Science Teachers’ Transformations of the Use of Computer Modelling in the Classroom: Using Research to Inform Training

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Abstract

This paper, from the UK group in the STTIS (Science Teacher Training in an Information Society) project, describes research into the nature of teachers' transformations of computer modeling, and the development of related teacher training materials.

Eight teacher case studies help to identify factors that favor or hinder the take-up of innovative computer tools in science classes, and to show how teachers incorporate these tools in the curriculum. The training materials use the results to provide activities enabling teachers to learn about the tools and about the outcomes of the research into their implementation, and help them to take account of these ideas in their own implementation of the innovations.

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Introduction

The starting point of the STTIS (Science Teacher Training in an Information Society) project is that teachers’ interpretations of a proposed novel teaching sequence may result in transformations of the original intentions (STTIS, 1998). So the project set out to investigate such transformations, as they occur in the implementation of different kinds of curriculum innovation in the science classroom. Based on the research, we developed materials to be used in the training of teachers and guidelines intended for policy makers.

This paper discusses research by the UK team into transformations in the use of computer models and simulations (Stylianidou & Ogborn, 1999) and presents the training materials that were developed based on this research (Boohan *et al.*, 2000a). The introductory paper (Pinto, *this issue*) outlines the general approach of STTIS, and references the extensive literature on teachers and curriculum innovation.

Modelling and simulation

There is wide consensus in science education concerning the value of learning to build and interpret models. Computer models can be used to develop a better conceptual understanding than traditional quantitative approaches (Osborne, 1990) and are a valuable way of making external representations of thought processes become open for reflection and discussion (Orhum, 1995; Tinker, 2000). Computer-based modelling environments, suited to a variety of kinds of student, have been developed. Examples of evidence of effectiveness of use of computer models include Weaver (2000) and Hennessy *et al.* (1995).

A useful classification of modelling activities distinguishes between ‘exploratory’ and ‘expressive’ learning activities (Mellar & Bliss, 1994). ‘Exploratory’ modelling activities (often simulations) allow students to interact with already constructed models. Such models can explore phenomena that are not accessible to direct observation. The outcome can be a qualitative understanding of complex processes without a need to worry about the underlying mathematics (Feurzeig & Roberts, 1999).

‘Expressive’ modelling activities invite students to create their own models, and then to explore their consequences. Tools used for this include LOGO, spreadsheets and modelling systems. Such activities can be a powerful way to engage students in doing and thinking about science (Nickerson, 1995; Spitulnik *et al.*, 1999).

In our study of the use of computer modelling, many of the case studies were concerned with the use of spreadsheets in different physics topics. Spreadsheets have a number of attributes that make them suitable for use as a modelling tool in the school laboratory and popular with science teachers (Brosnan, 1994). They can be used in either ‘expressive’ or ‘exploratory’ modes, and they can be used for data handling and graphing or display work as well as for dynamic models of physical situations. Finally, they are general-purpose software packages, used in everyday applications in the work-place.

Feurzeig and Roberts (1999), in claiming that model-based inquiry should become an essential part of pre-university science education, also point out a number of obstacles. Our choice to study the transformations science teachers make of the use of computer modelling reflects both our belief in its great educational potential and our resolve to try to remove some of the obstacles to its incorporation in the curriculum.

Methods and Sampling

Eight teacher case studies were carried out. The aim was to identify possible factors that favour or hinder the take-up of informatic tools in science classes, and to investigate how teachers incorporate these tools in the curriculum. The main research questions were:

- What are the fits (matches) or gaps (mismatches) between the intended or expected use of the tools and the way the teachers actually use them in practice?
- What do teachers identify as more and as less successful examples of uses of the tools, and what reasons do they have for identifying them as such?
- Are teachers conscious that they transform the suggested uses of tools in their own practice, and if so what reasons do they give? If not, are there clues about what may determine the teacher's practice?

