A Critical Appraisal of Learning Technology Using Information and Communication Technologies

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Introduction

The government of the United Kingdom is currently reaffirming its promise to link every school, college, university, and public library in the country to the “national grid for learning” at a cost in excess of £100 million (Howells, 1998). These links will be free, and access to all who require it guaranteed. Every child will have his or her own e-mail address to access learning resources worldwide. As well as this access, the Prime Minister is ‘online’ so that the public can pose questions electronically and, presumably, expect a reply.

This type of initiative together with the exponential increase in the availability of information and communications technologies (ICT) has created opportunities for teachers to exploit a new tool. However, the research base for exploiting these new tools, as well as examples of good professional practice, is in its infancy and still requires considerable thought and empirical investigation (Barnard, 1998).

Context

In the world of education the burgeoning in the availability of ICT has created exciting opportunities for its exploitation. However, ICT, like all new tools, provides a challenge to established thinking. The attractiveness of ICT to education is a two-edged sword. While it may lead to the provision of additional resources for education, it also leads to expectations that are often problematic to deliver (Bottino, Forcheri, & Molfino, 1998). The educational advantages claimed for ICT are often not translated into meaningful learning activity (Barnard, 1998), particularly in the specialized field of what can be termed school technology, and it is important, therefore, that these advantages are identified and justified by practitioners as well as being explained through learning theory. Technological developments occur in two ways: (a) as a solution to a known problem or (b) as a spin-off from other research and a search is made to find uses for them; technology becomes available and then opportunities are sought to employ its potential in the classroom. This approach is not the most appropriate strategy; it is frequently ineffective and sometimes leads to the early discarding of a potentially useful tool. The reasons for this vary. It could be that technologies have not been sufficiently developed and that they are being used before teething problems have been rectified. Or it may be that they are too “sophisticated” for the job at hand. In other words, the teaching and learning strategies may be over-engineered and busy teachers have no time to de-bug software or persevere with inefficient approaches.

It is, therefore, essential that as well as providing a new tool we should try to explain its application within current learning theories (Wild & Quinn, 1998) so that we are using it from a position of authority, based upon a sound knowledge base, and not relying upon serendipity. In other words, the design and manufacture of learning materials, particularly when utilizing new technologies, should be purpose built and not be media led (Dyne, Taylor, & Boulton-Lewis, 1994).

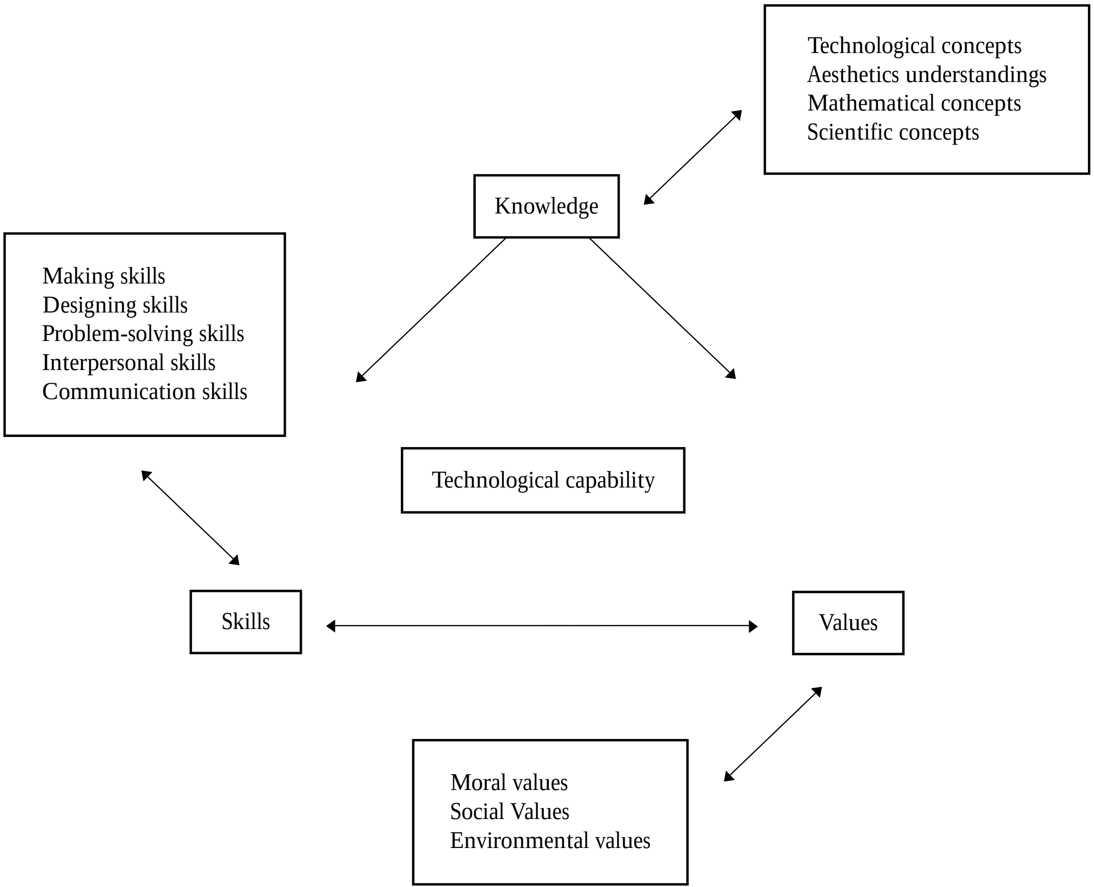
And within technology education we have even more particular issues to address. Technology within the context of education can be described and defined in several ways. For many it has to do with using technology to enhance the efficiency of the educational process. Within this context is the use of the personal computer and all that goes with it: its use as a word processor, highly efficient calculator, database, and communication system. In other words, the personal computer becomes a library and access system to the world's store of knowledge as well as a manipulator of that knowledge.

