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Teachers implementing pedagogy through REDEEM

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Abstract

Previous research has shown that teachers, working in computer supported classrooms, are often unhappy with what they perceive as a diminution of their role as educators. One solution to the problem of loss of control over the teaching and learning process is to provide teachers with tools to develop their own computer-based learning environments. The investigation presented here is a case-based evaluation of one such tool, the REDEEM authoring environment. REDEEM is designed to allow teachers to create intelligent tutoring systems (ITSs) by taking existing computer-based material as a domain model and then overlaying their teaching expertise. Three educators, one subject matter expert and two practising teachers, were observed using REDEEM to create an ITS for primary mathematics. They were asked to author for a 'virtual' class of students and were given the opportunity to review the consequences of their authoring decisions by watching videos of the 'virtual class' interacting with REDEEM. The evidence from an in-depth study of the participants' interactions with REDEEM confirms that the authoring environment is usable by authors with no previous experience in computer-based learning and that teachers can use it to achieve ITSs which match the perceived needs of their pupils. In addition, REDEEM can provide opportunities for teachers to reflect upon their professional knowledge.

1. Introduction

Teachers have the skills, knowledge and opportunities to provide learners with rich

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educational experiences in the classroom. However, existing computer-based environments provide little opportunity for teachers to put this knowledge into practice. For example, the evaluation of integrated learning systems (ILS) in UK schools provided evidence that teachers were unhappy with the diminution of their role which they saw as limiting the effective support they could give to their pupils (see Wood, Underwood & Avis, this volume). The ILS evaluation furnished a clear statement of teachers' criticisms of current systems that in turn provided a deeper understanding of how practitioners perceived a 'good' system would function. Teachers required greater control over the pattern of differentiation for individual children and clear and accessible feedback about their students' performance (see also Olson, 1988). There were also issues of content. Some teachers argued that they needed effective and usable tools to allow them to adapt the tasks and materials to suit their own context and purpose. Alternatively, other teachers felt that the system should simply be designed from the outset to support curriculum needs. In this paper we present a response to those teachers seeking greater control over computer-based learning environments.

One solution to this problem is to provide teachers with tools that they can use to develop their own computer-based learning environments. A number of authoring environments exist that allow the creation of computer-based teaching material (CBT). These include products such as ToolBook, HyperCard and Authorware. These environments allow authors to create learning environments that include a full range of multi-media and support fairly sophisticated interaction without the need to program. Unfortunately, these authoring tools do not solve all of a teacher's problems. The CBT that results from these authoring tools is rarely adaptive. Such software cannot easily adjust the content of material or its teaching strategy to suit the needs of different learners and functions. On the other hand, intelligent tutoring systems (ITSs) are designed to adapt to the varying needs of learners. Moreover, ITSs have been shown to be highly effective in a number of domains (e.g. electronics trouble-shooting, Sherlock, Lesgold, Lajoie, Bunzo & Eggan, 1992; LISP programming, LISP tutor, Anderson & Reiser 1985; algebra, Koedinger, Anderson, Hadley, & Mark, 1997). However, ITSs are estimated to require at least 200 hours of development per hour of instruction (e.g. Woolf & Cunningham, 1987). Until the time required for development is substantially reduced, ITSs remain too costly to be created to cover a substantial part of the school curriculum.

These observations have prompted the development of a range of authoring environments for intelligent tutoring systems. Such systems include Eon (Murray, 1998), Demonstr8 (Blessing, 1997), Diag (Towne, 1997), Idle-Tool (Bell, 1999), leap (Bloom, Meisky, Sparks, Dooley & Linton, (1995), and Rides (Munro, et al., 1997), Each focuses on a different aspect of the ITS development process and can be contrasted along such dimensions as depth of domain knowledge, generality and ease of use (see Murray, 1999). The system we report in this paper, redeem, represents one end of the continuum of these authoring environments. It allows authors to create adaptive learning environments by taking existing computer-based material as a domain model and then overlaying their teaching expertise. Thus, it aims to support authors with little or no previous experience in computer-based learning to develop simple but effective ITSs very rapidly. This goal identifies three important research questions:

1. Do teachers use the functionality that REDEEM provides? If all teachers view courses and students in the same way then REDEEM is redundant. Rather than provide teachers with tools we should instead give the 'right' ITS.
2. Are the REDEEM tools effective at eliciting teaching knowledge in order to create ITSs that are in line with teachers' expectations?
3. Are the ITSs more effective than the CBT alone? Does the additional time required to author with REDEEM result in sufficient 'value added' to justify its costs?

This paper reports on a study that addresses the first and second of these questions. We began with these questions because we aim to help teachers construct ITSs to match the perceived needs of their students. Only if these two questions can be answered satisfactorily does it make sense to explore the consequences of authoring on learners. We will start by providing a description of the REDEEM authoring process and the results of an initial formative evaluation to provide a context for the study.