The teachers in our case studies were selected by their willingness to participate and to make serious use of computer modelling and/or simulation. The choice of software and the way it was to be used were left to them. We did this as the only realistic way to get the desired number and quality of teaching instances. As a result however, the intended use of the tools in most cases was not closely pre-specified. A further consequence of this opportunistic sampling was that the majority of the cases studied concern computer modelling in physics and with students of 16 years old and over.

All teachers were observed making use of the informatic tools, in several cases for more than one lesson. Detailed notes were kept for each observation and worksheets and students' work were collected. We interviewed teachers both before and after the classroom observations, so far as possible.

In the interview before the lesson, teachers were asked about the school and its computer provision, and to comment on their own and their students' experience with modelling software. They were asked to explain what was planned for the coming lesson, and how it fitted with previous work with the class. They were asked what they hoped their students would achieve, and why they considered these gains important. Finally, what problems or issues did they think might arise and how were they going to deal with them? After the lesson, we asked them what problems they had encountered; whether they felt they had achieved their objectives, or whether they felt they had deviated from them and if so why. We also asked how easy or difficult it had been to incorporate modelling in their teaching.

The STTIS research methodology (STTIS, 1998) comparing intended aims with actual use, set a general frame for the data collection and subsequent analysis. However the comparison is not in this instance straightforward. The intended aims and uses of a computer tool are not necessarily clear or unique, and may be expressed in general terms that require interpretation by the teacher. There may well be competing ideas about the proper aims and use of a tool. In these ways, the computer tools studied here differ from a curriculum innovation in which the aims are made explicit. It was thus necessary to compare what the teacher and students actually did with more than one alternative, seeing the teacher either as choosing between alternatives or as constructing a position out of several alternatives.

We did not assume that teachers could clearly foresee and plan what students would do or what students would gain in learning. We anticipated (and found) a mixture of pre-planning and of actions in response to what students turned out to do. So we asked the teachers why they had reacted as they had, and reflected on the principles that might have guided such reactions.

We did not assume that teachers' intentions, however clear, were necessarily shared by or clear to students. Students may assume that the teacher has other intentions, or they may try to evade or subvert them.

Results of such studies are necessarily a "reading" of the situation by the researcher, taking into account a variety of evidence. This reading should focus on the main research question - how and why matches and mismatches arise between the ways teachers actually use tools and possible ways in which they may be intended to be used. In our analysis we tried not to forget that the critical comparisons are symmetrical. To describe a teacher's modification of a suggested use may be seen as implying a critique of the teacher's actions, or as implying a critique of the practicality or value of the intended use - or as both.

Together with other partners in the STTIS project, we identified the important themes we wanted to address in common (Stylianidou *et al.*, 2000). These were:

- *Accepting / changing external goals*. The designer of a computer tool may have certain intentions and goals concerning its use. The case studies attempt to characterise the whether the teachers accept, modify, replace or reject these goals.
- *Rationale versus Practice.* The case studies attempt to identify any differences between the rationale the teachers offered for their use of the informatic tool and their actual practice.*Actual / Realising goals (of teacher).* The case studies would also consider whether the teachers succeeded in the goals they had set.
- *Teacher's knowledge.* Important information about the teachers' knowledge and relevant experience is included.
- *Effects of physical objective circumstances.* The use of computer tools is affected by practical circumstances (technical, physical, etc.), and their role is described. *Existing practices.*
- *Effects of existing practices.* Finally, the case study takes account of effects of existing practices, such as examinations or a national curriculum.

Based on this pre-determined framework of issues, the data for each of the teachers were assembled and a first draft of the case study was drawn up. These drafts were then checked against the data in discussion among the researchers, and were modified as necessary.

An Overview of the Teacher Case Studies

In this section we give a brief outline of all eight case studies, in order to give an indication of their variation. All the teachers' names are pseudonyms. We decided to give each case study a short and memorable title, intended to convey the most important message we drew from it.

Albert - *Medium becomes message* (Modelling with a spreadsheet)

Albert deemed the content of physics (the discharge of a capacitor) as already known by the students and used it as a vehicle for teaching the use of Excel, thus transforming the *medium* into the *message*.

