Accepted refereed manuscript of: Gardner J & McClune B (1999) CREDIT to classrooms: an evidence base for pedagogical development. *Computers and Education*, 33 (2-3), pp. 217-222. https://doi.org/10.1016/S0360-1315%2899%2900034-2

CREDIT TO CLASSROOMS: AN EVIDENCE BASE FOR PEDAGOGICAL DEVELOPMENT

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For some two decades now, the education system and its consumers, students and their parents, have been assailed with all manner of seductive endorsements and imperatives to use computers in learning and teaching. Of the various claims made, the least convincing are to be found in the futuristic promotional literature of the many commercial interests, some of whom brazenly hail the teacher-less school or university as the ultimate and inevitable outcome of current 'progress'. More compelling, however, is the influence that informed argument from academia and government has on the expectations of students. Few would dispute the view that computers can enhance learning in many ways (the view endorsed by academia) or that students should develop the key skills associated with technology usage regardless of the phase of education they are in (the view of successive governments and given consistent endorsement in the various curriculum and system reviews e.g. Dearing 1996, 1997).

Society itself is in an increasing grip of technological engagement as the Information Society, envisaged and pursued by the European Union Bangemann report (1994), immerses us in *e*-commerce, the internet and digital communications and broadcasting. Educational institutions everywhere and in all phases (primary, secondary and tertiary) are being confronted with increasing demands to deliver a technologically enriched learning and teaching environment. And, of courses, it is the teachers in these institutions who are being challenged to embrace major changes in how they teach and how they support their students' learning.

And what of all of this progress? Clearly major gains have been made in the delivery systems - faster computers, digitized full motion video, easy and effective access to the Internet, greater sophistication in software tools etc. However it is equally clear that very few gains have been made in the design and development, from prototype to classroom level, of learning and teaching applications using these new information and communication technologies (ICT). The reasons for this are no doubt legion, but it is not unreasonable to argue that our knowledge and understanding of learning, and its complementary function: teaching, remains incomplete and therefore a major barrier to progress in the field. What we currently know and understand about learning offers insufficient support to those who have the ability to harness the technical sophistication of today's (and tomorrow's) computer systems for effective learning and teaching systems. Enter CREDIT!

The Centre for Research in Development, Instruction and Training (CREDIT) at the University of Nottingham, with funding from the UK's Economic and Social Research Council, has undertaken a programme of research focusing on several aspects of the deficiencies in our knowledge. The papers in this issue are testament to the progress that can be made when a concerted programme of research is undertaken. Of course, it would be difficult to conceive of a single programme that could tackle all of the issues needing addressed and in this respect CREDIT's objectives have been properly modest and successful. The central issues that the researchers have addressed might be summarized as:

- the concept of teaching in a CBT context and the role of the teacher in the student-system-teacher interaction triangle;

- the capacity of the computer to offer external representations that can effectively exploit learning theories in facilitating the learning of the knowledge they represent.

The first of these is tackled in the four papers looking at contingent help and help seeking (Wood & Wood), the building of learner expertise using computer based tutoring systems, CBTs (Gobet & Wood), enabling teachers to mould CBT systems using their own pedagogical style and knowledge of their students (Ainsworth, Grimshaw & Underwood) and the missing links in current research on the impact of integrated learning systems on students' learning (Wood, Underwood & Avis). The second issue forms the focus of the two papers on the multiple external representations (MERs) that are used in many learning contexts. Ainsworth offers an analysis of the way in which such representations function and the interactions which learners have with them. Cheng's paper describes an innovative means of increasing the effectiveness of MERs by guiding their design with laws which derive from the learning context itself.

And what do these papers teach us? .. or, more aptly in this case, what do we learn from these papers? Several matters struck us in reading the papers. Firstly there were new insights into the way we function as teachers and learners with computers. Secondly there were innovative ways of optimizing the way we use computer based learning and tutoring systems. And finally, perhaps most importantly, the papers provide empirical evidence of the effectiveness of learning and teaching methods which until now have informed good practice in the classroom from a largely theoretical and sometimes ideological perspective.

