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Using a Single Authoring Environment across the Lifespan of Learning

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ABSTRACT

For a single authoring environment to be sufficiently general to be applicable to contexts across the whole lifespan of learning, some of the benefits that come from knowledge-rich domain specificity have to be sacrificed. Consequently, it is an open question as to whether it is possible to achieve effective learning environments from a generic tool. REDEEM is an authoring environment that aims to achieve this by creating adapted and interactive learning environments from existing courseware. In this paper, a 10-year research program is described that has assessed the usability, functionality, and effectiveness of REDEEM's approach.

Keywords

Authoring environments, Evaluation, Usability, Pedagogy, Learning outcomes

Introduction

The goal of authoring environments is to make the creation of effective learning material easier. This could have a range of benefits: for example, authors without technical skills but with relevant pedagogical knowledge could create learning environments; the time taken to create learning environments could be reduced (as creation of learning environments is variously estimated at between 200 and 1000 hours per hour of learning); learners and authors could benefit from consistent interfaces across a wide range of courses; and good practice could be supported by providing tools that encourage (or enforce) specific designs.

To achieve these benefits for authors and learners, it is apparent that the authoring tool must be sufficiently general to adapt to different domains and potentially different types of learners. And this raises a problem. Typically authoring tools that are the most generic are only capable of creating learning environments with the least depth of knowledge and power (Murray, 1996; 2003). Consequently different authoring environments have taken different positions of the generality/depth continua. A system such as the LEAP Authoring Tool (Sparks, Dooley, Meiskey, & Blumenthal, 2003) is very specialized. Its purpose is to create material to train telephone operators to handle customer requests over the telephone. As a consequence of this domain specificity, however, the system can rely upon conversation grammars. These contain a description of all the individual actions that the actors in the conversation may take, as well as hints for each step of the conversation, and audio recordings and textual representations of actions. DIAG (Towne, 2003) is another specialized authoring system, this time for fault finding and diagnosis. It does not solely rely on general troubleshooting principles but instead uses domain-specific reasoning to monitor students' undertaking fault diagnosis on specific simulated equipment, demonstrating and explaining expert performance. Aleven et al. (2006) discuss the CTAT authoring system. A powerful authoring tool is available for authors with artificial intelligence programming skills, but for those without such knowledge, simpler intelligent tutoring systems can be built where authors create user interfaces by direct manipulation and then use a behavior recorder tool to demonstrate alternative correct and incorrect actions. Other authoring tools such as RIDES (Munro, 2003) and SIMQUEST (van Joolingen & De Jong, 2003) create powerful simulations to support discovery learning and guided practice.

In contrast, the authoring environment described in this paper (REDEEM) takes the opposite position of the generality/depth continua. REDEEM has shallow depth of knowledge and has only a limited range of tutoring actions, but can be applied in a very time-efficient manner to many different domains and learners. It remains, therefore, an open question: Can a single authoring environment that is sufficiently general to adapt to contexts across the whole lifespan of learning still have sufficient power to deliver effective learning experiences? Consequently, in the remainder of this paper, a brief system description will be provided (see Ainsworth, et al., 2003, for more details) and then the 10-year research program with REDEEM will be reviewed to examine the strengths and the weaknesses of taking this approach to lifelong learning.

System description

The REDEEM authoring environment was developed in Click2Learn ToolBook Instructor and runs on Windows 95+. It consists of two main pieces of software (authoring tools and REDEEM shell) through which authors and learners interact with courseware. This is one of the most unusual features about REDEEM: courseware is not created within the system but instead remains external to application and is delivered through REDEEM. For example, courseware can consist of pages of either Click2Learn ToolBook or HTML/Gifs/JPEGS etc. and can contain multimedia, simulations, animations, questions, and exercises. Examples of material used to date include existing ToolBook courses on topics such as genetics, communication and information systems, PCs and networking, html courses on statistics, and principles of photography. This decision significantly reduces the time needed to author learning environments and allows reuse of much existing material but obviously limits the tutorial actions available to REDEEM.

