teacher talk likely to support the development of students' conceptual understanding. A particular focus is on the characterisation of distinct 'communicative approaches' involving teachers and students. The framework presented in this book has been applied in a range of authentic school settings **[5]**. More recent studies have extended this work to focus on the ways in which teachers and students make connections between ideas during extended teaching and learning sequences **[6]**.

The research insights presented above were developed through a series of research grants based at Leeds. **[RG1]** and **[RG3]** supported research which evidenced enhanced student learning when following teaching interventions designed to address 'learning demands' through 'communicative approaches' better matched to teaching purposes. **[RG6]** and **[RG8]** supported research which evidenced the positive impact on teachers' practice of continuing professional development (CPD) activities based upon the practical application of 'learning demand' and 'communicative approach'.

Research **[3]** introduces the notion of *research evidence-informed practice*, or practice that arises when materials or training incorporate insights or evidence from research. Materials to promote research evidence-informed practice were developed for science teaching **[RG1,3,4,5,7,8]**, initial science teacher training **[RG2,7]**, and CPD for science teachers **[RG2,4,5, 7]**.

Members of the research team involved in developing these outputs in the School of Education at

the University of Leeds include: Dr Jaume Ametller (University of Leeds 2003-2012, now a visiting fellow), Professor John Leach (University of Leeds 1990-2010, now a visiting chair), Dr Jenny Lewis (University of Leeds 1994-2012), Professor Phil Scott (University of Leeds 1988-2011), and Professor Jim Ryder (University of Leeds 1994-present). Another key collaborator was Professor Eduardo Mortimer (based at UFMG, Brazil).

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

[1] Driver, R., Asoko, H., Leach, J., Mortimer, E. and Scott, P. (1994) Constructing Scientific Knowledge in the Classroom. *Educational Researcher*, 23(7), 5-12. All University of Leeds authors, with the exception of Mortimer DOI:10.3102/0013189X023007005.

[2] Leach, J. and Scott, P. (2002) Designing and evaluating science teaching sequences: an approach drawing upon the concept of learning demand and a social constructivist perspective on learning. *Studies in Science Education*, 38(1), 115-142. DOI:10.1080/03057260208560189. **Output in RAE 2008 (rated 3 star)**

[3] Scott, P., Leach, J., Hind, A. and Lewis, J. (2006) Designing research evidence-informed teaching sequences. In: R. Millar, J. Leach, J. Osborne and M. Ratcliffe, *Improving subject teaching: Lessons from research in science education.* London: Routledge. All University of Leeds authors. **Output in RAE 2008 (rated 3 star)**

[4] Mortimer, E. and Scott, P. (2003) *Meaning Making in Secondary Science Classrooms.* 141pp. Buckingham, UK: Open University Press**.** Mortimer and Scott co-authors. **Output in RAE 2008 (rated 4 star)**

[5] Scott, P., Ametller, J., Mortimer, E. and Emberton, J. (2010) Teaching and Learning Disciplinary Knowledge: Developing the dialogic space for an answer when there isn't even a question. In: Karen Littleton and Christine Howe (Eds.). *Understanding and promoting productive interactions,* London Routledge. Emberton local teacher.

[6] Scott, P., Mortimer, E. and Ametller, J. (2011) Pedagogical link making: A fundamental aspect of teaching and learning scientific conceptual knowledge. *Studies in Science Education*, 47(1), pp. 3-36. DOI:10.1080/03057267.2011.549619. Scott as lead author.

Relevant Research Grants

[RG1] 2000-03: ESRC: *Evidence-based practice in science education: Improving learning through research-based teaching*. Involving Ametller, Leach, Lewis and Scott. £450,000; £120,000 to University of Leeds.

[RG2] 2002-2004: Institute of Physics (IoP) funded: *Supporting Physics Teaching 11-14*. Involving Scott and Ryder, at University of Leeds, and a consortium of collaborators from other universities in the UK. £80,000.