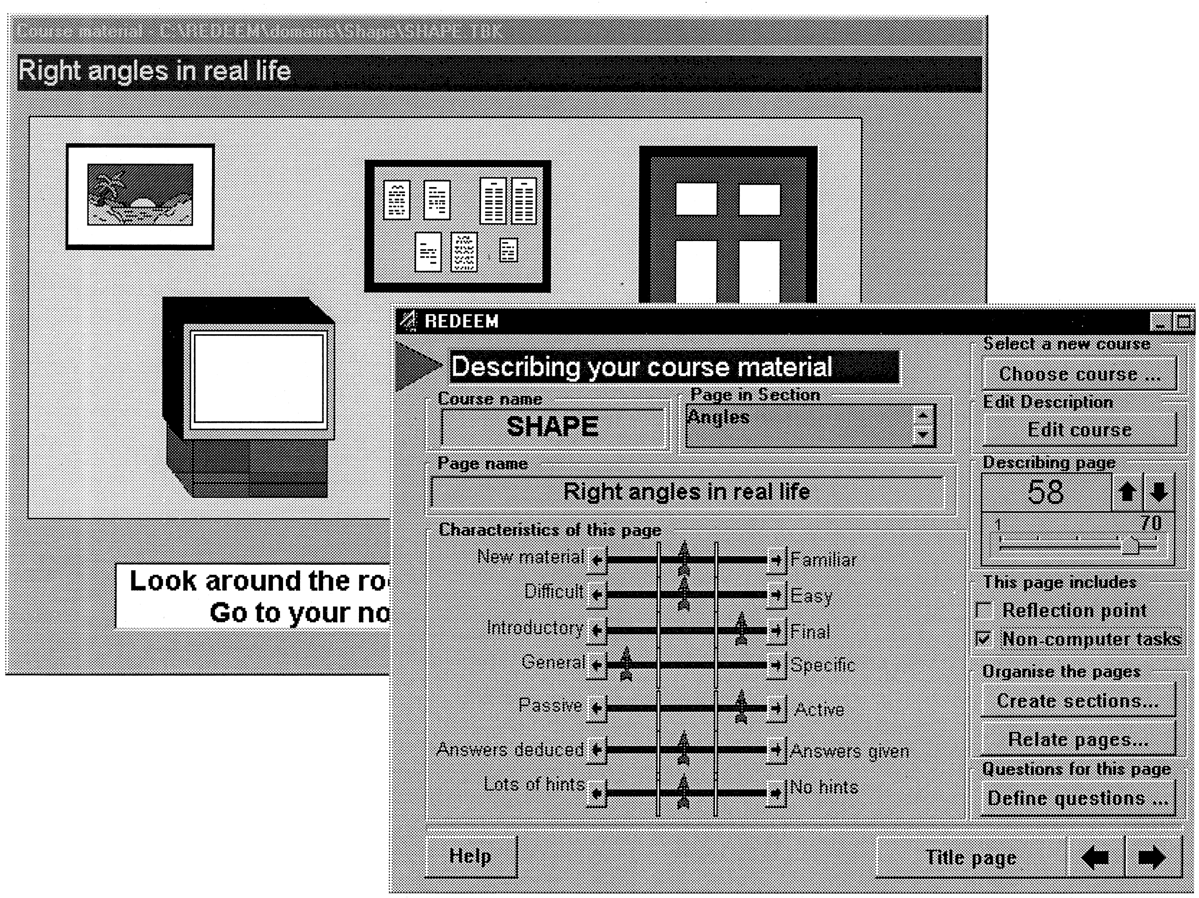


Fig. 1. The course material tool and page from the courseware.

2. Authoring with REDEEM

In contrast to many existing authoring environments, REDEEM is not designed to help in the construction of domain material. Instead, REDEEM allows existing course material to be delivered in an adaptive way to meet the needs of different learners. Consequently, a teacher uses REDEEM's ITS authoring tools to describe these existing courses, construct teaching strategies and identify students. The REDEEM shell uses this knowledge, together with its own default teaching knowledge, to interpret the courseware in such a way as to deliver adaptive instruction. The shell's role is to sequence this material for different users, provide a number of teaching strategies, supplement the course material with additional questions and feedback, support integration into classroom teaching by the use of non-computer-based tasks and reflection points, and to provide teachers with detailed feedback on students' performance. However, it is limited to the content of the pre-existing course.

Thus, REDEEM consists of three main pieces of software: courseware catalogues, ITS authoring tools and the ITS shell. In this section, we will describe the basics of each of these three elements, focusing on how the authors use REDEEM rather than on the software per se. A more technical description of the system can be found in Major, Ainsworth and Wood (1997).

2.1. Courseware catalogue

The first task for the author is to identify suitable domain material. This may either be in TOOLBOOK, downloaded from the WWW, or taken (with permission) from a commercial resource (see Fig. 1). Ideally such a course will include little pedagogic knowledge and will contain material that would benefit from more adaptive teaching. If the course contains existing control knowledge then this must first be removed. In principle, REDEEM is able to structure any CBT that contains individual pages of material. It should be noted, however, that the content of an individual page is treated as a black box by REDEEM.

2.2. ITS authoring tools

The ITS authoring tools allow teachers to describe courses, to construct teaching strategies, to categorise students and to assign different strategies and different material to those student categories.

