Further information

Further information on the project, including full text of several articles and conference presentations aimed at both professional and academic audiences, can be downloaded from the EPSE Network website (address below). The teaching sequences developed in the project can also be downloaded free of charge from our website.

A discussion of the use of the teaching sequences by teachers involved in their development, and the outcomes of this, can be found in: Leach, J., Ametller, J., Hind, A., Lewis, J., & Scott, P. (2003). *Evidence-informed approaches to teaching science at junior high school level: Outcomes in terms of student learning*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (NARST), Philadelphia, March.

A TLRP 'gateway' book, in the *Improving Learning* series, is in preparation on the outcomes of all four EPSE Network projects and their implications for efforts to increase the impact of research on practice in science education. This will be published by RoutledgeFalmer, in 2004. Other articles for academic and professional journals on various aspects of the work are also planned.

The warrant

In the *Development Phase* of the study, we worked with a group of 9 teachers to develop three short teaching sequences (one physics, one chemistry, one biology). Each sequence focuses on key conceptual content in the secondary science curriculum, which research evidence suggests is particularly difficult for pupils to learn. The design of each teaching sequence was informed by research evidence about pupils' common difficulties and mistakes, and approaches to teaching the content that have previously been shown to be effective. In addition, drawing upon contemporary perspectives on science learning, guidance was built in to the teaching sequences about the *communicative approach* to be used by the teacher in working with pupils.

Each teacher implemented the teaching sequences. All the lessons were video-recorded.The video-recordings were analysed to monitor the treatment of content and the communicative approach. We evaluated pupils' understanding before and after teaching, using diagnostic questions. We administered the same tests to similar classes of pupils in the same schools, who were following the school's usual approach to teaching the content. We interviewed each teacher at key points to find out about their reactions to the design and implementation of the teaching.

In the *Transfer Phase* of the study, we asked 13 teachers not involved in designing the physics and biology teaching sequences to have a go at implementing them in their schools. We collected similar video and test data as in the Development Phase, including data from similar classes in the same schools.

EPSE Network website:
http://www.york.ac.uk/depts/educ/projs/EPSE

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Teaching and Learning Research Programme

TLRP involves over 30 research teams with contributions from England, Northern Ireland, Scotland and Wales. Work began in 2000 and will continue to 2008/9.

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T·L·R·P TEACHING & LEARNING RESEARCH PROGRAMME
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Teaching and Learning | RESEARCH BRIEFING

June 2003 Number 2

Towards Evidence-based Practice in Science Education 2:

Developing and evaluating evidence-informed teaching sequences

Can it be shown that some science teaching approaches work better than others for achieving specific curriculum aims? The science education research literature identifies learning difficulties andmay suggest ways of addressing these. Few studies, however, develop and evaluate teaching interventions. This project involved designing, implementing and evaluating short teaching sequences, drawing on available insights from research. Pupils' learning was measurably better inseveral important respects than for others following the schools' normal approach to the same content.

- It is possible to design teaching sequences, informed by research, which result in better understanding by pupils of conceptual goals. → Curriculum development and accompanying CPD programmes, focussing on the teaching of key scientific concepts and informed by research, can raise the achievement of pupils.
- Pupils following the designed teaching sequences are no better than others following the school's usual approach, at questions requiring factual recall. → Science testing regimes that focus heavily on factual recall may well over-estimate pupils' understanding of key conceptual content.
- Teachers not involved in the development of the teaching sequences can use the materials to achieve better results with their pupils. → Implementation of carefully designed teaching approaches, particularly when linked to systematic CPD, has the potential to lead to widespread improvement of pupils' understanding of key science concepts.
- The use of research-informed teaching materials can lead to significant changes in the way teachers deal with content and classroom talk. → CPD programmes aiming to increase science teachers' effectiveness could usefully contain acomponent on the use of research-informed teaching materials.
- Teachers responded positively to teaching sequences which draw on insights from research, providing the sequences were perceived as being workable. → A potentially successful method of disseminating, to teachers, the results of research on science teaching and learning involves transforming those findings into workable practices for the classroom.

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The research

The EPSE Network

This project is one of four undertaken by theEvidence-based Practice in Science Education (EPSE) Research Network. The Network is a collaboration involving the Universities of York, Leeds, Southampton and King's College London. Its overall aim is to explore ways of enhancing the impact of research on practice and policy in science education, by improving our understanding of the interface between researchers and practitioners. The EPSE Network has developed and evaluated several examples of evidence-informed practice, and has explored practitioners' perceptions of the influence of research on their practice. Whilst focussing on science education, the findings and outcomes may also illuminate the research-practice interface in other subject areas.