[RG3] 2005-07: ESRC: *Dialogic Teaching in Science Classrooms*. Involving Scott and Ametller, with Professor Neil Mercer (University of Cambridge). £135,256.

[RG4] 2007: DfES: *Interactive teaching in science classrooms*. Involving Ametller, Leach, Lewis, Ryder and Scott. £55,000.

[RG5] 2008: DfES: *Interactive teaching in science classrooms*. Involving Ametller, Leach, Lewis, Ryder and Scott. £11,500.

[RG6] 2009-10: Science Learning Centre Network: *Impact of focused CPD on teacher's subject and pedagogical knowledge and pupils' learning*. Involving Ametller and Scott. £50,000.

[RG7] 2009-11: Institute of Physics funded: *Supporting Physics Teaching: 14-16*. Involving Ryder and Scott, at Leeds, and a consortium of collaborators from other universities in the UK. This project finished before the planned date of 2012 due to the death of Phil Scott in July 2011. £45,000.

[RG8] 2009-12: EU funded Project: *Science Teacher Education Advanced Methods (S-TEAM): Dialogic inquiry and science teaching*. Involving Ametller and Scott. £88,620.

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

The above research programme has resulted in three broad areas of impact:

1.Content of curriculum materials used by physics, chemistry and biology teachers in their practice

The *Interactive Teaching in Science Classrooms* e-learning package was commissioned in 2007 by the then Department for Education and Skills (DfES) and made available through the National Strategy for Science in 2008. These research evidence-informed teaching schemes aimed to address major conceptual areas in physics, chemistry and biology for the 11-16 age range. The e-learning package incorporated lesson plans, teaching strategies and video exemplars which were underpinned by the research **[4]** and were funded by **[RG4]** and **[RG5].** Components a, b and c are evident throughout and the videos include Scott presenting the research insights. As an example, the Science Teaching Unit 'Forces in Motion' **[A]** uses the communicative approaches presented in Mortimer and Scott **[4]** throughout (as 'Dialogic Hotspots'), to guide teacher-student dialogue in the classroom.

These curriculum materials were disseminated to science teachers throughout England by National Strategy consultants and through the (then) DCSF website. A Senior Adviser for STEM/Science at the Secondary National Strategies stated: "The launch of 'Interactive teaching in science' was supported by national training for the 220 local authority science consultants who were in post at that time (…) the materials were very well received by both local authority and school colleagues and such was the effectiveness of the dissemination that demand outstripped availability." **[B]**

Although the National Strategies website closed in June 2011, a number of the popular teaching resources have remained accessible, and the materials remain available at the National Archive and the National STEM Centre (York) **[A]**.

2. The initial training of science teachers

The research was also instrumental for the Institute of Physics (IoP) and its Supporting Physics Teaching (SPT) project. In response to the chronic shortage of suitably qualified physics teachers in England, the IoP commissioned **[RG2, RG6, RG7]** with the aim to develop and distribute (with training) UK-wide DVDs of materials to support the teaching of physics to pupils aged 11-16 years, particularly for beginning science teachers.

Regarding the SPT materials, the significance of the research to their development and their subsequent impact, the Head of Education (Pre-19) from the Institute of Physics, states:
"The Institute of Physics has used the expertise of the members of the School of Education for at least the last ten years…The SPT materials were commissioned by the Institute and developed by a team that included Phil Scott and was co-led by him in the early stages….The SPT materials have been distributed to student teachers of science since 2006 (about 12,000 individuals) and some of the methods and pedagogy have been widely adopted by teacher trainers." **[C]**.

In addition, training courses are provided nationally for PGCE tutors and for other Continuing Professional Development (CPD) providers in the use of SPT materials. The IoP reports that the SPT materials form the basis of the approach of the Institute's Stimulating Physics Network (SPN), which has involved over 20,000 teacher-days of CPD to June 2012. Independent evaluation has shown that over 90% of participants in SPN training have modified their teaching as a result **[C]**.