Bernard - *Demoting goals* (Using a simulation)

Bernard used a simulation of alpha-particle scattering. He demoted the designers' exploratory goals for this activity by using it only after the end of the teaching of the topic as a supplementary activity, rationalising that this might help students' preparation for exams.

Chris - *Ad-hoc - 'virtues from necessity'* (Using a web-based simulation)

Chris's goals for using a web-based simulation of an earthquake were *ad hoc* and seemed to derive more from what the simulation could offer and not from any particular teaching or learning rationale. When the simulation proved to have a flaw Chris decided that this was a 'valuable feature' that offered educational benefits to the students.

Ivan - *Computer as a work-a-day routine* (Modelling using a spreadsheet)

Ivan is a very experienced teacher who uses IT as a work-a-day routine. For him the use of computer does not require a special teaching strategy; but is there to support his teaching, in which he wants students to be thinking about things and relating them to one another. This rationale guided the lesson about the discharge of a capacitor that we observed.

Norton - *Driven by high expectations* (Using a simulation and a modelling programme)

His excellent mathematical ability and high expectations for his class led Norton to using sophisticated modelling applications when teaching about heat transfer to his younger students. In doing so, he sometimes showed a lack of appreciation for the difficulties mathematical abstractions may pose for these students.

Paul - *We are cleverer than the computer* (Using a simulation)

Paul regards computer work as one among other opportunities for students to practice intelligent thinking. A flaw in the programme was treated as an opportunity for students to ask pertinent questions about the physics of electromagnetism.

Simon - *‘Getting it all together’ - realism* (Modelling with a spreadsheet)

Simon’s rationale for using IT in the classroom shows that he has thought hard about the role of computers in physics teaching and learning, and in students’ general education. As a consequence the use of computers in his lessons (on the lens formula and potential dividers respectively) appears blended with other modes of teaching.

Stewart - *Flexible autonomous variation* (Modelling with a spreadsheet)

Stewart’s use of IT in his teaching fits with his tendency to experiment with new ways of doing things. He is willing and able to modify his lessons as they develop, shifting the emphasis as the situation seems to him to demand, whilst keeping a clear goal in sight. In the observed lessons he was concerned with the modelling of capacitor discharge.

The notion of ‘transformation’ is exemplified in these case studies. In each we see teachers transforming the use of modelling programmes in their effort to construct viable classroom events. Their transformations however vary widely, and arise from very different causes. In the following section, three case studies are discussed in more detail, before moving on to identify some of the factors we think may give rise to these transformations.

Examples of Teacher Case Studies

The cases of Stewart, Albert and Ivan are presented below. We describe the case of Stewart in some detail, followed by a summary. The contrasting cases of Albert and Ivan are presented only in summary form. These three cases have been chosen because they all use a spreadsheet to teach about capacitor discharge, which facilitates comparisons. It turns out that each teacher uses the software in very different ways.

This particular example of modelling is one of the more popular with UK teachers, and ideas about the goals of the exercise are rather commonly known and shared. This fact makes it more straightforward to look for transformations.

Stewart - ‘Flexible autonomous variation’

The two lessons observed were part of a sequence on electric circuits, following work on potential difference, current and internal resistance of a source. The next step was to study the discharge of a capacitor. Stewart had decided to do something new: previously he had given students a lot of experimental work with capacitors and then tried to model the discharge; now he intended to reverse the order, and develop models before trying any experiments.

> I just thought I would try it this way this year, just to see if we could just take the equations, build the picture, and implement it without any further experience of capacitors. In the past I spent a long time, maybe a week or two, doing basic capacitor experiments and getting some data first. I just did it the other way round this year, to see how it would work.

A key factor appears to be Stewart’s self-confidence. He is quite willing to take risks:

> …today’s work will be mainly constructing the computer model…Last lesson I gave them some ideas about the sorts of things that ought to go into the model. But the critical thing is that they will have to create the model on the spreadsheet. That is very difficult. I don’t know whether they are going to do it or not. Some will.