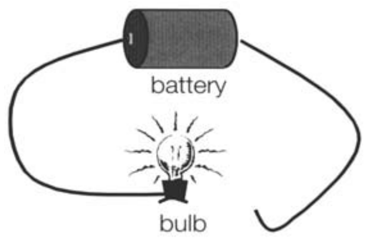
Background and context

There is now a large volume of published research on teaching and learning science, which includes advice about the relative merits of different approaches to teaching specific scientific concepts. However, there is still remarkably little *evidence* as to whether some teaching approaches are more effective than others at teaching scientific content. Furthermore, most of the studies that do evaluate the effectiveness of different approaches tend to suffer from one or both of the following weaknesses:

- A teaching approach is evaluated against stated aims, but not compared with other possible approaches. We can therefore conclude that one approach has the potential to be effective, but we can say nothing about whether it is more effective than other possible approaches. This is a particularly serious weakness when the proposed approach involves teachers in changing their current practices.
- A teaching approach is evaluated in a small-scale study, where the teacher is also the researcher (or has worked very closely with a researcher). Although such studies allow us to conclude that a teaching approach is successful *for one teacher working in one school*, after a considerable investment of time, it tells us nothing about whether *other* teachers can use the same teaching approach with similar results.

We are still some way away from an *evidence-based* rationale as to what constitutes 'good practice' in science teaching. This study involved designing and implementing short teaching sequences, drawing on available insights from research. The teaching was carried out by teachers who had been directly involved in the design of the teaching and other who had not. The pupils' learning in all cases was compared with that of others following the schools' normal approach.

Have a look at this question:



When the second wire from the battery is connected up to the bulb, what will happen?

There is clear research evidence that most people tend to answer this question assuming some kind of 'source-consumer model'. That is, electricity leaves the battery (the source) and travels to the bulb (consumer), where some is used up in lighting the bulb [See, for example, Shipstone 1985]. You might therefore expect a short delay between connecting the battery and seeing the bulb light, particularly when using *long* wires to connect up the circuit. However, when a circuit like this one is completed, the bulb lights instantaneously.

The first lesson of the electricity teaching sequence therefore begins with an activity called *The BIG Circuit*. The teacher prepares a circuit with a bulb at one end of the room and a battery at the other end, with wires stretched right the way around. When asked to predict what will happen when the circuit is connected, many pupils expect a significant time delay before the bulb lights, due to the length of wire involved. This allows the teacher to challenge the pupils' thinking and to create amongst the pupils the need for a model to explain the instantaneous lighting of the bulb.

Figure 1 The BIG circuit

Designing science teaching sequences

Working with a small group of teachers, we designed three short teaching sequences (4-6lessons) for use with secondary school pupils. The teachers were enthusiastic and talented, but had no background in educational research. The teaching sequences each address conceptual content that research evidence suggests is difficult to learn – plant nutrition, modelling changes in matter in terms of particles, and the behaviour of simple electric circuits. The researchers in the team provided information from existing research about the conceptual difficulties in these topic areas, together with examples of possible teaching activities. The teachers provided insights about activities that would work in real classroom situations, and helped to turn ideas into workable lessons.

Figure 1 shows an example of how an insight from research was drawn upon to inform thedevelopment of a teaching activity. In designing such activities, we did not feel that we were *disseminating* research findings to teachers. Rather, we were *transforming* an insight about learning from research into a teaching activity, drawing upon the creative wisdom of the team, together with the team's professional insights about what works in science classrooms.

We also drew upon contemporary perspectives on science teaching and learning in paying particular attention to different modes of classroom communication. The belief that science teachers should 'do more discussion' in lessons, and that teacher-led whole class interaction is somehow bad, have gained currency in some circles recently. We take the view that different forms of teacher-pupil talk are useful for addressing different purposes, at different points in a sequence oflessons. In planning lessons we therefore propose that teachers adopt different *communicative approaches* (Mortimer and Scott, 2003) in addressing different teaching aims. For example, in introducing new scientific ideas it is important that the teacher should be able to present them in a clear and logical way. At other times, the teacher might be asking more open questions as they try to find out what the pupils think about specific ideas or phenomena. Here the teacher is asking genuine questions, 'what do you think', and it is much more difficult to anticipate pupils' responses.

Figure 2 shows how we built ideas about communicative approach into the design of the teaching materials

Evaluating the teaching sequences

Two teachers teaching the same package of materials, with different groups of children, will do very different things in the classroom. In order to evaluate the teaching, we collected video recordings of all the lessons and each teacher wore a microphone. We analysed the video records of the classes to find out whether the teachers had followed the planned scheme, both in introducing the conceptual content and using the different forms of talk outlined in Box 2. We also collected video data of each teacher teaching another lesson involving similarly demanding content, that we had had no part in planning, in order to gain insights about their preferred use of different communicative approaches.

Unsurprisingly, we saw no evidence that the teachers spent significantly different proportions of their time overall on different kinds of talk in the designed lessons, compared to their usual approach. Teachers have deep-rooted ways of working in the classroom. In particular, the amount of *dialogic discourse*, focused upon the conceptual content of the lessons, was generally quite low (between 9 and 18% ofthe time for all teachers except one). However, these short interactions with groups of pupils were often focused upon conceptual content identified as critical in thedesign of the teaching sequences. We areinterested to explore further the communicative approach used by teachers around critical conceptual details [Viennot, 2003] within the teaching sequences.

