Teaching about energy and training for innovation

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ABSTRACT

The curriculum is in a constant state of rapid change. The role of teachers in implementing curriculum innovation is critical, though in the absence of suitable training, the intentions of the innovation may be transformed. This paper discusses the development of training materials based on research into the nature of teachers' transformations of innovations in the teaching of energy. This was carried out as part of the STTIS project (Science Teacher Training in an Information Society). Two innovations were studied. One is the large scale introduction of the concept of 'energy transfers' in the National Curriculum for England and Wales. The other is the smaller scale curriculum development project 'Energy and Change'. The training materials provide activities to enable teachers to learn about the innovations and about the nature of the research into their implementation, and to take account of these ideas in their own implementation of the innovation.

1. INTRODUCTION

The STTIS project (Science Teacher Training in an Information Society) is an EU project involving five countries (France, Italy, Norway, Spain, United Kingdom). The starting point of the project is that teachers' interpretation of a proposed teaching sequence may result in transformations of the original didactic intentions. The areas of research include the use made by science teachers of informatic tools, the difficulties in teaching and learning graphic representations, and the transformations made when implementing innovative teaching strategies. The output from the project will include materials to be used in the training of teachers and guidelines intended for policy makers. This paper discusses one example of the the training packs, concerned with the teaching of energy, developed as part of the work of the UK team.

The UK team chose to look at two kinds of curriculum innovations concerned with the teaching of energy and their transformations by teachers [1]. One is the change from 'transforming' to 'transferring' energy which first appeared in the recommendations concerning the teaching of energy of the 1989 Science National Curriculum for England and Wales. The other is the smaller scale innovation introduced by the curriculum materials developed by the 'Energy and Change' project. This project aimed to provide novel ways of teaching about the nature and direction of changes and energy introducing ideas related to the Second Law of Thermodynamics. Each of these curriculum innovations is described in more detail below.

We saw these two kinds of innovations as complementary in many ways. The first is intended to be applied by all teachers at national level. It is expressed in the form of general recommendations of what pupils should be taught, but does not suggest teaching strategies. The second innovation should be seen as working at the local level. The approach is relevant to the teaching of a number of topics, and provides materials to be used by teachers both in the classroom and for their professional development.

2. ENERGY TRANSFER

The first innovation studied was the national-scale change defined in the text of the first National Curriculum for England and Wales [2] about the teaching of energy. The concept of energy *transfer* as one to be learnt by pupils at the secondary level replaces that of energy *transformation* used by previous syllabi and most textbooks. It had been argued that the concept of energy transfer is both more scientifically appropriate and more useful [3].

The change arose out of the debate that took place as part of the consultative process on the drafting of the national curriculum. It drew on the strong interest in the teaching of energy expressed in the international science education scene during the 1980s as evidenced by the many publications on the issue [e.g. 4, 5, 6, 7, 8, 9, 10, 11]. During the debate on the National Curriculum for England and Wales, although most people accepted that 'energy transfer' is a more straightforward concept, this view was not universal. Some thought that it might be best to start off teaching younger children about forms of energy and only later, when they are older to tackle the notion of 'energy transfer'.

Though there have been changes in subsequent revisions of the National Curriculum, the essence has remained the same. The latest version [12] requires, for example that 11-14 year old pupils are taught 'the distinction between temperature and heat, and that differences in temperature can lead to transfer of energy' and 'the ways in which energy can be usefully transferred and stored'.

3. ENERGY AND CHANGE

The other innovation we chose to look at is the smaller scale innovation introduced by the curriculum materials developed by the 'Energy and Change' project [13, 14]. This project aimed to provide novel ways of teaching about the nature and direction of changes and energy, in particular introducing ideas related to the Second Law of

Thermodynamics in a way accessible to pupils aged 11 upwards.

The key idea in our approach is to pay attention to the differences which drive change [15]. For example, pollution spreads out and mixes with the air in the atmosphere because of a *concentration difference*, and hot coffee cools because of a *temperature difference*. Differences tend to disappear because matter or energy or both become more spread out. This essentially simple idea is also powerful. We can use it to make sense of a wide range of phenomena from a hot cup of tea cooling, to the direction of chemical reactions and even to the complexity of life.

This approach is clearly not simply confined to topics related specifically to energy, and the project developed a very wide range of pupil activities and supporting teachers' notes which could be used alongside existing work in many areas of the science curriculum. In understanding such a wide range of different kinds of processes, it is necessary to help pupils see that many changes are essentially similar, even though, superficially, they appear to be very different. Making such abstractions is not easy, so a central feature of the project was the development of a range of pictorial representations to help pupils to do this. A discussion of these abstract pictures and examples of their use can be found in [16] and [17].

4. RESULTS OF RESEARCH ON TEACHERS' TRANSFORMATIONS

There has been considerable research into teachers' understanding and implementation of curriculum innovation for a least twenty years [e.g. 18, 19]. The findings of these studies, that traditional patterns of teaching were maintained in the implementation of innovations, are consistent with the findings of the STTIS research. STTIS investigated the transformations of the didactic intentions of the innovations through teacher case studies using questionnaires, interviews and classroom observations, and the details of this research have been reported elsewhere [1].