The first decision when deciding upon the structuring of the material is to create and describe sections. Authors create sections by selecting pages from the course that they consider to be appropriate to a particular topic (see Fig. 2). A single page can be included in several sections. Each section is given a name that serves to describe its content and these should be 'child friendly'. Authors use dimensional sliders to rate each section and the pages within each section in terms of familiarity, degree of difficulty, generality, and whether the material is introductory or final (see Fig. 1). This leads to a set of dimensional ratings for each page and section. Relations between sections and pages can also be specified. So, for example, one section could be described as a prerequisite to another section or sections. These ratings, and any relations, are then used by the ITS shell to make decisions about routes through the domain (assuming a teaching strategy with low student control). The shell uses this

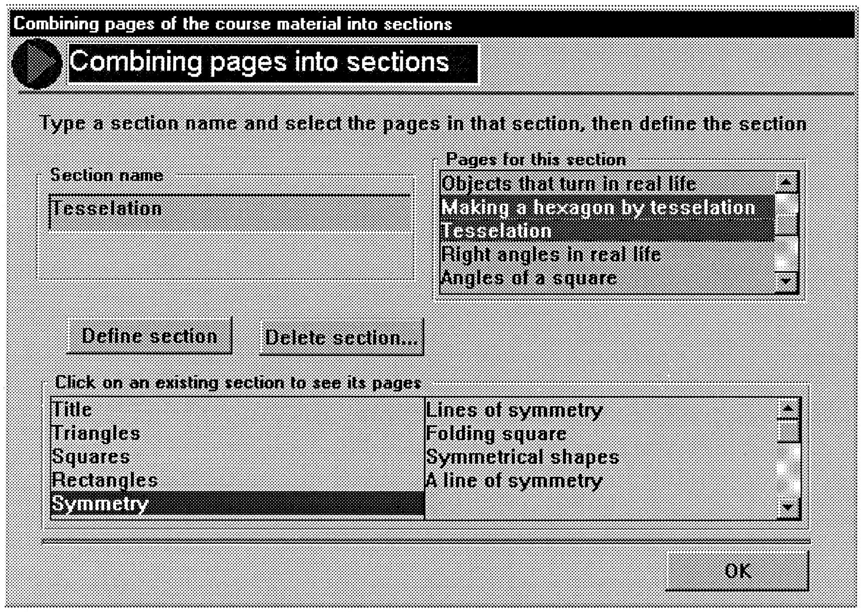


Fig. 2. The sectioning tool.

information to implement teachers' preferred routes through material and to make decisions about adapting content. Question templates allow teachers to define questions, specify answers and design contingent help (see Wood & Wood, this volume). Suitable points for non-computer-based tasks or note taking may be indicated.

Having either described a course or been provided with a pre-described course, authors can then customise it to their class by developing (or applying) teaching strategies for specific individual children or groups of children. Different teaching strategies can be created by manipulating dimensional sliders of eight different components of instruction (Fig. 3). Such dimensions include the amount of student control, position and amount of testing, and the nature of any help offered. Teachers are free to use previously developed strategies, edit them or develop new ones using the specified dimensions.

The next task for the author is to place students into a set of *author-defined* categories. The categories can either be fixed through the session or, if so wished, the validity of categories can be evaluated against a student's performance so that the categories can be performance related. The shell is designed to automatically change the category as the overall standard of the student (as defined in the student model) changes, commonly resulting in a new teaching strategy. Alternatively, dimensions such as learning styles or level of literacy of the target pupils can be used.

The final two tasks for an author are to associate these different groups of students with the teaching strategies that they have described and to identify suitable domain material for each group by associating sections and categories. Hence, one group of learners may be provided with the easier material from the course, whereas another group may have these sections removed to allow them to spend more time on more complex aspects of the material.

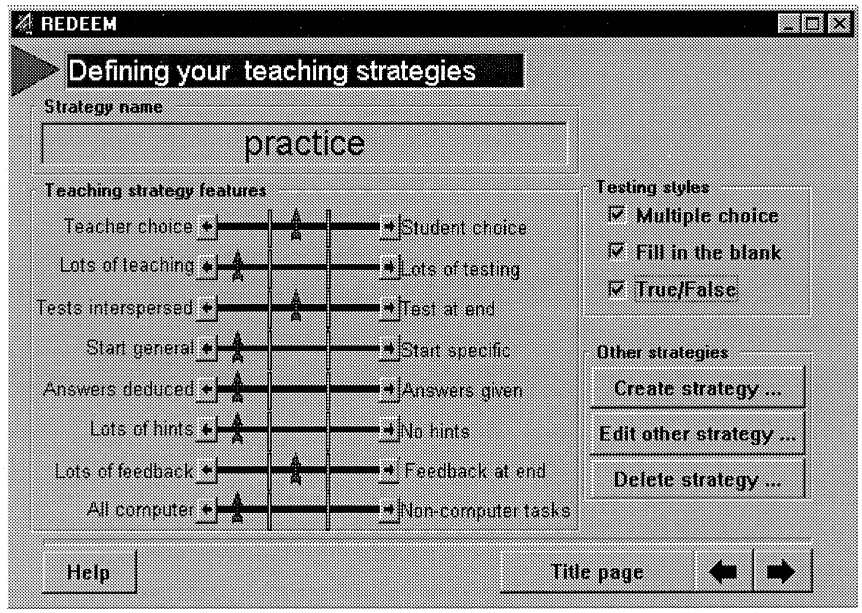


Fig. 3. Defining teaching strategies.