Authoring tools

REDEEM's authoring tools use simple graphical interfaces to allow authors to describe how they want the computer-based teaching (CBT) to be taught for different learners. There are four main tools: domain tools (which describe the material and add interactivity); student tools (to describe student categories); strategy tools (to develop different teaching strategies); and macro-adaptation tools (which assign particular domain materials and teaching strategies to the categories of students).

Domain tools

The first major task that needs to be performed is to describe the domain material, which ultimately the system will use to make decisions about how to present material to the learners. Sections are created by combining pages, which need not consist of contiguous pages in the underlying courseware. Pages can also be in multiple sections. Sections are then described upon a number of dimensional ratings, (i.e., familiar, easy, general, or introductory). Authors describe relations between sections, for example, the prerequisite relation, which ensures that a section is not taught until prerequisite sections have been completed. Pages are then described using the same process, dimensional ratings are provided and, if required, prerequisites can be set.

The second major aspect of domain authoring is to add interactivity. Authors create questions (multiple choice, fill in the blank, multiple true, true-false, or matching questions) and provide feedback that will explain to the student why an answer is correct. Five different hints for each question can be created, which ideally increase in specificity. Authors describe a number of characteristics of the question that the shell uses to implement a specific teaching strategy (e.g., difficulty, pre- or post-test). Authors can also associate a reflection point (which means that students are prompted to take notes) or a non-computer task (which directs student attention to another activity) with a page.

Student tools

Student categories can be created at any degree of granularity, ranging from a whole class to an individual student. Authors typically have tended to use performance-based measures (e.g., high flyer, struggler) or task-based measures (e.g., revising) or have combined these (e.g., high reviser). But, it is possible to use any dimension that authors find appropriate and that the domain material will support (e.g., maths phobe, visualizer). The validity of performance-based categories can be evaluated against students' question performance. The shell can then automatically change the category as the overall standard of the student (as defined in the shell's student model) changes. If this occurs, then both content and teaching strategy may change as the system macro-adapts to the new category.

Strategy tools

REDEEM allows authors to create multiple teaching strategies. Different instructional principles can be embodied in various strategies by manipulating graphical sliders. Each slider in Figure 1 has three discrete positions that result in different instruction. For example, slider 7 (post-test) allows authors to describe if questions should be asked after each page, at the end of the section, or at the end of a course; and slider 5 sets the way that help is provided to either help on error and request, help on error only, or no help at all. By combining these different settings, different strategies can be created. For example, an author might create a "Free Discovery" strategy where students choose the material they see and the questions they answer, and the number of attempts allowed for each question is unlimited; they can chose to receive help and whether to perform non-computer-based tasks. In total, REDEEM can offer nearly 10,000 different teaching strategies, each (very) subtly different to each other, although to date no author has created more than eight for a particular class of students.