A slightly different justification for technology education is the understanding that one can acquire knowledge of a range of other subjects through the study of technology. For example, by building a model bridge in cardboard or wood or even modeling it on a personal computer, learners will apply mathematical skills and understand scientific concepts through their application (McCormick & Murphy, 1998). Some would take this argument further and claim that other more ephemeral attributes such as communication skills are gained through technologists explaining their solutions to others, and ethical and moral problems are confronted by debating controversial issues.

While these two descriptions of the value of technology education are both valid and widely held, the most common view is that technology education should be about the acquisition of a thorough grounding in technological principles. This understanding of the activity features prominently in the curriculum of schools through the requirements of the National Curriculum in the United Kingdom and similar directives and recommendations in other countries (e.g., Botswana Ministry of Education, 1996; International Technology Education Association (ITEA), 1997). While the other considerations, those of "learning through technology" are more general imperatives, they are rarely addressed as prime objectives by technology teachers.

If we look at technology education as being concerned with learning about technology, there are said to be three components: skills, knowledge, and values (Assessment of Performance Unit [APU], 1981).
In the United Kingdom, these technological understandings and accomplishments are said to be acquired through the processes of designing and making. The subject is essentially one concerned with practical action and capability (National Curriculum Council [NCC], 1990) although some of the content is acquired through focused tasks designed to facilitate problem-solving capability through the development of specific skills and knowledge. It is within this

Figure 1. The interrelationship between skills, knowledge, and values in technological capability.



broad definition that this article was written.

While it should be remembered that a number of other curriculum subject areas also lay claim to a wide range of desirable attributes with problem solving, social awareness, and knowledge acquisition featuring prominently in their aims and objectives, technology education is perhaps unique in that the results of such problem-solving activity is often translated into tangible artifacts or solutions.

A further factor to note is that such practical activity is not necessarily employed to explain a scientific concept or justify an aesthetic principle, but one that constructs the technological reality of schoolroom learning. It transforms scientific experiments with string and meter rules into machines found on building sites or dockyards and applies the aesthetic principles used in art studios to the creation of functional and attractive artifacts. Involvement in designing and making activities thus enables a number of technological concepts to be established or existing ones enhanced.

This demand may be said to require of teachers and learners in the subject area a much wider range of skills (both professional and pedagogical) than are often expected elsewhere in the curriculum.