In the event, the risk was justified.

> I am pleased that all but two of the boys managed to get the model on their own without any further help… What really worked nicely was that most of the boys got the model and started playing with it. I liked that. And then they were able to go away, make some measurements, bring the data back and start questioning, matching, comparing the data with the model. And in that respect it was a far greater success than I expected.

Stewart's confidence is further evidenced by the fact that he is willing to let later teaching develop out of what happens – planning 'on the fly'. Thinking about the next lesson:

> Tomorrow I think we need…to look carefully at what the model can tell us about the discharge process in theory… We are going to have a look at the time constant – what does that mean?… Can the time constant lead us to choose a sensible value of dt? Does the voltage affect the discharge time…etcetera. There are a lot of ideas for a lesson there. I will obviously, in the next 24 hours, think about how I might play that one with the group.

As it turned out the next lesson also took up something else that was on Stewart's mind. It was the question whether one should believe the model or the data:

> I try to stress that…the model is an attempt to account for the data, not the other way round… I think generally children tend to…think that the computer is absolutely paramount…(that) it gives a more accurate or true a picture of nature.

In the second lesson one student had done the experiment wrongly, leaving a source connected while the capacitor 'discharged'. He questioned the possibility of testing whether the data curve shows a constant half-life, as Stewart had just asked them to do. Stewart (not yet knowing the problem) responded very directly and forcefully:

> You've got your model and you've got your data. Why do you think it is wrong? This is your theory graph. You think this data is wrong. Data can't be wrong. You measured it – unless you measured it incorrectly of course. Do you want to go and repeat it? Why do you think you measured it incorrectly?

An important factor in Stewart's ability to improvise seems to be that he has thought about and internalised some clear, deep and general goals of teaching through modelling:

> Do they understand the physics that has gone into the model first and foremost? – that is the most important thing. Secondly…do they understand what the mathematical model is allowing them to do? Some of them will think that it just simply replaces doing an experiment, which is not what I am trying to get across… Really what I would like them to be thinking is: Ah, this is the theoretical way of understanding what is going on in the laboratory…

This thinking of Stewart's has a long history. He can remember his first meeting with modelling:

> …the Dynamic Modelling System – the thing that was in Nuffield – I think that made a big impact on me. I saw it when I first came to the school in 1985 and I thought, this really makes you understand physics – it really does…I remember … thinking 'This is great, I wish I'd done this before I went to the University to do physics, this is really giving an insight'.

He is very clear however that a teacher, including himself, has a lot to learn before being able to use modelling with confidence:

> …There is quite a steep learning curve to go up before you could actually do a lesson like that off the top of your head… The first thing I would say to a new teacher is that you need to play with a modelling system, because it is going to teach you a lot of physics, a hell of a lot. … I learned so much, so much… you've got to give it time to develop gradually.

The school is extremely well equipped with resources, and this no doubt made a positive contribution. However, there is reason to think that this is not a dominant factor. Stewart has done similar work in the past in much less good conditions, and – even more important – he notes that several of his colleagues would not attempt it even now under excellent conditions:

> Modelling is being used a lot by me, because I am interested in it. Some of my colleagues take up ideas when I show them, 'This is what I've done, have a go'. So I think it will be a big factor in the future, but at the moment it is just a few keen people that are trying it.
>
> If you talked to some of my colleagues they would say, 'Total waste of time'. 'Cause at the end of the day they've got to…do A-level questions; that is what you've got to work on. So we have two very extreme views in this department…Luckily I am head of science, so I can do what I like.

<u>Stewart: Summary of case study</u>

- Accepting / changing external goals

Stewart has (over many years) kept to a settled idea – even 'ideology' – of modelling as laying bare physical ideas in a transparent way. It taught him a lot, and he believes it will do the same for students.

Stewart has accepted – and made his own – the intentions of those who promoted the use of modelling in teaching physics. Stewart is not fixed on the spreadsheet as the only tool: in the interview he describes several other modelling systems he has used or is investigating.