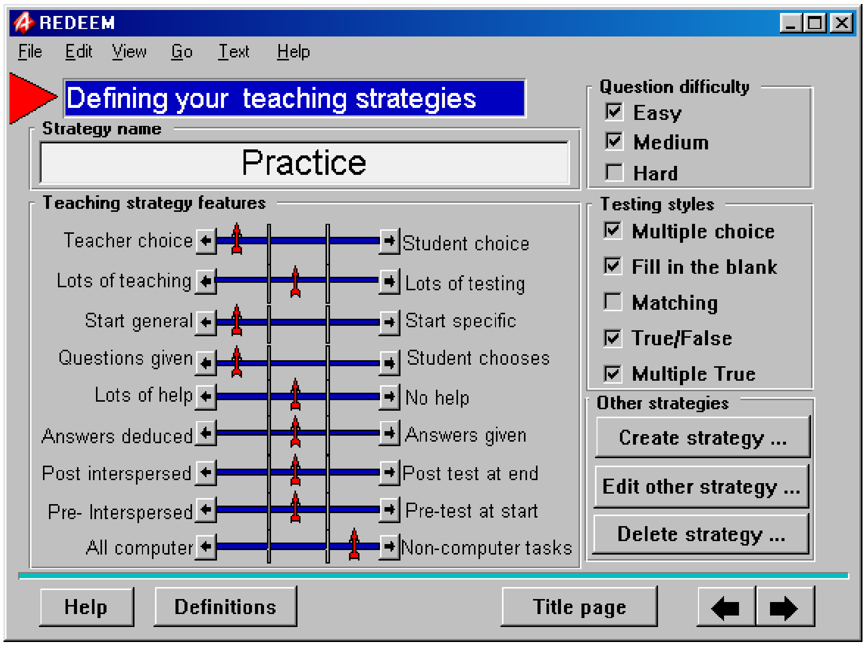

Figure 1. Strategy Authoring

Macro-adaption tools

Macro-adapting the material is achieved through the use of student categories, as content and strategies can be associated with a specific category. By default, learners see all the material, but the author can choose to remove sections for a particular category (e.g., to focus on introductory material for learners who need more help or include extension activities for students who could benefit from more challenging tasks). Each student category is also given a teaching strategy (e.g., high flier with free discovery). To date, authors have varied from creating a single preferred strategy to creating a unique strategy for each group or even for an individual student.

REDEEM shell

The REDEEM shell uses the output of the authoring tools, together with its own default teaching knowledge, to deliver adapted (occasionally adaptive), interactive courseware. The main role for the REDEEM shell is to deliver the course material to each student in the way that the teacher specified with the authoring tools. Tutorial actions available to the shell (depending upon the teaching strategy) are: teach new material; offer a question (and help if appropriate); suggest that students make notes on the online tool; offer a non-computer-based task and by means of password protection check that is has been completed; change student category; or summarize students' progress. To achieve this REDEEM uses a basic overlay model that records the system's understanding of the student's knowledge of an area. The values of the model change over the course of a session as the student sees new material and answers questions. If student categories are performance-based, then the student model is used to determine if learner should change category. The shell also maintains a student history. This is used to offer reports to the author either on an individual student's progress, a student category's progress, or to give a report on the course.

Mixed-initiative REDEEM

The version of REDEEM described above has been used in situations where a teacher is available who wishes to take responsibility for macro-adapting REDEEM (i.e., assigning material and strategies to learners via student categories). This has been the way REDEEM has been used in conventional classrooms (primary, secondary, and military). However, not all learning situations are teacher-led, and to allow REDEEM to be useful in informal and student-led learning, it seemed appropriate to create a version where learners macro-adapt REDEEM to suit themselves. Consequently in the mixed-initiative version of REDEEM, authors use the domain tools and strategy tools as described above, the student tools set up categories (but do not assign students to categories), and the macro-adaption tools prescribe a default strategy and a range of available strategies per category. Now when the students log in, they select one of the learner categories, and this now results in a default teaching strategy, which they can change to any of the other strategies that are available. For example, for a statistics revision unit available to university students, we created four categories (confident learner/reviser and unconfident learner/reviser). Each category was assigned a default strategy (e.g., confident reviser received "challenge me") but could choose to one of six other strategies). This design is a trade-off between giving students significant choice yet only requiring minimal interaction (less than 30 seconds typically) to utilize this functionality.

Empirical Studies

To examine whether REDEEM could achieve its objective to be general across a range of domains and users and still be effective educationally, we needed to analyze both the authors' and the learners' experiences. Each type of user has different requirements and consequently the type of analysis needed to differ as well. Table 1 summarizes the main studies that have been conducted.