2.3. ITS shell

The ITS shell is given the teacher's pedagogic decisions and uses this input in combination with its predetermined defaults to deliver the course material. For example, it must decide upon the appropriate tutorial action, i.e. teaching, testing, summarising performance, suggesting note taking or a non-computer task. It uses rules developed from interviewing teachers. These include preferences for easy or introductory material when a student is starting a new section, and for more difficult material when the student is judged to be performing well. REDEEM, in a sense, incorporates a commonsense model of teaching. Other rules concern psychological principles such as those generated from contingent instruction, which helps determine the level of help students receive when answering questions (Wood, Bruner & Ross, 1976; Wood & Wood, this volume). Thus, REDEEM has general underlying 'black box' teaching knowledge that is overlaid by authored teaching strategies. For example, teachers do not have to tell REDEEM to prefer easy material before difficult, or familiar before novel. But, they can specify when these principles need to be violated.

REDEEM maintains a simple overlay student model to use as the basis of these decisions. The values of the model change over the course of a session as students see new material and as they answer questions. The shell also maintains a student history to keep trace of all modules taken, including pages visited, questions asked and answers given, number of hints offered, scores and time on tasks. This information is used for the basis of a report given to a teacher. Such a report is crucial if teachers wish to determine the impact of their authoring decisions on a learner's performance (Wood, Underwood & Avis, this volume).

2.4. Are the tools usable?

Ainsworth, Underwood and Grimshaw (1999) report a formative evaluation of REDEEM that examined whether the tools were usable by authors with no prior experience in developing computer-based learning environments. Overall, it was shown that it was possible for teachers to use these tools to express, represent and assess their teaching knowledge to create an ITS within a feasible time scale. We found that authors were able to use the REDEEM tools to structure the course. For example, they were able to use the dimensional sliders to describe pages and to create sections. They also appreciated the ability to differentiate instruction to their students in terms of material and teaching strategies. A number of small changes to the REDEEM interface were developed from author feedback and this led to some re-implementation of the system (e.g. the tools now support more flexibility in the way that sections are created). One area identified as a more substantial concern was how effectively the REDEEM tools support authors in understanding the consequences of their decisions. REDEEM is being redeveloped with this in mind and this paper explores the issue of feedback to teachers in some detail.

Furthermore, to stand a realistic chance of use in the classroom, REDEEM must not just be usable and effective, it must also be efficient of teachers' time. The first author took 11 hours to author the six- to eight-hour course and the second took eight hours. This resulted in a ratio of less than two hours per hour of (teacher-estimated) instruction. This timescale makes it a feasible option for teachers to be involved in the development of ITSs. Of course, this does not include the time taken to develop the course material, nor the time to develop the non-computer-based tasks. So it might be suggested than this comparison is untenable. However, we believe that as there is much CBT material than can be reused in this way, it is a useful metric.

However, this study left open the question as to whether teachers will be able to effectively use the functionality that REDEEM provides to meet their pedagogic goals. We now turn to that issue.

3. Comparing authors' pedagogy

It can be seen from the discussion of the different authoring tasks that there are two distinct roles in creating a REDEEM ITS; a subject matter expert's (SME) role, and a teacher's role. To some extent, these roles can be considered as analogous to the author of a textbook (SME) and a teacher deciding how the textbook should be used in a classroom (teacher). The role of the SME is to create the course material and (sometimes) to provide an initial course description. The role of a teacher who has detailed knowledge of the population being taught is to describe their class, to develop or adapt preferred teaching styles, to support a given body of learners and generally to customise the ITS to fit the perceived needs of a specific group of learners. It is perfectly feasible for one person to take on both roles but we would envisage that once the system has been adopted for classroom use, this situation would arise infrequently. These two roles for authors have informed the design of the study we have conducted and are referred to below as describing or customising the course.

Three educators were recruited, one SME and two teacher practitioners (TPs). The SME was a teacher trainer with over 20 years' experience in teaching primary mathematics, who had previously been instructed in the use of REDEEM. Her role was to choose the domain and develop the course content. She chose to develop the 'Understanding Shapes' course and she created a booklet that contained a short description of the course and stated its relationship to the UK National Curriculum (England and Wales). 'Understanding Shapes' is suitable for primary school children (7–11 years). It focuses on mathematical concepts such as angles, vertices and symmetry. The material covers around eight hours of teaching and includes a full range of multimedia presentations, with text, graphics, sound and video. As well as designing the course content, the SME was asked to author the course in order to provide a basic structural description to be given to one of the TPs. The SME authored the course on a laptop at some distance from the researchers, making notes as she proceeded. She was asked to review her decisions at the end of the study and additionally chose to perform some customisation of her original course as well. We refer to these two stages as SME1 and SME2.

Both teacher practitioners were classroom teachers. They were the maths coordinators in their respective primary schools and had not developed computer-based material prior to this study. They were asked to describe and customise the course. TP1 was asked to author with REDEEM from the raw CBT provided by the SME, whereas TP2 was made aware of the SME's authoring decisions and asked to alter them as she felt appropriate. Giving the TPs two different roles has allowed us to explore the varying ways that REDEEM might be used in a school. Authoring by the TPs took place over a number of sessions at the research base. The TPs' interactions with the program were video taped and, in addition, the researchers made notes on any interesting and/or anomalous events as the work progressed.