- Rationale versus Practice

The main kind of transformation he is involved in is what we might call 'flexible autonomous variation'. Stewart knows what he wants to achieve, and his practice is consistent with his rationale. Nevertheless, within that framework he is constantly experimenting. Sometimes this is to deal with a problem he has found in the past. Sometimes it is "just to see how it would work." It is in that sense that we want to call his transforming activity 'autonomous'. By 'flexible' we mean that Stewart is willing and able to modify his lessons as they develop, shifting the emphasis as the situation seems to him to demand, whilst keeping a clear goal in sight.

- Actual / Realising goals (of teacher)

Stewart realised his goals; the students were engaged with modelling much as Stewart hoped. Evidence of this is seen in how they confidently and correctly describe their models, in how they debate with one another about what the models mean and why a model may be wrong, and in how they are led to ask and attempt to answer a number of interesting and important questions.

- Existing practices

It is important to remember that Stewart (and his colleagues) are working in a curriculum framework which does not include modelling as a necessary feature. So Stewart is also transforming the intentions of the curriculum and examination designers, by assimilating them to the modelling 'ideology' he has accepted. One might call his transformation an 'ideological re-direction' of aims.

- Teacher's knowledge and Effects of physical objective circumstances

We have little doubt that the key to understanding Stewart's autonomous flexibility is his long history of experience, based on an initial commitment. No doubt good conditions have helped. They may not even be necessary, though in most cases they probably are. But they are not sufficient.

It seems clear to us that this is a case of a teacher "taking ownership" of an idea, and adapting it to his own well thought out purposes (see Pinto *this issue*).

<u>Albert - 'Medium becomes message'- Summary</u>

The two lessons observed had to do with modelling capacitor discharge using Excel, and were part of a sequence on electric circuits. The class (five 17 year-old girls aiming to get good grades in physics) had previously studied capacitor charge and discharge curves empirically, using data logging software.

Albert is a biologist by first degree and has recently taken up teaching physics at this level. He sees himself as being at the forefront in the use of computers for teaching in his school.

- Accepting / changing external goals

Albert distorted most common external goals concerned with the use of Excel as a modelling tool to teach science. First he transformed the medium into the message, treating Excel as the object of learning, instead of using Excel to teach about modelling capacitor discharge. In using the computer with Excel, he is doing something new, which he believes in. However, he does not want to take chances. So, he chooses a topic that he is confident that the students have already understood. He then transforms the role of the spreadsheet, using the physics as a vehicle to get the students familiar with the process of using it.

- Rationale versus Practice and Teacher’s knowledge

A second transformation indicates a discord between his rationale as just described and his practice, and seems to arise from his feelings of insecurity. These drive him to convert the knowledge to be taught into recipes. As a result the process of modelling becomes a process of following steps and blindly copying a set of formulae (which at first contained an error) on to a spreadsheet.

- Actual /Realising goals (of teacher)

As a consequence of these transformations, we believe that Albert only partially realised his goals and certainly not in the space of one lesson as he had intended to.

- Effects of physical objective circumstances

The school provision of computer laptops for the students made it possible for Albert to use them when he wanted to, without long pre-planning.

- Existing practices

The physics examination syllabus is always in Albert’s mind, but this does not seem to stop him from trying something ‘a little bit off it’, since he believes that in the long-term his venture will pay off.

We incline to see this as a case of "fragmenting the holistic view" (Pinto, *this issue*). Albert transforms a use of Excel for understanding a physical process into learning isolated pieces of knowledge about how to construct the content for the spreadsheet in this instance.

<u>Ivan - ‘Computer as a work-a-day routine’ - Summary</u>

Ivan has been using modelling in teaching physics for some thirteen years. For him the use of computer is not a special teaching strategy, and he treats its use as a matter of workaday routine.

The observed lesson was about the discharge of a capacitor, with a class of twelve 16-17 year-old boys. The students had ‘played’ with capacitors and seen qualitatively how they behave. They had looked at RC discharge experimentally as a demonstration carried out by Ivan, using a data logger.