For the 'energy transfers' innovation, the findings seem to indicate that the didactic intentions of the innovators of the National Curriculum may not be fulfilled in today's teaching of energy. None of the case study teachers shows any evidence that they have seriously thought about the difference between 'energy transfer' and 'energy transformation'. Although the term 'energy transfer' has been partly adopted in the teaching of energy, its conceptual implications have not. Thus, most teachers do not explicitly use the term 'energy transformation', they see no problems in talking about energy being *transferred* from one *form* to *another*. When the idea of energy transfer was adopted, there was a certain specialisation, since it was seen as more appropriate for accounts of microscopic changes and for processes which involve heat transfer, both topics which are studied by older pupils. In summary, the teachers in the case studies accommodated the new nomenclature to their existing schemas. A similar finding also emerged in the analysis of the science textbooks.

The amalgamation of fundamentally different concepts and ideas is something that we also saw happening in the use of the 'Energy and Change' materials. Two case studies illustrate very different approaches to the adoption of the innovation. In the first case study, the teacher attempted the difficult task of adding a novel approach without major modification to what already existed. The project's approach appealed greatly to him, since an important goal was to widening the pupils' perspective so that they can think in the abstract, which is according to him is what science is all about. However, he used the abstract pictures to add an explanatory dimension to existing pictures of energy change which show an energy transformation approach. An 'energy transfer' approach is inherent to the 'Energy and Change' innovation. We could say that he has *accommodated the new in the old*. In a second case study, the approach was to create a new topic called 'Energy and Change' in the school's curriculum which consisted exclusively of the innovations teaching materials. The idea seemed to be that the pupils would learn about the basic new ideas, terms and abstract pictures in one large dose, so that teachers in subsequent topics could draw on this knowledge.

In these two case studies, the 'Energy and Change' innovation was transformed in different ways related to local circumstances. In the first case we have integration at the macro level which is more in line with the intentions of the designers of the innovation, though with important transformations at the micro level in the way in which the ideas were used. In the second case we have a major transformation at the macro level in how the work is organised, though as it happened with almost no transformation at the micro level of the teaching in the classroom.

For both the Energy transfer' and 'Energy and Change' innovations, mere acceptance of their merits was not enough for their successful take up. Deep understanding and commitment to the innovation appeared to be some of the preconditions. In addition, attention to the details as well as to the general framework of the innovation is essential, since it is these details which may often undermine its overall effect. A key factor is the extent to which an innovation does something which is related to what the teacher has customarily been doing, as least in the mind of the teacher. There are concerns about practical issues such as whether an activity will keep pupils occupied and interested, and about the amount of preparation time. This has been characterised as the importance placed by teachers on the maintenance of 'normal desirable states' of pupil activity in the classroom [20]. These considerations are very prominent for teachers, even if they are not always for curriculum innovators.

5. DESIGN OF THE WORKSHOP MATERIALS

Based on the research into teachers' transformations of innovations, we have developed training materials to address the factors we identified affecting the innovations. The approach was to incorporate the teacher case studies into activities that aim to help the teachers being trained to consider the implications of innovation in their own context. The activities need to support trainees in exploring their existing ideas, learning about new approaches, and considering these in relation to their existing practice. It has been argued that while innovation-focused is useful, it is too limited, and development needs to take into account the teacher as a person, theor purposes and the contexts in which they work [21].

Teachers' decisions about what they do in their classrooms, as identified in the STTIS research, are dependent on a variety of factors. These can be usefully summarised under the following four headings:

a) *Content* – includes the content of the proposed innovation and the content of the existing curriculum, and the perception of the teacher about how the new relates to the old.
b) *Beliefs about learning* – include what teachers think that they ought to be doing to support pupils in the classroom, what pupils find easy or difficult and why, and the role and nature of motivation.
c) *Values* – include what teachers believe about the nature of their subject, about the purposes of education, about their own role as a teacher, and so on.
d) *Contexts, customs and constraints* – includes a wide range from local factors such as the layout of their classroom or the availability of resources, to more global factors such as prescriptions laid down by government, as well as teachers' knowledge of the subject they are teaching, their repertoire of pedagogic strategies, their social skills, and so on.

If teachers are to be able to make explicit the factors which inform their decisions, they need to do this in the context of their own teaching. Training which is divorced from their own practice is unlikely to have long term consequences. The materials therefore use an approach in which there is an initial and final training session, with a period of some weeks in between in which teachers can use the ideas in their own practice.

The intended audience, the trainers of teachers, would themselves, of course, transform the approaches of the materials dependent on the local contexts in which they were being used. This suggests that the materials would be better seen as a 'kit of parts' rather than a fully specified training programme.