The tasks that each author had to perform can be seen in Table 1. As each author was given a different remit, it can be seen that they did not all perform the same tasks in the same order. For example, the SME and TP1 began by considering the raw CBT whereas TP2 started by playing through the SME's course in REDEEM.

In order to compare the three educators' descriptions of the course, it was necessary for them to author for the same group of learners. However, we also needed to record learner interaction with the ITS to examine authors' reactions to the course. This produced a chicken and egg problem. No learner could use the course until it had been authored, but authors

Table 1
A description of the tasks that each author performed

	Describes course	Play-through review	Outcome of review	Redescribes course	Customises course	Finished course	Virtual class review	Outcome of review
SME1	Raw CBT					SME1 course		
SME2		SME1 course	Major changes to SME1	SME1 course	Yes	SME2 course		
TP1	Raw CBT				Yes	TP1 course	Yes	Minor revisions
TP2		SME1 course	Major changes to SME1	SME1 course	Yes	TP2 course	Yes	Minor revisions

without learners cannot judge the consequences of their authoring decisions. A seemingly simple solution would be to trial the courses with a group of children. However, this would either mean the same children being asked to operate four versions of the course — a nonacceptable option on pragmatic and ethical grounds — or compromising on the level of equivalence between the target learner populations. We chose a third option of creating a simulated class. That is, we developed a virtual class of 7-year-old girls. Using a virtual class not only ensured standardisation of child behaviour, but also allowed the educators to focus on the performance of REDEEM rather than on the behaviour of an individual child per se. Vignettes were developed describing each child's performance in mathematics over the last year. The class was constructed to represent a wide range of abilities although extremes were avoided. The profiles were developed from records of real children personally unknown to any of the participants. A headmaster from a local school then reviewed them for interpretability, authenticity and language. An example of a child profile is shown below (Fig. 4).

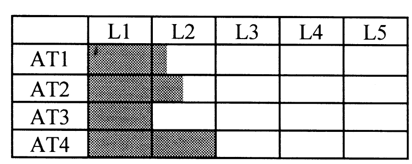
After each participant had finished authoring, simulated 'learner' interactions with the ITS were recorded. These consisted of a video of the screen while a researcher acted out the role of each child in the 'virtual class'. Every effort was made to keep these interactions as consistent as possible with the profiles. For example, error profiles were developed for each child and this 'learner' behaviour was scripted. An example of such a script can be seen below.

Sally (level 1, first time on course)

- She will work through the course quite slowly.
- If the information on the page is relevant, she will use it to help her answer the questions correctly.
- If the information on the page is irrelevant to the question, she will probably get the answer wrong.
- She will make errors 50% of the time.
- If a hint mentions any critical features, then it will help her get the correct answer 75% of the time — otherwise there is only 25% chance she will be right.

In a structured interview, the TPs were shown the videos and asked to comment upon whether the ITS was behaving as they expected (not on the 'child's' performance). Whilst this technique

Sally is a steady mathematician who is showing increasing confidence. For example, she can work successfully with concrete objects to solve addition and subtraction problems and is easily able to order 2 digit numbers. Her number bonds are weak in some places and she finds independent investigations hard. She works successfully with the 2D and 3D shapes she has met. This is her first time with the 'Shapes' course.



AT1 – AT4 = UK National Curriculum Attainment Targets

AT3 refers to Shape

L1 – L5 = Levels of attainment

Fig. 4. An example of a child profile.

cannot be used to evaluate learning outcomes with REDEEM, it provided insight into the processes of authoring and teachers' evaluations of the educational effectiveness of the system.

4. Results

In order to test the claim that teachers want to structure material presented to their students, we compared the different teaching decisions made by the three authors. We have chosen to focus on their views about structuring the teaching content in this paper (describing the course). Subsequent analysis will address authors' views about who they are teaching and how they prefer to teach (customising the course). In this section we will present fine-grained analyses of these decisions to ascertain whether REDEEM does allow authors to express different views. It should be emphasised that we have no views as to the relative merits of any of the course structures. The relative effectiveness of different decisions such as these will be evaluated when REDEEM's role in promoting learning outcomes is addressed in future classroom trials.

Table 2 shows the different sections formed by the different authors and the order in which they were presented by the ITS. The numbers in the columns headed 'DR' refer to the weighted sum of the decisions based on the REDEEM shell's interpretation of the dimensional ratings. It is important to remember that sections given the same weight could have been constructed from very different dimensional ratings. For example, 'vertices' which was given the same weight by the Shell for SME2 and TP2 was described as:

Table 2
A comparison of the resulting order of sections created by the authors

TP1 (start from CBT)	DR[a]	TP2 (start from SME1)	DR	SME1 (start from CBT)	DR	SME2 (start from SME1)	DR
Title	4	Title	4	Title	4	Title	5
Triangles	5	Circles	5	Circles	5	Triangles	5
Squares	5	Squares	6	Squares	6	Circles	5
Rectangles	5	Rectangles	6	Vertices	7	Squares	6
Circles	6	Triangles	6	Tangrams	8	Rectangles	7
Tangrams	8	Vertices	8	Triangles	8	Right Angles	8
Symmetry	10	Angles	8	Tessellation	7	Concept of an angle	8
Tessellation	10	Tessellation	9	Symmetry	8	Vertices	8
Vertices	11	Polygons	10	Angles	8	Tangrams	8
Angles	12	Right angles	10	Polygons	9	Tessellation	8
Regular and irregular polygons	12	Tangrams	11	Rectangles	10	Symmetry	9
Quadrilaterals	12	Quadrilaterals	11	Quadrilaterals	9	Polygons	9
		Symmetry	12	Applications	10	Triangles 2	9
		Triangles 2	12			Quadrilaterals	10
						Applications	10
						Names of polygons	11

[a] DR = derived rating.