Learning and Teaching

Education is seen, certainly at its higher levels, to be concerned with developing the ability to explain and predict the outcomes of innovative situations as they occur (Wild & Quinn, 1998). This ability is necessary to solve problems and comes from a combination of experiential and academic learning and is acquired through the skill of being able to make appropriate judgments based on personal reflection. Another common definition of learning, which stems from behaviorist theory, is that learning takes place when a relatively permanent change in behavior occurs. This definition takes the word behavior to mean any observable change that takes place. In other words, if someone can now do something (e.g., remember a fact, demonstrate a skill, perform an operation) that he or she couldn't do before, it is said that learning has taken place. Behaviorism underpins much learning that takes place formally and informally and has also led to a great deal of current educational practice in assessment and evaluation. Constructivists attempt to explain the principles of learning by encompassing the understanding that knowledge is constructed by the learner in the context of his or her environment. It is therefore acquired when the learner actively tries to make sense of new experiences based upon his or her previous understanding (Bruner, 1972).

Sociocultural theories rely heavily upon the value of communication in the learning process (Meadows, 1998). This can be between teacher and learner in the formal sense, but it may also be between peers and others that occurs within a normal social context. Language is therefore extremely important to allow for successful interaction and, hence, learning to take place. The principles behind scaffolding and the zone of proximal development (ZPD) fall within these theories (Gredler, 1992; Kincheloe & Steinberg, 1993; Tharp & Gallimore, 1988).

These more complex theories of learning do not totally exclude behaviorist theories that propose the independence of knowledge from social and cultural influences, as such instrumental approaches are useful for understanding the basis of some teaching strategies, particularly those concerned with lower level skills (Atkins, 1993).

Figure 2. Cognitive Theory and Computer Use, McLaughlin and Oliver, 1998. p.128

Theory	Behavior	Constructivist	Socio-cultural
Activities	Drill and practice tutorials	LOGO programming Micro worlds	Collaborative learning
Learning Process	Individual instructions and feedback drill and practice	Individual, discovery based generalisable skills	Social scaffolding interactive, reflective

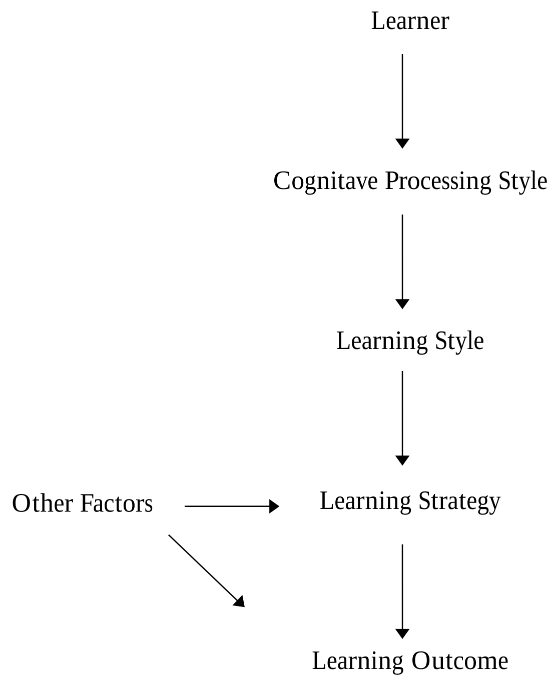
Examples of these theories of learning and their application provided by McLoughlin and Oliver (1998). These theories are very rarely used independently of each other to explain learning: Most skilled teachers are simply adept at knowing when and where to employ them, often subconsciously, to produce the most effective results.

Strategies based upon behaviorism can be used effectively for factual and rote learning, and teachers use this theory frequently by rewarding a learner with encouragement or other more tangible signs of approval. Such basic learning theories are also often used in programmed learning where a student is rewarded through an encouraging comment before moving on to the next learning objective.

It is in this type of learning that the use of ICT is immediately apparent. The computer games that are so highly addictive to teenagers are perfect examples of learning behavior being progressively rewarded as each level of the game is mastered. This learning is not restricted to the cognitive field in which the game is mastered but also in the area of psychomotor skills when the reflexes of learners are constantly refined to produce ever faster reactions to visual stimuli.