3. Professional development programmes for science teachers

'Interactive approaches to teaching and learning forces' is a series of CPD workshops for practising teachers provided at the National Science Learning Centre (NSLC) in York, an organisation which engages with over 60% of secondary schools and post-16 colleges across the UK. During 2008-2010 there were six workshops involving groups of about 30 teachers, drawn nationally. In evidencing the role of the research insights drawn from the research projects **[RG1** and **RG3]** for these workshops, an Associate Director from the NSLC stated, "The research from the University of Leeds has not only informed the CPD experiences, there has also been direct input into courses and evaluation." **[D]**.

As evidence of the research changing practice, the evaluation of three of these workshops **[RG6]** indicates a significant and lasting impact on participant teachers' pedagogical content knowledge

and a positive impact on pupils' learning in comparison with outcomes from normal teaching **[D]**. As an example, in a 'Leading Assessment for Learning' course in 2010, the NSLC reported that "the teachers were very impressed with what [Scott] had discussed with them…Dialogic teaching is now being implemented more in schools as a result." **[D]**

Furthermore, the impact from this programme of research also has global reach. **[RG8]** (S-TEAM: Dialogic Inquiry and Science Teaching) is an EU funded project to develop effective CPD approaches to support interactive dialogic teaching of science concepts, and associated workshop materials are being disseminated internationally through the S-TEAM network and beyond.

During 2008-2011, the research team made 16 international key-note presentations to disseminate research findings and associated research evidence-informed materials to mixed audiences of researchers and practitioners (with 11 by Scott). In addition, Mortimer (co-author of outputs **[1]**, **[4]** and **[6]**) has made several presentations of the research (components b and c) to audiences of science teacher educators and teachers in Brazil. Arising from these presentations, various projects were started outside the UK, including, for example:

- Finland. An initial teacher education programme on teachers' talk in subject teaching.
- Norway. Approaches to analysing interactions in Norwegian classrooms.

Components (b) and (c) of the research programme have led directly to 6 doctoral studies, 4 of which completed during the assessment period. The doctoral students were based in 5 different countries and three of these former students now occupy positions of influence on in-country reform of school science education as government officials or teacher educators:

- Mohammed Alzaghibi, supervised by Leach and Lewis, completed a study on teaching/learning about plant nutrition in Saudi schools, 2010, and is currently working as a government officer in Saudi Arabia. Since returning to Saudi Arabia after graduation, he has held various senior positions where he has used work from strands (b) and (c) in the initial and in-service training of many hundreds of teachers. **[E]**
- Nur Jayhan Ahmad, supervised by Leach and Scott, completed a thesis examining a teaching sequence in the area of electrochemistry in Malaysia, 2010. She now works in the Regional Education Centre for Science And Mathematics (RECSAM) in Malaysia, which serves teachers in Indonesia, Brunei, Singapore, Thailand and other countries in the region. She has drawn upon insights from strands (b) and (c) in her development work with science teachers from the region.
- Gultekin Cakmakci, supervised by Leach and Donnelly, completed a thesis on the design and evaluation of a teaching sequence on chemical kinetics in Turkey, in 2005. He is now Associate Professor of Science Education at Hacettepe University, Turkey. He has drawn upon strands (b) and (c) to develop and evaluate teaching approaches in the area of chemical kinetics at university level in Turkey. He is now involved in a research study funded by the Scientific and Technological Research Council of Turkey which draws upon perspectives on teacher-student interaction (strand c) to support learning about the nature of science amongst students at grades 6-8. **[F]**

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

[A] webarchive.nationalarchives.gov.uk/20110809091832/http://www.teachingandlearningresources.org.uk/secondary/science.
[B] Testimonial from a Senior Adviser for STEM/Science at the Secondary National Strategies, available on request
[C] Testimonial from Head of Education, pre-19, Institute of Physics, available on request.
[D] Testimonial from Associate Director, National Science Learning Centre, available on request
[E] Testimonial from former doctoral student, now at the Ministry of Education, Saudi Arabia, available on request.
[F] Testimonial from Associate Professor of Science Education, Hacettepe University, Turkey, September 2013, available on request