- Teacher’s knowledge

Ivan is a keen user of computer modelling; he has used it for teaching physics for some thirteen years and he keeps looking for new software packages to use.

- Accepting / changing external goals

Many teachers see the usefulness of the exercise he chose. The calculations involved are easy enough and the step-wise approach of the model gets the students to think about the nature of the change. The use of computers has made the teaching of exponential change much easier. Ivan has clearly accepted these external goals.

- Rationale versus Practice

He is also very aware and clear about the advantages the use of modelling may bring to students’ learning of physics. These he seems to see as being accomplished over the longer term and he does not expect them to happen overnight. Within the span of an individual lesson his practice seemed not to conform with his rationale, but over a longer time scale he is consistent.

- Actual / Realising goals (of teacher)

In many ways Ivan did not realise his goals. He casually deferred certain goals and modified the lesson plan when he saw students struggling with the model. However, he appeared to do all this in a very low-key way, not seeing it as a problem.

- Effects of physical objective circumstances

His teaching style changed with the change of physical circumstances, that is when the students moved from the classroom to the computer room, and this is important to note.

- Existing practices

Knowledge of the nature of capacitor discharge is required by the standard examination syllabus. Ivan is aware of this but he does not make a big deal of it. He is very confident of being able to meet any external requirements.

We see Ivan as concerned with what has elsewhere been called "critical details" (Pinto, *this issue*). His concern for the success, moment by moment, of the lesson leads him to modify goals 'on the fly'. In this respect he happens to be rather successful, because he does have steady longer-term goals always in view. In others of our case studies, however, changes that look like matters of detail only have a much less favourable outcome (see e.g. the case of Bernard, outlined previously).

Discussion of Teacher Case Studies: Similarities and Differences

The teachers in these case studies all work in an educational system that expects them to be independent and to take the initiative. This has various consequences for our research. It means that these teachers did not have any specific guidelines or explicit intentions to conform to, so that what they choose to do can only be compared to what might be generally expected in the circumstances.

It is important to report that the case studies were hard to find. We had considerable difficulty finding science teachers who claimed to use modelling in their teaching and who were also willing to participate. In the end, and in order to get high quality examples, we ended up with teachers from some of the better schools. Thus these teachers are not representative; our case studies should be seen as giving a picture of what is possible, but not of what happens on average. Putting it more strongly, visit a typical science lesson in an English secondary school and you are not likely to see computer modelling going on. This observation agrees with the national survey data discussed in the STTIS report on the use of informatic tools (Stylianidou & Ogborn, 1999).

We expected – and found – variation in how the teachers used computers in their teaching. This variation points to some very obvious assertions, but that are important to establish and re-affirm. One is that there are differences between teachers and that these differences cannot be either avoided or overlooked. In other words, it mattered a great deal in our case studies what teachers believed of themselves, who they were, what they could do and how they related to other people, all of which differed from teacher to teacher. Knowing about the school context was important. As well as differing provision of resources, differences in ethos influenced the expectations teacher and students had of each other, and thus of their interaction with the tool.

The provision of computers and informatic tools has not stopped being an issue for schools. Even in those schools that had a good level of provision, the lessons we observed were unquestionably adapted to the type of provision, though not heavily constrained by it. Technical difficulties made their presence felt in almost every case. Both the computer and the informatic tool used make practical demands that have to be dealt with.

The nature of the tool the teachers used always shaped the possibilities for what activities or interactions could take place. The computer and tool constitute an autonomous complex object, which will do what *it* can do, which is not always what you want.

The most significant variation was in the way the teachers handled the tension between subject matter and computer experience. Norton, Paul and Stewart were clearly interested in using the computer to deliver the science content; Simon and Ivan balanced somewhere in the middle, the first because he believed in balancing and blending, the second because he was of the view that 'we make what we can'. Finally, Bernard, Albert and certainly Chris focused primarily on the experience the students would have with the informatic tool.