A strength of the work reported in the papers is its relevance outside the computer based environment. Take 'Hazel' for example. Hazel features in Wood & Wood's paper as the potentially frustrating attention seeker, continually seeking help even when she was clearly mastering the tasks. The temptation to ignore her, or to try to discipline her repeated and unnecessary requests, was not open to the machine tutor and the outcome was positive; despite the apparent abuse of the help facility, she learned the material "extremely well". The classroom teacher, not blessed with the machine's patience, might perhaps miss the opportunity to facilitate the learning that she clearly managed and the result reminds us to be careful in dismissing such students as superficial time-wasters or as relying too much, unproductively, on the teacher.

Whether they are like Hazel or not, the individualism of learners, in their needs and learning styles, taxes the skills of human tutors and Wood & Wood's paper points to ways in which help systems in computer based tutors (in this case the QUADRATIC tutor) can be made more effective. This essentially demands that they be made more contingent on the learner's level of achieved learning at the time of seeking help. The use of the system with GCSE students showed that the extent of prior knowledge of the learning domain determined how successfully the students could exploit the (computer) tutor's help. More knowledgeable learners worked faster and had better outcomes but the research was able to show that when prior knowledge was partialled out, slower operation times generally and longer time spent before seeking help were both associated with positive learning outcomes. Tutor help designs, which initiate help sequences that are based solely on time elapsed between acceptable entries, do not have the necessary sophistication to cater for these perhaps more thoughtful or deliberate learners. Instead they must ".. leave decisions about *when* to seek help to the learner. The tutor then decides *what* help to provide". The introduction of such subtlety in the help functions of the tutor more accurately mirrors the well-judged interventions of human tutors who have the advantage of continually analysing a variety of verbal and non-verbal signals from the student, in deciding if or when help is needed.

Seeking help in many instances can be characterized with a different slant: seeking feedback. In a scaffolding context, the human tutor continually assesses the level of the student's achievement and then intervenes and supports or extends the student to assist them in reaching the next learning stage. This student-teacher feedback loop in the conventional classroom is often termed formative assessment, or 'assessment for learning', and has been

shown in a review of some 500 empirical studies to be one of the most potent processes that the teacher can contribute to the learning environment (Black & Wiliam 1998). Gobet & Wood focus upon such feedback and help-giving skills of the human tutor, and the processes of acquisition of expertise that the learner has to undergo. They argue that we have a very incomplete understanding of the repertoire of functions that the human tutor has mastered and that current computer based systems are simply not yet capable of supporting them. Their paper puts forward a computational theory of expertise, CHREST, which extends existing theories and exposes the limitations of current applications. Systems of the future may well address these issues more successfully than at present, but Gobet and Wood conclude by endorsing the view that by trying to "... identify any gaps between what the system has to offer and what is needed to support learning generally we can start to outline the possible roles that teachers may have to play in integrating the use of systems alongside their other practices". Leaving the CBT system in the corner of the classroom as an add-on or worse still as a diversion, is clearly not enough to achieve the potential of the technology. Perhaps one solution, often considered in the past, is to enable teachers to design and develop the tutors and thereby generate a much more obvious integration with their own classroom practice, curriculum and teaching objectives.

Again one of the CREDIT projects picks this issue up and takes our thinking forward another step. Ainsworth, Grimshaw & Underwood's paper on the REDEEM authoring system used a simple empirical study to explore how different teaching styles and curricular approaches may be accommodated in tutoring systems. Teachers exhibiting different teaching styles probably do so on the basis of a variety of personal attributes and experience but teaching approaches to the same topic will also importantly vary within the person according to their knowledge of the needs of the learners they are currently teaching. Easily and truly adaptable tutor systems have therefore been an aspiration of the teaching profession for many years as the cry of 'not invented here' has condemned many inherently clever and serviceable computer based learning packages to storage shelves. The REDEEM system aims to reverse the loss of control over the learning and teaching process involved in CBT usage. This is not to be achieved simply by enabling the teaching material to be created in a facile way but by the more innovative and yet, in teaching terms, probably more realistic manner of identifying materials that form the knowledge domain and then creating an access system for the students that is driven by the teachers' own teaching strategies for the students they are targeting. It is not a soft option by any means and the authors point out that the teachers, who participated in

the empirical trials of the system, had to become more explicit about their views and had to reflect more deeply on the conceptual models they have of the learning domains. Overall the process contributed to the teachers' professional development most notably in their understanding of the course content and the implications of their pedagogical decisions. This professional development dimension and the replication of conventional classroom strategies i.e. where the teacher identifies material such as textbooks, practical activities, assessment activities etc. and then designs the scheme of work for themselves and the students, represents another promising dimension of the CREDIT approach to ICT pedagogical development.