Table 1. Description of REDEEM studies

Study	Purpose	Subjects	Course	Location	Author	Primary Reference
1. Primary Shapes	Usability, Functionality	3 teachers, 1 teacher trainer	Introduction to shape and area	University	Teachers, Lecturer	Ainsworth, Grimshaw, & Underwood, (1999)
2. Naval authors	Usability, Functionality	2 trainers	Comm. & Info Systems Protocols	University & naval sites	Trainers	Ainsworth, Williams, & Wood, 2001).
3. Genetics at Uni.	Learning effectiveness	86 students 14–16yrs	Genetics	University	Teacher	Ainsworth & Grimshaw (2004)
4. Genetics in School	Learning effectiveness	15 students, 14–16 yrs	Genetics	Secondary School	Teacher	Ainsworth & Grimshaw (2004)
5. Navy full time	Learning effectiveness	19 students 17–22 yrs	Comm. & Info Systems Protocols	HMS Collingwood	Trainer	Ainsworth et al. (2003)
6. Undergrad	Learning effectiveness	25 students, 20–28 yrs	PC & Networking	University	Researcher	Ainsworth, Williams & Wood (2003)
7. RAF	Learning effectiveness	16 students, 20–45 yrs	PC & Networking	RAF Waddington	Researcher	Ainsworth & Fleming (2006)
8. Undergrad Mixed Initiative	Functionality, Learning effectiveness	167 students, 18–20 yrs	Statistics	University	Lecturer	Ainsworth & Fleming (2005)

Author-focused studies

Studies 1 and 2 were the main author-focused studies and they were primarily concerned with usability and functionality. Primary (K–12) and secondary (high) school teachers, lecturers, and military instructors found it easy to use the tools to express, represent, and assess their teaching knowledge to create a learning environment within a feasible time scale.

REDEEM's usability has been assessed by asking authors to create learning environments either for their own class of learners or a set of hypothetical learners. Then teachers were interviewed throughout the process of creating the environments and about their satisfaction with the outcome. Initial training in the use of the REDEEM tools required between one and two hours. No author found the overall decomposition of the teaching process incompatible with his or her approach. REDEEM's use of graphical and form-fill style interview tools has mostly proved simple and easy for authors to use. Time taken to author (once an existing suitable course has been found) has been acceptable, ranging from between 6 and 11 hours to author the four-hour course, Understanding Shapes (Study 1). In Study 4 a teacher took less than 25 hours to create two environments (around eight hours of instruction). Navy authors began by requiring 10 hours per chapter (around 6:1), which dropped to 6 hours by the end of authoring (around 3:1) (Study 2). It is not unrealistic to claim that creation of a REDEEM learning environments from an existing course can be done at a ratio of under five hours development per hour of instruction.

In terms of functionality, overall, authors were pleased with the functionality that REDEEM offered. Compared to the original courseware or to courses authored by others, they all felt their learning environments were more suitable for their classes' needs.

Classroom teachers and military instructors used REDEEM in very different ways, with teachers focusing more on personalization. The teachers wanted to structure the domain material in ways that reflected their own beliefs and to create multiple student categories with unique strategies. In contrast, the military authors used REDEEM to create a single teaching strategy that reflected their own preferred strategy rather than the courseware designer's strategy. What both groups had in common was the value they placed on increasing interactivity by adding questions and reflection points.

However, these studies have revealed some interesting dilemmas about REDEEM's design. Firstly, REDEEM requires users to shift from storyboarding to knowledge-based authoring. The most problematic part of this is domain sequencing, with authors describing characteristics of a page (e.g., familiarity and complexity) and the shell computing a route. However, this proved too time-consuming, was difficult for authors to visualize, and so was unpopular and resisted. Unfortunately, knowledge-based authoring ignores the important role that narrative plays for authors and learners when they are interacting with new material. In retrospect, we would stick to knowledge-based authoring for interactivity but use a more narrative-based approach to structure the domain content.

The second concern is with the adaptive features of REDEEM, which allow the shell to compute its own route through material and to change student category (if desired), and so allow students to receive different teaching strategies. This proved very unpopular with all authors as they were reluctant to surrender control to the system. This limits the functionality that REDEEM can offer, turning it into a courseware authoring tool rather than its original intended goal of intelligent tutoring system authoring tool.