6. STORIES OF TRANSFORMATIONS

The research case studies provide evidence of how the four factors described in the previous sections influence the transformations. These factors interact with each other in complex ways and influence the nature of the transformations which themselves show subtle differences between teachers. To make the case studies more accessible, a range of different kinds of 'stories' have been written to capture essential features of the factors and the transformations. The stories are simplified and imaginary accounts, written to exemplify particular issues raised by the implementation of the pupil activities in the classroom. They draw heavily on the real case studies of the research, but they do not simply summarise them.

The first factor is concerned with transformations in the subject content, and the stories look at the views that teachers have about the scientific ideas in the 'energy transformation' and 'energy transfer' approaches, and at the approach of the 'Energy and Change' materials. They address the issues of how the new approaches relate to what is currently taught, and how the ideas can be incorporated into existing schemes of work. Two examples of stories are shown below.

a) "I have now adopted the approach taken in the National Curriculum, and all of my teaching about energy is in terms of energy transfer. I teach pupils that there are six different kinds of energy, and in an energy change, energy is transferred from one kind to another. I think that this is a helpful way of looking at things. I think it is probably better to say that chemical energy is *transferred* into heat energy than to say that chemical energy is *transformed* into heat energy."
b) "I am quite enthusiastic about introducing this kind of 'Second Law' thinking into my teaching. I think that it would be possible to modify our existing schemes of work to integrate these ideas. I don't think, however, that it would be possible to use the *Energy and Change* activities as they stand. I think that what I would do would be to adapt some of the ideas to fit in with our existing approach, and to include some abstract pictures in our current worksheets. I think that the pictures work well in illustrating the different ways in which energy can change from one form to another."

The second factor is related to teachers' beliefs about learning. When teachers were asked how they approached teaching about energy, and their reasons for it, they had strong views about how pupils could be supported in their learning. The stories are concerned, for example, with the kinds of approaches to energy which teachers think pupils will find easier and which gives them a better understanding of the science.

The third set of stories is related to personal values. Our actions are guided by what we see as important and what we value. When teachers described their work on teaching energy, they referred to personal values about what should be in the curriculum and how it should be taught in the classroom. Teachers' views about the kind of science that should be taught and the nature of scientific knowledge affect the curriculum transformations that they make.

The final factor is concerned with the way in which innovations are constrained by the contexts within which teachers' work and their customary practices. Even when teachers were committed to the innovation, it might not always have been easy to implement it because of the particular contexts within which they worked. The stories look at how teachers are affected by factors related to department or school, by factors outside the school, including the national context, and by the capabilities and experiences of the teachers themselves.

7. STRUCTURE OF THE WORKSHOP MATERIALS

The training materials produced are intended to be used over two sessions. In the first session, teachers review their current practice on the teaching of energy, and identify particular areas that they would like to address. A substantial section deals with learning more about the curriculum innovations. There is then a review some of the research findings through the stories about teachers' implementation of the innovation, and they are encouraged to think about some of the general issues and how they might relate to their own practice. Finally, they draw on the ideas that they learned in the earlier activities in order to plan, teach and evaluate a trial lesson. In planning and evaluating the lesson, they are encouraged to use the stories of transformations and to reflect on how their choices have been influenced by factors such as subject content, their beliefs about learning, their values, and by customary practices and constraints. The sections in this first session are:

Exploring current practice
Learning about the innovation
Transformations: content
Transformations: beliefs about learning

Transformations: values
Transformations: contexts, customs and constraints
Planning

The second session is designed to help teachers to build on the experience of the trial lesson about energy in order to plan more extended sequences of lessons within the schemes of work. To support teachers in developing this work, they review and evaluate the trial lesson, learn more about research work through examples of case studies, relating these and their own experiences to the general findings of the research, and consider again the factors that affect their planning choices and review the appropriateness of teaching sequences on energy. The sections in this second session are:

Evaluation
Relating to research case studies
Innovation and transformation

In this session, teachers explore 'real' case-studies in order that the 'richness' can be appreciated, and the 'stories' can be seen in a broader context. The stories are simplified because they viewed the factors that affected teachers' transformations in isolation. Reality is more complex, since transformations are brought about not by single factors, but by factors that overlap and interact with each other. A key feature of the second session the opportunities provided to teachers to report back to each other and to discuss their experiences, and to reflect on the factors that affect the transformation of curriculum innovation.

7. CONCLUSION

Teacher development needs to be seen as a long term process. The training materials described here are modest in scope, and can have only limited impact. They may have some small impact on teachers' capabilities, and a role in helping them to change some of the contextual factors within which they work, though the materials are unlikely to have any major effect on their values. What can be done in these materials, however, is to make teachers' aware of some ways in which the curriculum is transformed in implementation, and the factors that affect the transformations that teachers make. By making these factors explicit, teachers can make informed choices in their implementation of new ideas.

There is increasing emphasis on teaching as a research-based profession, but there are difficulties in creating a culture in which communities of researchers and teachers can create a shared body of knowledge [22]. This paper has discussed one possible way in which research findings can be made accessible to teachers involved in curriculum innovation.

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