The student's mastering of basic technological terms, descriptions of components, and understanding of theory behind technical processes can be achieved through structured programs delivered through CD-ROMs or similar media. We can, therefore immediately see a place for ICT in technology education, both as a source of information and also, if structured effectively, a context or structure for learning simple skills and concepts.

Figure 3. Learner characteristics that affect learning.



Obviously, such teaching and learning strategies are not sufficient for all learning. They are, however, often needed at some time to service processes that will enable learners to acquire basic information to undertake higher order activities including problem solving (Atkins, 1993).

Different learning objectives may require different teaching and learning strategies to achieve them. Some aspects of learning require basic low-level information as a preliminary activity before the more complex can be internalized. Often the rote learning of factual information is essential before a learner can be engaged in problem solving or those higher order activities deemed more desirable (Underwood & Underwood, 1990). While behaviorism is said to have a number of views, this view of learning drives a lot of current educational practice where competencies and standards have become established indicators of achievement.

Thus, in technology education we have a subject that inherently has a philosophy that is overlaid by effective learning theories. By the very nature of students being involved in design and make tasks, they are learning through real-life contexts and strategies that in many other school subjects have to be artificially created. Therefore, we must think carefully before we change a learning experience, which can provide a worthwhile education in its own right.

The links between teacher and taught are of crucial importance. Satisfactory learning often takes place when the teacher identifies where the learning blockage occurs. In other words, by determining where the difficulty is occurring in the student, the teacher can rectify the wrong concept or build upon work already understood. Based upon this understanding, Andaloro and Bellomonte (1998) suggested that a way forward is to use the computer to model the student's learning strategies to signify where they are likely to encounter difficulties in the future and thereby build up a learning program for each student, ensuring that the ICT programmers' emphasis recognizes that learners are different in the learning strategies they employ and the material is adapted accordingly. This activity can be used as a precursor to the use of design packages and simulations. Much is currently being made of the use of computer-aided design and simulation packages to aid student problem solving, but without an understanding of the learning profile of the child (which the good teacher uses in traditional contexts), most of this activity may not be used to its best advantage and is directed to task achievement rather than the development of a learning skill (i.e., they may assist a student to design a specific product but not necessarily teach that student how to develop design skills).

Learning is a personal activity. It depends upon a series of factors that are often very difficult to control and manipulate. Some of these factors are related to the individual, including cognitive processing style and learning style. Some people learn better within a group situation; others by reading the printed word. Some learn through graphic symbols (Thompson, 1990); others through instruction. Other factors include the learning strategy employed (often controlled by the teacher) and the expected outcomes. Lord (1998) illustrated this view in diagrammatic form:

A number of learning tasks can be readily aided through the routine use of ICT. Simple skill acquisition, knowledge building, and modeling through simulations can give practice to aid creative development. However, when the tasks are related more to higher cognitive tasks, the benefits become more problematic. Passey (1998) suggested that in developing higher order skills, ICT has a more restricted role than with work in lower order domains, with the concomitant suggestion that work in the higher domains requires more in the way of teacher intervention. The continuum lies between the teacher being assisted by the technology and the teacher teaching to the technology.

Most learning theories have much in common, such as the need for motivation and consideration of individual differences in learners. Students are not all interested in the same topic, do not have the same physical or psychological characteristics, and do not come from the same environment. These individual differences are clearly evident in design and technology and particularly in their design project work (Atkinson, 1998; Wu, Custer, & Dyrenfurth, 1996). This would indicate that the most effective way forward would be an individualized learning program for each student where the acquisition of knowledge, skills, and values could be tailored to each student's special needs. This student-centered approach in technology education, sometimes called the investigative learning approach (Sellwood, 1991), creates heavy demands on the teacher and, consequently, it is often modified to ensure that it is manageable within the classroom context. The resulting curriculum and its implementation is a compromise between the resources available and what is required by the student (Barlex, 1993). This concept of individualized and differentiated learning as an ideal methodology has strong advocates and yet is not very common in school (Thomas, 1992) because teachers, understandably, find it difficult to determine and meet the needs of both the better able and those with learning difficulties. They also find this methodology time consuming when working under pressure to transmit facts and achieve observable changes in behavior (Kyriacou, 1992) such as design folios or technological reports and records for assessment purposes.