The Wood, Underwood & Avis paper digresses from the exposition of technical-cum-learning theory developments to consideration of the existing research on commercially available integrated learning systems (ILSs). ILSs represent a family of computer based learning materials that in some of their forms claim to be fully adaptive to learner needs and performance. In what might be described as a qualitative meta-analysis of three existing ILS-based studies from the UK, the problematics of evaluating the use (benefits, effectiveness etc.) of such systems are analysed. These are then generalized to propose how research in the use of computer based systems in the classroom might provide more consistent findings than studies to date. The argument develops from an endorsement of the central problem in evaluating effectiveness of computer based learning, i.e. that it is contextually dependent. The running theme is here again made clear. They argue that "... the possibility that the impact of the ILS may be mediated by the teaching practices surrounding its use" is implicated in all three of the studies examined. They conclude that the learner-system interaction cannot be completely effective unless the teacher takes a full role in the process, forming the third corner of the triangle and optimizing the integration of the courseware into the classroom context and into his or her management of the learning process. In a tack taken up by Ainsworth, Grimshaw & Underwood, the aspiration of teachers in the studies to be provided with tools to adapt the tasks and materials to their own purposes is emphasized. The paper rounds off with a discussion of the potential contribution that research, which properly recognizes the importance of the triangle of interactions, can make to CBT design.

One of the simplest features of computer based learning is that it can offer representations of entities from 'reality' which can then be manipulated in a learning activity or experience. These representations may be simple diagrams or complex audio and video montages or they

may be passive data structures for user manipulation or virtual ‘microworlds’, which obey system or user-defined rule systems. In the same manner as the teacher creates stimuli in the classroom (diagrams, worksheets, experiments etc.) the computer generates representations of various aspects of learning activities to engage the students. Ainsworth in her paper tackles this second issue, that of multiple external representations (MERs) used in teaching materials, by firstly categorizing them under the three functions: ‘complementary’ - supporting other learning processes, ‘constraining’ - acting to prevent mis-interpretation and ‘constructing deeper understanding’ of a process or situation, and then explaining them. She questions the manner in which multiple representations may require the student to translate between them and postulates principles for guiding this aspect of CBT design.

Ainsworth’s discussion of complementary and conflicting models of MER usage fits conventional teaching activity just as well as it covers the CBT environment, and will provide insights for teachers across the teaching spectrum. The paper is doubly functional inasmuch as it also uses the various systems on which the other papers are based to illustrate the points being made. One of the MERs featured is the interesting concept of the law encoding diagram, LED.

According to Cheng, LEDs are a means of encoding “... the laws of the [knowledge] domain in the structure of diagrams in such a way that each ... drawing ... of an LED represents one instance of the phenomenon and one case of the laws”. Such diagrams will be immediately familiar to teachers of the natural sciences e.g. diagrams for chemical bonding and particle collisions can be constructed as LEDs. Cheng uses an example of how two groups of students tackled a simple ‘faulty circuit’ problem in a physics curriculum, to illustrate the manner in which LEDs can enhance conceptual learning. The arguments are persuasive but Cheng also identifies the difficulty of introducing the ideas to a traditional teaching force with well established means of teaching their subjects. Nevertheless if the ideas can be demonstrated to be effective on a larger scale, and can be used in learning enrichment, they will prove important in the continuing development and integration of CBT systems in the traditional classroom.

All things considered the papers offered in this edition provide significant food for thought, for the CBT designer and developer, for the classroom teacher and for the researcher. The reader will not fail to be challenged by the innovative dimensions of the work or by the insightful analyses of well known phenomena and behaviours. Neither will they fail to

recognize that much of the evidence that is on show identifies the basis for effective CBT usage as being the development of a better theoretical and practical understanding of the teacher-student-technology interactions and a consequent improvement in CBT design. A particular emphasis in this respect is that ways need to be found to ensure that teachers are able fully to embrace the responsibility of integrating appropriate technological applications into their pedagogy and their students' learning. As the title on this commentary suggests, CREDIT is providing part of the evidence-base that such developments in pedagogy will increasingly require.

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