SME2 {Easy, Fairly Introductory, neither General nor Specific, Unfamiliar}
TP2 {Fairly Easy, Fairly Introductory, General, Unfamiliar}.

For the purposes of this paper we will generally not need this level of description. If two sections have been given the same weighting by the teachers' use of the dimensional sliders, then the REDEEM shell will differentiate between those sections by applying relational information such as prerequisite information. The consequences of this can be seen in SME2's trace. The 'title' section is given the same weight as the subsequent two sections, but is a prerequisite to those sections and so occurs first. Similarly for SME1, 'rectangles' is prerequisite to 'quadrilaterals' and is chosen first, even though its weighting is higher and it would normally come later.

A number of important points should be raised about these decisions. Firstly, we need to determine if the structure of the underlying CBT solely determines the structure of the REDEEM course. In all cases, the authors, although influenced by the structure of the CBT, go beyond it to impose their own views of the learning experience that they wish to provide. It should be noted that the CBT itself has a flat structure — there are no sections, just individual pages. For example, all authors created a section and called it 'circles'. Each included the same four pages (pp. 36–39 in the CBT). Yet, the decisions authors made about its content using the dimensional sliders ensured that it is presented to learners very early on whereas in the underlying CBT these pages are placed in the centre of the course. Additionally, pages within a section are not simply composed in a linear order from the CBT. For example, there is material on triangles throughout the CBT (pp. 2–7, 9, 41, 42, 64–66, 68) and this is recomposed by all of the authors into either one or two sections.

Unsurprisingly, given the simple nature of the underlying material, there are striking correspondences between the sections that the authors describe. This can be seen, for example, in the similar names given to various sections. Table 3 compares the content of the sections created by the TPs and the SME. It distinguishes between sections that were identical across authors in terms of the pages included, although not necessarily identical in terms of the descriptions of the pages or sections; and sections that were merely similar, that is containing no more than four different pages across authors. In addition, it highlights concepts which

Table 3
A comparison of the content of sections created by the authors

Identical	Similar	One section	Divided section	Distinct
Circles	Rectangles	SME1, TP1	SME2, TP2	SME1, SME2
Quadrilaterals	Squares	Angles	Concept of angles	Applications
Symmetry	Vertices		Right angles	
Tangrams	SME1, TP1, TP2	SME2		
Tessellation		Polygons	Names of polygons	
			Polygons	
		SME1, TP1	SME2, TP2	
		Triangles	Triangles	
			Triangles 2	

some authors chose to include within a single section and some authors subdivided in two or more.

Together Tables 2 and 3 give a global view of the basic similarities and differences between the authors (we will return later to some more fine-grained analyses). They show how all the authors constructed sections concerning basic shapes and primarily described those sections as 'more easy', 'familiar', 'introductory', etc. They then created more advanced sections on properties of shapes such as 'vertices', 'symmetry' and 'angles' and also sections that were concerned less with familiar shapes (or shape terms) such as 'polygons' and 'quadrilaterals'. There is less agreement about the properties of these sections although they are generally described as 'more difficult', 'less familiar', etc. For example, the 'tangrams' section would be presented fifth to TP1's class, tenth to TP2's class, fourth to SME1's class and eighth to SME2's class.

The authors did not identify the same number of sections in the course — without the title section, they constructed between 11 (TP1) and 15 (SME2) sections. As can be seen from Table 3, the majority of the additional sections comes from creating sections that were more fine-grained. Whereas TP1 and SME1 described a section 'angles', TP2 and SME2 split this into two sections; one that introduced the term angles and one that concentrated solely upon right angles. Generally, it can be seen from the tables that authors tended to see the same 'concept' (e.g. circles, polygons) but sometimes differed in their views of the relevance of individual pages to that 'concept'. When this occurred, it was often because some authors (TP1 and SME1) were keen to emphasise redundancy by placing a single page in multiple sections (e.g. 'vertices of triangles' in the 'vertices' and 'triangles' sections) whereas others (SME2 and particularly TP2) tended to keep clear boundaries between sections. The only section that was distinctly different from those created by all other authors was 'applications' created by SME1 and retained by SME2, which covered a broader range of pages concerned with applying properties of shapes.

However, even if the authors tended to agree about the relevance of pages to a section, they sometimes described those individual pages quite differently. In short or simple sections, like 'circles', all authors gave the pages essentially the same ratings and the order in which they appeared in the shell is the same. This can be contrasted with the sections concerning angles. This is shown in Table 4 where the order in which the angles would have been presented in the ITS shell is shown. (Note that all pages have been renamed so as to be consistent across authors whereas in reality each author chooses their own names for pages. Double lines in the table indicate a section break.)