Overall, we can say that the use of computers in the science classroom is still not fully naturalised or blended into the scenery. To use the computer is still a distinctive choice, needing justification. By now, though, it is not completely innovatory either, and there is increasing pressure for teachers to incorporate it in their teaching.

Developing the Training Materials

Having outlined the research results, we now describe the construction of training materials informed by them (Boohan *et al.*, 2000a). Their generic structure has already been applied to another curriculum innovation, on the teaching of energy (Boohan *et al.*, 2000b).

In programmes of teacher development, there is a balance to be struck between individual and institutional development (Bradley, 1991) and it has been argued that in the current climate of institutional accountability the balance has moved too far towards the latter (Bolam, 1993; Morley, 1994). However, a focus on individual development does not imply an individualistic approach. Indeed, many have argued that social activity and collaborative working are essential for personal development (Bell & Gilbert, 1996; Ruiz & Parés, 1997). In Joyce and Showers' (1988) widely discussed model, interaction with colleagues is seen as vital if changes in classroom practice are to result (see also Hargreaves 1994). In the STTIS workshop materials, we provided a set of resources that can be used to support this kind of collaborative work. The training activities are designed to help teachers to explore their existing ideas, learn about new approaches, and consider these in relation to their existing practice. Training which is divorced from their own practice is unlikely to have long-term consequences (Briscoe, 1991).

The design of the training materials starts from the fact that mere acceptance of the merits of an innovation is not enough for its successful take-up. A key factor is the extent to which an innovation requires activities to which the teacher is accustomed (or not). Teachers are concerned about whether an activity will keep students occupied and interested (Brown & McIntyre, 1992).

The STTIS training materials are intended to be used over two sessions. In the first session, teachers review their own practice, reflect on what drives that practice – using material deriving from the research results – and plan a lesson to try out new ideas. In the second session they review and evaluate that lesson, and plan a further sequence, discussing its rationale. The materials include activities for the teachers, notes for the trainers, and briefing sheets based on the research studies. The materials are best seen as a 'kit of parts' rather than as a fully specified training programme.

Building in research results

In order to design the training materials we chose to group factors that influence transformations under four headings:

- *Content* – the content of the proposed innovation and of the existing curriculum, and teachers' perceptions of how the new relates to the old.
- *Beliefs about learning* – what teachers think about how they should support students in the classroom, about what students find easy or difficult and why, and about what motivates students.
- *Values* – what teachers believe about the nature of their subject, about the purposes of education, about their own role as a teacher, etc.
- *Contexts, customs and constraints* – local factors such as 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, etc.

We next needed to find a way in the training materials to help teachers reflect on these sources of transformations. To bring them ‘alive’ for teachers we created a number of ‘vignettes’ or ‘stories’, in which imaginary teachers explained reasons for their decisions. In the training materials these are used to initiate and focus discussion on one or other of the four groups of factors. Teachers are asked to agree or disagree with positions stated in a number of ‘stories’, and to discuss their reasons with others. The aim is to help make explicit the effect of various factors, and in so doing pave the way for future possible changes of mind.

The main research results summarised in the four sets of ‘stories’ are discussed below.

<u>‘Stories’ about Content</u>

These ‘stories’ were written to illustrate different kinds of relationship between the use of computer modelling or simulation and knowledge to be taught. Some portray teachers who see computer modelling as potentially providing more effective ways of doing the kinds of things they are already doing. Examples are simulations as providing a useful resource for consolidation of knowledge, as an alternative to practical work, or as supporting students in testing predictions. Others portray computer modelling as providing new possibilities in learning about scientific modelling itself, or as teaching skills useful beyond the context of science.

An example is:

> I suppose that I see computer modelling as a complementary activity to practical work. In practical work we collect data, and we try to come up with a formula that accounts for the patterns. In modelling we start from a formula, and then make predictions about what should happen, which we can then test out experimentally. When I use a computer model, I usually start off by doing practical work, but I think that sometimes it might be interesting to start with a simulation first.