The final concern is time efficiency. Authors need to create learning environments in a time-efficient way. REDEEM achieves a ratio of around three to five hours of authoring to one hour of instruction when a trained author, familiar with the domain and with teaching, creates an environment from imported domain material. But it does not include time to locate the domain material that meets their needs. However, many authors felt that the 5:1 ratio was not fast enough. If authors had been happy to leave decisions to REDEEM, some of this time could have been reduced (e.g., authors often hand-coded a sequence of material when the shell would have produced the same route automatically). Authors also often spent a considerable amount of time on details that potentially may not have been too important (e.g., one teacher edited every help message to include a full stop after each message). However, on the positive side, one of the features that teachers appreciated most was the way that REDEEM allows quick assignment of different strategies and content to different student categories. Analysis of authoring times suggests that this is normally achieved in less than 30 minutes, irrespective of the size of the course.

Learner-focused studies

Two types of studies were conducted to explore whether REDEEM helped students learn: experimental studies conducted in either in the laboratory or in a semi-naturalistic setting (studies 3 to 7) and quasi-experimental studies conducted in a real-world setting (study 8). Studies 7 and 8 also included questionnaires to assess learners' satisfaction with the environment.

The experimental studies all had the same basic design and employed the same comparison. Learning outcomes from students working with the original courseware (which had been developed prior to the studies and was already in use in classrooms) was compared to those from the REDEEM-enhanced version of the CBT. In all cases a partial crossover design was employed —– half the participants received REDEEM then the original CBT, and half the original CBT and then REDEEM. If learning outcomes are higher with REDEEM, then the conclusion that the REDEEM/Author partnership in the situation provided better support for learning than the original courseware is warranted.

Table 2. Experimental Studies

Study	Authoring	Gain	Effect size
3. Genetics at University	5 student categories based on teacher views of ability in which each received a unique teaching strategy and content	RED = 10% CBT = 8%	.21
4. Genetics in School	3 student categories based on school sets which varied content but not strategy	RED = 16% CBT = 8%	.82 *
5. Navy full time	1 student category/teaching strategy	RED = 21% CBT = 22%	–.04
6. Undergrad	1 student category/teaching strategy	RED = 53% CBT = 44%	.82*
7. RAF	1 student category/teaching strategy	RED = 47% CBT = 32%	.76*

Table 2 shows the learning outcomes of the five experimental studies. Overall it shows that REDEEM could be used to create learning environments that are more effective than the CBT they are based on. On average, REDEEM led to a 30% improvement from pre-test to post-test, whereas CBT increased scores by 23%. This advantage for REDEEM translates into an average effect size of .51. This compares well to non-expert, human, individual tutors (an average of .4 sigma [Cohen, Kulik, & Kulik, 1982]) but is significantly below that of expert human one-to-one tuition at 2 sigmas (Bloom, 1984). However, given the efficiency of creating REDEEM courseware and the fact that the comparison was CBT which was already in use, this overall increase in effectiveness is highly satisfactory.

Given REDEEM's proven effectiveness in experimental settings, we felt justified in using it in a real-world situation. In 2005 a semester of a statistics courses at the University of Nottingham was REDEEMed. Ten lectures (originally in PowerPoint) were imported into REDEEM, and additional interactivity was authored. Four learner categories were created: non-confident learner (NCL), confident learner (CL), non-confident reviser (NCR), and confident reviser (CR). Four default teaching strategies were created (Table 3) and four optional strategies were devised that provided contrasting experiences such as using REDEEM in "exam style" or in "pre-test" mode (test me after the course, before section, or course).

These lectures were made available over the intranet for students to use on a completely voluntary basis. At the end of the year, students took an exam, which assessed their understanding of this course, and a prerequisite first-semester statistics course. Over the year, we kept process data that recorded which students used REDEEM on which lectures and asked students to complete questionnaires assessing their experience with REDEEM.