Some teachers have already recognized the use of a personal computer can facilitate individualized learning, particularly as a source of information. The provision of information is, of course, not sufficient for learning to take place as it does not necessarily lead to understanding. For example, the importance of cultural and social interaction is stressed by Bruner (Wood, 1988) as necessary for cognition (Jenkins, 1994). (Technology teachers often take advantage of this understanding and build such work into their programs. Hill and Smith [1998] described a program of manufacturing technology education in which they base the work on community needs specifically to harness this student involvement with others.) However, the additional dimension of the individual's cognitive makeup (Salomon, 1991) is also important in the development of technological concepts. It is this combination that forms the basis of individuality that could explain the value of ICT with some learners and yet totally fail to connect with others. The social interaction that is essential to many learners may take a unique form with others. It is possible that the interaction becomes one step removed so that the relationship is at second hand and is mediated through the technological hardware. McLoughlin and Oliver (1998) demonstrated that students working in groups using personal computers interact in such ways that cognitive abilities and concepts are developed much like face-to-face interactions. The interaction between learners using the Internet could be as valid as the interaction between teacher and learner in a traditional setting. In an

Australian study, Williams and Williams (1997) recognized the validity of this interaction and also identified some practical problems when engaged in collaborative designing using remote interaction. Clayden, Desforges, Mills, and Rawson (1994) elaborated upon the view that learning is a product of negotiation, a constant initiation into socially constructed webs of beliefs, thus requiring much more than the transmission of knowledge. This socially constructed web, however, may not necessitate a physical presence. It is the quality of the interaction that is important, not the means of exchange.

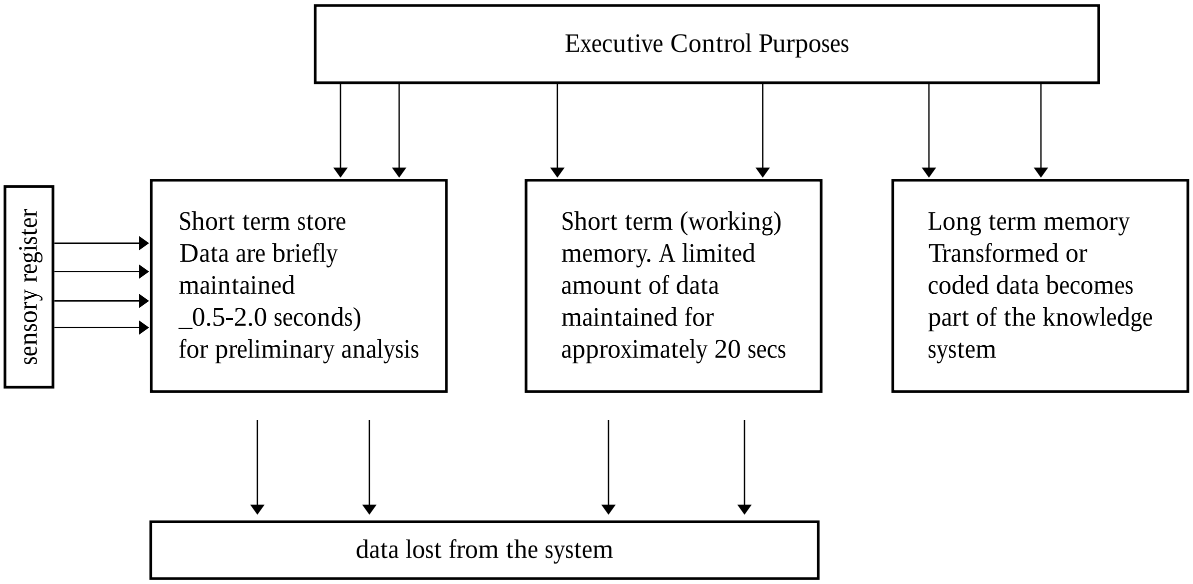
One Way Forward

One way forward is to switch our attention from the design of software packages (which act solely as storehouses of information) to an interactive problem-based environment in which the student assumes the key. Currently, where it is common practice to produce learning materials that are uniform for all learners the learners must "fit in" with the suggested activities. The learner should not have to adjust to the equipment available; the learning task should always be the dominant factor (Beardon, Malmborg, & Yazdani, 1998) and the software designed to this end. In this model, the first task of the learning package is to develop a picture of both the student's learning strategies as well as an analysis of the student's existing knowledge and cultural base (Tweddle, 1998). With this profile in place, the learning task can be tailored to the student's capabilities rather than the student having to fit in with the software designer's generalized understanding of how learning should take place (Andaloro & Bellomonte, 1998). The creation of these rich learning environments will also have to ensure that texts, reference sources, multimedia, and communication facilities are fully integrated.