Pupils' learning was evaluated using diagnostic questions addressing the stated content aims of the National Curriculum for Science. The questions involve both factual recall, such as stating what will happen tothe number of starch granules when a photosynthesising organism is kept in the dark, and other parts requiring the use of scientific concepts to formulate explanations. The questions were administered before and after teaching, and the same questions were used to evaluate pupils' learning following the designed ('experimental') teaching, and the learning of pupils in similar classes in the same school following the school's usual approach ('baseline' classes). We analysed the success of pupils on questions requiring factual recall, and the extent to which their explanations were consistent with, partially consistent with, or inconsistent with the taught science point of view.

We collected these pupil learning data both from classes where the teachers had worked with us to develop the teaching sequences *(development case studies)*, and by other teachers not involved (transfer case studies). Overall, we have 7 *development case studies* involving both experimental and baseline data, and 10 *transfer case studies* involving both experimental and baseline data.

According to our findings, there are no statistically significant differences between the ability of pupils in experimental and baseline groups at answering questions requiring factual recall. However, significantly more pupils in all 17 case study classes offered explanations that were consistent, or partially consistent, with the science view taught, compared to pupils in baseline groups. The size of the difference between the performance of pupils in experimental and baseline groups ranges from 20% to 74% in all except 2 cases, where the differences were 6% and 10% respectively.

We are well aware of the difficulties involved in making comparisons between different teaching approaches. There may be testing bias, and pupils may not be comparable. Nonetheless, these results suggest to us that it is likely that the designed teaching approaches were more successful than the approaches normally used in schools at developing pupils' understanding of key conceptual content in the National Curriculum for Science.

Major implications

The teaching sequences developed in this study were informed by research evidence about teaching and learning specific key science content, contemporary perspectives on teacher-pupil talk, and the rich professional knowledge of a group of science teachers and researchers. The teachers who were involved in designing the teaching sequences, generally speaking, achieved better learning improvements with their pupils than other teachers not involved in the design of the teaching. Nonetheless, all teachers not involved in the design of the sequences achieved better learning improvements with their pupils when implementing the teaching, compared to pupils following the school's usual approach.

A potentially fruitful approach to utilising the findings of research on teaching and learning science, and making them available to science teachers, involves working in collaboration with science teachers to *transform* those findings into useable classroom practices.

These findings have implications for policy initiatives designed to raise standards of science learning in schools. They suggest that a strategy involving curriculum development focussing on key *conceptual content*, involving researchers working in collaboration with teachers, together with a CPD initiative, has the potential to produce a measurable impact on standards of attainment in science across the education system. The focus of such a strategy would be upon both the conceptual content of teaching, and the *communicative approach* to be used in the classroom.

There is a widely held perception amongst science teachers, that current testing regimessuch as the Key Stage 3 SATs and someaspects of GCSE examinations rely excessively upon questions requiring factual recall to assess pupils' scientific understanding. We believe that there is some truth in the science teachers' perceptions. Results from all 17 case studies, where it is possible to compare pupils' performance on diagnostic questions with others following the school's usual approach to teaching, suggest that pupils following the designed teaching sequences were better at using scientific concepts to generate explanations than their peers. However, in each case the schools' usual approach was at least as good as the designed teaching sequence at equipping pupils to answer questions requiring factual recall. These results suggest that current testing practices may result in an overestimation of pupils' conceptual understanding in science, and that a more realistic picture of pupils' understanding could be gained by the use of questions requiring pupils to use scientific concepts to generate explanations.

The sociocultural literature characterises different kinds of classroom talk, and considers the various purposes that these might have. Drawing upon this literature, we identified three different patterns of teacher-pupil talk which were introduced at the start of the teaching scheme. A set of icons was then used throughout the materials to draw teachers' attention to the kinds of talk planned for different points in the sequence:

		The purpose of the talk	How and When it happens
Presenting		You are introducing or reviewing **new ideas** relating to the analogy and to the scientific model.	This may be through a presentation by you or by whole-class discussion led by you.
Discussing / probing		You are finding out about the pupils' ideas and understandings relating to the analogy and to the scientific model.	This may be through asking open questions, 'what do you think?' in whole-class or small group situations.
Supporting		You are supporting the pupils as they talk about theirdeveloping ideas, using keyquestions and offering appropriate responses to their questions.	This is likely to be achieved as the pupils are working on paired or small group activities.

Figure 2 Planning teacher-pupil talk

References

Mortimer, E. F. and Scott, P. H. (in press). *Meaning Making in Science Classrooms*. Buckingham: Open University Press.

Shipstone, D. (1985). Electricity in simple circuits. In: Driver, R, Guesne, E. and Tiberghien, A. (Eds.), Children's Ideas in Science (pp. 33-51). Milton Keynes: Open University Press.

Viennot, L. with others (2003). *Teaching physics*. Dordrecht: Kluwer Academic.