Analysis of this data is complex, given the quasi-experimental nature of the research (see Ainsworth & Fleming, 2005), but demonstrates a clear benefit of REDEEM. Those students who used REDEEM scored more highly on their second semester exam scores. But, this could be because students who were more motivated or of a higher ability chose to use REDEEM. Happily, this explanation is unlikely as these students did not also have higher performance on the first semester scores (for which REDEEM was unavailable). Furthermore, a stepwise linear regression showed that students were predicted to do 1% better for each REDEEM lecture they completed, allowing them to improve by 10%. Finally, we examined performance specifically on those lectures the students had studied with REDEEM and related that to particular exam questions. Using REDEEM increased performance only on the exam questions that corresponded to the lectures that a student had studied with REDEEM (students scored an average of 64% on those lecture's questions versus 54% on those they had not studied).

Table 3. Teaching Strategies

Name	**Default**	**Description**
Simple Introduction	NCL	No student control of material or questions; easy/medium questions (max one per page), 2 attempts per question, help available. Questions after page.
Guided Practice	NCR	No student control of material/questions; easy/medium questions (max one per page). 5 attempts per question, help is available. Questions after section.
Guided Discovery	CL	Choice order of sections but not questions. 5 attempts per question, help only on error. Questions after section.
Free Discovery	CR	Choice order of sections and questions. 5 attempts per question, help available
Just Browsing		Complete student control of material. No questions.
Test me after the course		No student control of material or questions. All questions at the end, 1 attempt per question, no help.
Test me before each section		Choose order of sections. Questions are given before each section. 5 attempts per question and help available on error.
Test me before the course		Student control sections All questions at the start. 5 attempts per question. Help is available.

Students views about the usefulness of REDEEM for supporting their learning was generally positive. They considered it to be less useful than lectures for learning statistics, but more useful than tutorials, textbooks, or working with friends. They reported they would definitely use REDEEM for the 2^{nd} year statistics course if it was available (4.47/5) and would recommend REDEEM to next year's first years (4.45/5). Only one respondent (out of 99) would not use or recommend REDEEM. We also asked students why REDEEM helped them learn and they ranked REDEEM's features in the following order of usefulness: Questions, Hints & Explanations of Answers, Choice of Strategy, Review facilities, Student History, and Notes tool.

Overall then, REDEEM was appreciated by students and had a noticeable impact on exam performance (equivalent to a whole degree class in the UK system) for students who studied with it, even when we factor explanations based on differential use of REDEEM by motivated or higher ability students.

Conclusions

This program of research has been aimed at exploring whether a single authoring environment could be sufficiently general to be used across many learning contexts but still be able to create effective learning environments. We proposed that in order to meet its goal the system must have high usability, appropriate functionality, and enhance learning outcomes. Eight different studies have been conducted to explore if REDEEM meets its goals.

In terms of usability, the results were encouraging. Authors across all the observed contexts found the system easy to learn and could create learning environments in a time-efficient way. This could be substantially improved if we changed the model of content structure and sequencing from knowledge-based to storyboarding. Further improvements could come from making question authoring more efficient, for example, using generalization features similar to those found in CTAT (Aleven et al., 2006) and from reusing existing authoring. However, to truly calculate how long it would take to create a course we should include how long it would take authors to locate suitable domain material and, in the case of content with its own structure, strip this structure out. REDEEM has been described as one of the most usable ITS authoring tools (Murray, 2003), and our results tend to support this conclusion.

REDEEM's functionality has been assessed by examining how well it fitted the needs of primary (K–12), secondary (high school) teachers, university lecturers, and military trainers. For classroom teachers, the most important tool that REDEEM offered above existing courseware was the opportunity to personalize it to their specific needs. The teachers felt that the trouble with trying to use much courseware was that it contained material that was not required by their students or that the material was organized in ways that did not match with their curriculum. REDEEM allowed them to exclude material they did not want extremely easily (if you don't name a page, REDEEM won't offer it to students) and they could reorganize the structure of the material to meet their desired goals. The other feature that was welcomed was the opportunity to macro-adapt the material to different student categories. This allowed teachers to give all their students the opportunity to interact with (apparently) the same material but in ways that stretched their more able students and supported their struggling students. Some teachers chose only to macro-adapt content, whereas others adapted content and strategies.