Generally, all authors placed the same pages within these sections, although TP2 and SME2 created two sections whereas SME1 and TP1 described only one. However, each decided on a very different structure for the sections. TP1's course started on pages that introduced angles, then moved on to pages that introduced the concept of right angles. She returned to properties of angles to consider the size of angles and then ended on pages which she viewed as difficult ones on right angles. This was fairly similar to TP2, although she had two sections, so this meant that the 'size of angle' page came earlier. TP2 introduced right angles by reference to pictures of right angles in real life, whereas TP1 used this page only after defining right angles more technically. SME1's course again started by 'defining an angle' but then moved to consider real-life examples of right angles. She placed 'corners of rectangles' last whereas for TP1 this page was the first that the children were presented with on right angles. Finally, SME2 on re-authoring her earlier course, changed her mind quite radically about her earlier course. She now introduced right

Table 4
Pages in the angles sections for the different authors

TP1	TP2	SME1	SME2
Defining an angle	Defining an angle	Defining an angle	Angles of a square
Objects that turn	Objects that turn	Size of angles	Symbol for a right angle
Corners of rectangles	Size of angles	Right angles in real life	Right angles in real life
Symbol for a right angle	Right angles in real life	Objects that turn	Corners of squares
Angles of a square	Corners of squares	Angles of a square	Defining right angles
Corners of squares	Defining right angles	Symbol for a right angle	Corners of rectangles
Inside/outside angles	Corners of rectangles	Corners of squares	Inside/outside angles
Right angles in real life	Inside/outside angles	Inside/outside angles	Recognising right angles
Size of angles	Counting right angles	Recognising right angles	Counting right angles
Recognising right angles	Recognising right angles	Defining right angles	Defining an angle?
Defining right angles		Counting right angles	Objects that turn
Counting right angles		Corners of rectangles	Size of angles

angles first and only after this had been completed did she introduce the defining properties of angles. It can be seen from these decisions that even when the authors identified comparable concepts and included similar pages it did not follow that they shared a similar view about the right way to structure the material.

The final decision about sections that authors must make is to relate sections to the various student categories they developed. This is presented in Table 5. Although the authors' approaches to classifying the virtual class are not addressed in this paper, it can be seen that each spontaneously developed five categories. However, these categories were not the same and did not include identical children. For example, SME2 and TP2 did not make reference to a learner's familiarity with the course whereas TP1 did. Although these differences are interesting in themselves, they are not important for the purposes of comparing how sections are used. Table 5 shows each of the author's decisions about sections and categories of student (note SME1 did not perform this task). Each new category includes all of the previous category's sections unless indicated, so for example TP2's Group B receives 'triangles', 'circles', 'squares' and 'rectangles' in addition to 'symmetry', 'tangrams' and 'tessellation'.

TP1 related students to sections in a way that matched her course structure. So, for her class, she started with basic shapes, then as she progressed through the groups, she included sections of increasing difficulty, less familiarity etc. With the final group, she removed basic shapes (those pages that she had given her first group). TP2 followed a similar format to TP1, but differed in that she started with many more sections for her first group. The only additional sections she introduced for other groups were 'symmetry' and 'triangles 2'. The last change was for the high group where she added 'tangrams' whilst removing basic shapes but for 'triangles' (which remained as it was prerequisite to 'triangles 2'). SME2, in common with TP2, also included many more sections to start with. She included sections in an order that was not so strictly related to the dimensional ratings that she had used to structure the course. For example, 'concept of angles' was presented for the first time to the group 'high' even

Table 5
A comparison of authors' identification of sections and students groups[a]

	TP1		TP2		SME1	
Group	Sections +	Sections –	Sections +	Sections –	Sections +	Sections –
A	Circles, rectangles, squares, triangles		Angles, circles, polygons, quadrilaterals, rectangles, right angles, tessellation, triangles, squares, vertices		Applications, circles, names of polygons, quadrilaterals, rectangles, right angles, squares, tangrams, tessellation, triangles, triangles hard, vertices	
B	Symmetry, tangrams, tessellation				Symmetry	
C	Angles, quadrilaterals, regular and irregular polygons, vertices		Symmetry, triangle2		Polygons	
D			Tangrams	Circles, squares, rectangles	Concept of an angle	Circles
E		Circles, rectangles, squares, triangles				

[a] Note: For clarity each cell in the table shows only the changes that the authors make for each group of children. So children in group B receive all the sections given to children in group A plus any additional sections (in the sections + column) minus any sections that the authors think are not relevant for that group (indicated in sections – column). Blank cells indicate no change.

Key:

Name	A	B	C	D	E
TP1	Towards level 1 unfamiliar	Level 1 unfamiliar	Level 1 familiar	Level 2 unfamiliar	Level 2 familiar
TP2	Group 5	Group 4	Group 3	Group 2	Group 1
SME	Very low	Low	Middle	High	Very high

though in terms of its weighting it was less difficult than some sections that were included for the 'very low' group.