<u>‘Stories’ about Beliefs about Learning</u>

These ‘stories’ reflect a number of issues. Some describe the possible benefits of increased motivation through using computers, and the potential difficulties raised by lack of technical competence. Others state the view that simulations in science can make theoretical ideas more memorable through visualisation, or that they allow students to become intellectually engaged in theoretical thinking. Some portray motivation as simply a matter of making something ‘enjoyable’. Others offer a more complex view of motivation, suggesting for example that working with computers allows learners to take more responsibility for their learning by creating their own models, or through a more active engagement with the task.

An example of a ‘story’ related to student learning is:

> I think that computer simulations are very useful for making things memorable for students. In that sense, they are a bit like practical work. When students read something in a textbook, they are likely to forget it. But if they see a computer simulation of something, then they are much more likely to remember it, and to be able to write about it later. I think that this visual memory is very powerful, which is why I would be reluctant to let students build their own computer models. I would be worried that this might just reinforce ‘wrong knowledge’.

<u>‘Stories’ about Values</u>

These ‘stories’ reflect the way teachers, in describing their work on computer modelling, referred to personal values about what should be in the curriculum and how it should be taught.

One issue is how teachers see the nature of science itself and its consequences for learning. Computers may be seen as a tool for learning science or they may be seen as a tool that is central to science itself. These ‘stories’ illustrate the differing importance that teachers attach to experiencing phenomena first-hand, to understanding of science as a body of concepts and theory, to experiencing what is like to 'do' science, to understanding about the process of constructing scientific knowledge and to learning 'transferable' skills.

An example of a story expressing a personal value about what should be taught is:

> I am concerned about the use of computer models because I think that it is essential that students get first hand experiences of the physical world. This is what understanding science is all about. Simulations give the impression to students that it is easy to manipulate variables and to discover relationships. In reality it is very difficult to carry out experiments on the real world, and I think computers don't help students in appreciating this.

'Stories' about Contexts, Customs and Constraints

These 'stories' concern constraints of the context within which the teacher works and the influence of customary practices.

A first set is concerned with time constraints; teachers often report that computers do not in fact save time, while others think that there are gains, but only in the longer term. An important factor is the time required because of technical demands made by software and the competence of the students in using it.

A second set is about the availability of resources. How resources are used can have a major impact on the way that computer modelling is integrated into the teaching and on the style of learning. Computers may be used in small group work during the course of other activities or for independent work in a whole class setting. Activities may be less effective than they could be because of resource constraints.

The final set is about teachers' own competence and confidence. Some teachers feel that it is particularly important to retain control when using computers, and some find that the use of computers has made them become more open in their style of teaching. Others think that what really matters is the teacher's expertise in *science*.

Here are two examples of these 'stories':

> I use computers a lot in preparing my teaching materials because it saves time, so I hoped that using computer simulations in the classroom would also save time. However, in practice it does not seem to have worked out like that, because I seem to do things in more detail when I use a simulation than I did before.

> One difficulty of having to use the computer suite is that it is difficult to integrate the simulation activity into the rest of the work. It is not practicable just to go to the room for a few minutes, so sometimes I feel that I have to make the activity artificially longer than it would otherwise be. It is not possible just to use the computer in a spontaneous way at the points in the lesson where it would make most sense.

Conclusion

It has been argued that while innovation-focused training is essential, by itself it is too limited, and development needs to take into account the teacher as a person, as well as the purposes and the contexts in which that person works (Fullan & Hargreaves, 1992). Our approach focuses not just on the innovation but on teachers' beliefs and the contexts in which they work, and recognises that it takes time for teachers to change their practice.

The training materials developed are modest in scope, and can have only limited impact on modifying the effects of the factors identified in the research. Change needs to be seen as a continuous process and not a discrete event (Fullan, 2001). What can be done with these materials, however, is to make teachers aware of some ways in which the curriculum is transformed in implementation, and of how various factors affect the transformations that teachers make. By becoming more aware of these, teachers become able to make more 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 (White, 1998). This paper has discussed one possible way in which research findings can be made accessible to teachers involved in curriculum innovation.