The navy authors did not use this feature at all, but did like the opportunity to add additional interactivity. They felt that the courseware they were provided with was not sufficiently interesting for their students and liked to use questions to focus students' attention. However, they did see a potential role for macrodaption in adapting to role (e.g., initial training, skill updating). The naval author who worked in reserve training was also more enthusiastic about macro-adapting, saying it would help him deal with his varied learner population (from medical officers to 16-year-old trainees).

Finally, the university lecturer particularly liked the way that REDEEM could be available to support students in times and ways that teachers could not. Because 200 students take the statistics course that we REDEEMed, giving individual feedback on their performance is not normally possible. Furthermore, the majority of use of REDEEM happened after teaching had ended — approximately 66% of REDEEM use occurred after the end of term and 25% of total use occurred in the 36 hours prior to the exam!

REDEEM was shown to improve learning outcomes in both experimental and non-experimental situations. The average effect size is a very respectable 0.51. The benefit of REDEEM was observable even in real-world situations where other factors such as aptitude or effort might be expected to dilute its impact. However, the variability in the outcomes is very large and there is no consistent relationship between whether the course was authored by a researcher or a practitioner, the topic taught, whether the study was conduced in an artificial situation or in a realistic context, and whether REDEEM's macro-adaptive features were used to create learning environments for specific learner categories. We propose that one of the explanations for this variability lies in the behaviour of the learners in the study, which we can observe by inspection of the process data. The two studies without a significant REDEEM benefit were also the ones with the highest number of students who were least interested in learning this material. Analysis of the process logs suggests a wide variation in how much these learners interacted with the system. Adding features to enhance learning can only impact when learners chose to engage with them.

Consistent with this analysis is our view about those aspects of REDEEM which most helped learning. Students indicated they felt that questions and hints were the most useful features, and analysis of the process logs also confirms this view. These results suggest that any advantage of REDEEM was due more to increasing interactivity than to macro-adaptation. That degree of interaction predicted learning outcomes does not seem contentious, but the question that remains is why benefits from macro-adaptation were not observed. This may be because inappropriate categories were used (authors chose only to use ability) or that strategies were not assigned appropriately. Moreover, from this design benefits might be difficult to identify. For example, if an author assigned a unique teaching strategy to every category of learner and they all made equal gains, does this mean that the strategies were ideally targeted or that they had no effect? Consequently, further research is needed to examine the educational significance of macro-adaptation and to consider which are the most important learner characteristics and strategy dimensions. In terms of learners themselves, macro-adapting this was a popular feature with students, who chose strategies that were appropriate to their context (for example, a large amount of "test me before the course" was observed as students crammed just before the exam).

In terms of using a single authoring environment across all learning contexts, we did not quite achieve our goal. The versions used in schools and for the military had identical functionality; however, we changed the interface (friendly primary colours and larger fonts in school). The mixed initiative version used at university could be used in a large number of contexts where learning is more under control of learners themselves and may be less suitable to some of the school and military situations.

REDEEM is now a senior citizen in the world of authoring environments. It was developed well before the importance of meta-data standards were envisaged and even before the use of the web was commonplace in learning environments. As such, it is now time for the system to retire. It requires its own learning management system to be installed onto each computer and does not create learning environments that are SCORM compliant. However, some of the ideas pioneered by REDEEM are only now becoming standard. In particular, the central design concept of REDEEM is that information and pedagogy are kept separate, and REDEEM focuses on allowing authors to describe how they want the content taught (rather than the content itself). This focus on pedagogy is still far from common, although its importance for the use (and reuse) of learning objects is recognized (Sloep, 2004). Recent projects such as Educational Modelling Language (Koper & Manderveld, 2004) and its successor IMS design, (see IMS, 2003)) are demonstrating the importance of pedagogical meta-data.

In conclusion, we acknowledge that there are many situations in which learning environments with more knowledge or power than REDEEM will be needed, for example, in simulation-based learning. However, we propose that the REDEEM approach of usable authoring tools to create adapted and interactive courseware over a large range of learning contexts has been a success.

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