5. Outcome of reviews

Each of the TPs was shown videos of the virtual class interactions with REDEEM. Overall, both TPs were happy with the way that REDEEM interpreted their decisions to order the way in which the pages and sections of the course appeared. TP2 commented that she found REDEEM to be 'very versatile'. It is this versatility that makes REDEEM such an effective application. As the TPs' experience with REDEEM grew they increasingly appreciated it and began to make more use of this functionality. For example, after reviewing their authoring decisions, all the authors suggested that they would like to make some sections more fine-grained in order to have more flexibility about how material was presented. So, TP1 suggested that her sections — 'triangles' and 'squares' — needed to be split into smaller subsections. TP2 had already subdivided 'triangles' and 'angles' into 'triangles'/'triangle2' (harder material) and 'angles'/'right angles', respectively. However, she felt that further subsectioning of 'right angles' was necessary. This would have allowed her to present the 'easier, introductory' material to the lower groups, reserving the more difficult material on 'inside and outside right angles' for the higher groups. They also began to consider less obvious ways of structuring the course. For example, TP1 proposed a new section called 'easy shape' which included the easy pages on squares, rectangles and triangles. Splitting the sections in this way would have allowed her to present just the easier material to children in her lower groups.

6. Summary of results

In general, although there were some marked similarities between the authors, each produced a distinct version of the course. When reviewing the consequences of their decisions, each author was generally happy with how the shell had interpreted their authoring. Such genuine differences between authors illustrate that not all educators view even a simple course in the same way. We would argue that this justifies the REDEEM philosophy. It also suggests that the REDEEM tools are effective at capturing different views of courses.

There was greater similarity in course structuring between the TPs than between the TPs and the SME. Whilst, with such a small study we cannot be sure that this reflects differences in roles rather than between individuals, it is an interesting avenue for further exploration. Further statistical analysis is on-going. This difference was particularly striking as TP2 had been given SME1's course to author and so we might have expected more convergence between these two authors. The significant restructuring of the course by TP2 attests to teachers' abilities to reshape computer-based material. Given the right opportunities, they do not feel obliged to stay with the decisions made by an external authority.

The similarities between the TPs are based in part on their knowledge and use of the National Curriculum for the teaching of Attainment Target 3 (Shape, Space and Measures). Their courses align to it closely in places. However, the TPs did differ especially in the way they described sections such as 'symmetry' and 'tangrams'. They also differed in the way they related sections to student categories. TP1 gave far fewer sections to her lower performing groups. In contrast, SME1 was much less tied to the National Curriculum. For example, for all groups she included 'tangrams' and 'vertices' before all the basic shape sections had been covered. Unlike all the other authors, SME1 positioned 'rectangles' very near the end of the course. Furthermore, after the virtual class review, the TPs appeared to converge even closer. This can be seen in TP1's use of more fine-grained categories for 'triangles' and 'angles' and

TP2's new decision not to give her lower group sections on 'tessellation', 'polygons', and 'quadrilaterals'.

7. Conclusion

It can be seen from the evaluations presented in this text that the REDEEM tools allowed teachers to construct courses that were adapted to their views of the perceived needs of learners. They imposed their own views about the structure of the course being influenced by, but not reliant on, the structure of the underlying CBT. There were noticeable similarities between the authors, but at the same time the differences between them were striking enough to warrant the provision of authoring tools. Overall, the two TPs were more similar to each other than either of them was to the SME.

We also investigated the authors' views on the consequences of their authoring by playing the videos of a virtual class. For the most part, the authors were happy with the REDEEMed courses. All authors continued to suggest improvements to the course descriptions, but this does not mean they were overly critical of their initial authoring. Instead, this is a product of the way that REDEEM can provide a real opportunity for teachers to reflect on their understanding of the course content and the implications of their pedagogical decisions.

In this study with REDEEM we noted three avenues for professional development. These opportunities were present throughout the authoring process (1, 2 and 3) and after the virtual class review (2) — a procedure that aimed to approximate the experience of observing children using a REDEEMed course in the classroom.

1. Teachers are required to become more explicit about their views and this can cause them to reflect more deeply upon their underlying conceptual model. For example, TP1 commented "A lot of the confusion I've had has been to do with the way we teach shape — where we don't start 'These are polygons'... So I've put triangles and squares together, but if you were doing it like a tree diagram, quadrilaterals and triangles would be on the same level".
2. They can experience the consequences of their own teaching decisions. TP1 upon reviewing the course began to change her views from 'questions as tests' to 'questions for prompts for engagement'.
3. Teachers can compare views of the course provided by different authors. The participants in this study looked at the other authors' views of the course in the REDEEM tools after the study was completed. They all expressed interest in the other views to the extent that they either wished to talk to them or asked the experimenters to ask questions on their behalf. REDEEM by providing an external representation of teachers' views of course structure can prompt these sorts of discussions.

In previous evaluations of computer-based learning environments, some teachers expressed a desire to have a formative role in creating the educational experience of their pupils (e.g. Wood, Underwood & Avis, this volume). In this paper, we have shown how the REDEEM ITS authoring environment can support teachers in these goals. Furthermore, we argue that in so doing, the REDEEM environment provides teachers with the opportunity to reflect upon their pedagogic practice. In analysing content, describing their pupils and developing teaching strategies, teachers are provided with new opportunities to test and improve their understanding of core pedagogic skills, including the structuring of the knowledge base and adapting content to learners' needs.

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