While it can be seen that major benefits can accrue from the use of ICT in technology education, it will not be sufficient on its own to provide a meaningful program of learning activities that can deliver the full range of desired outcomes. Technology education as it is practiced in schools is essentially a practical activity and the making element is fundamental to the learning activity. Other theoretical models must be identified to explain the shortcomings.

What appears to be a fundamental difficulty in the utilization of ICT in this subject area is the basic belief that in technology we are involved in education through the use of materials (i.e., if the connection is broken between the content and the process through which it takes place, the subject's raison d'etre is nullified). A computer simulation cannot be used as a substitute. Baird (1990) used the concept of metacognition to explain this differential understanding. He claimed that metacognition can be enhanced through both the content of what is to be learned and also the context in which it is to be

Figure 4. Information Processing (Gredler, 1992)



learned. The reason for this understanding can be illustrated through an information processing model of learning shown in Figure 4. While such models are hypothetical, they provide a valuable insight into the value of technology education as a process as well as a body of knowledge.

These theories are derived from models in which data, developed from perceptual cues, are processed in a logical fashion to provide desired outcomes through the systematic ordering and restructuring of new information. In information processing models of learning, information is received through our sensory organs where some of it is lost and some of it is filtered for its importance before being passed to the short-term memory store. (When working in a workshop or studio, the range of senses employed by the learner is increased. The tactile and olfactory senses employed when working with resistant materials together with sounds generated must all help to build more accurate concepts than those obtained from working solely with the printed word or even a computer simulation). At this stage, information is consciously worked upon and sometimes used for routine operations. Data or information that is recognized to be of greater value is subjected to transformation and transferred to the long-term store for appropriate concepts that "make sense'" and for use when needed.

This is obviously a very complex process that relies upon the accuracy of the interpretation of the perceptual cues that are received from our sensory organs and also the ability of the brain to recognize appropriate schemata or connections. The learning process can therefore be enhanced if the learner uses a range of sense organs (Eisner, 1985) to help form the concepts under development. The wider the range and the more accurate the inputs, the more effective the learning is.

While information processing models of learning are useful in explaining how changes in behavior in the cognitive domain may occur, these theories are not solely concerned with that domain because the sensorimotor skills necessary for the implementation of much technological/scientific/physical activity are said to have much in common with the mental skills used in categorizing and processing knowledge for other forms of activity (Welford, 1971). We could, therefore, have an understanding that encompasses and explains a lot of activities found in technology education. Again, it is important to stress that while an information processing model is of value, it cannot be the whole story. Dyne et al. (1994) suggested that information processing explains in part the learning that takes place while acknowledging that what they term "student approaches to learning" (SAL) as an essential component. Learning occurs both within the student as well as within the teaching\learning context.

Conclusion

We are often confused by the virtues of ICT. Its advantages for data retrieval and routine, lower order activities are obvious and often valuable. However, the application of ICT to technological problem solving or other higher level research activities still leaves much work to be done.

In summary, there appears to be at least five stages or levels in the use of ICT in technology education:

- Level 1 is the development of routine skills such as word processing or graphics packages as an aid to clarification and communication.
- Level 2 is the use of ICT to search databases such as CD-ROMs and the WWW as a powerful library. It is important to realize, however, that it is not sufficient to give students practice in using such sources; they also require skills in finding the information and in discrimination of the results.
- The third level is the adoption of existing programs to gain a deeper understanding of the power of ICT to "number crunch," to control mechanisms, or for modeling simple solutions to attainable problems.
- In Level 4 the learner moves from the direction and guidance of the teacher to the development of creative thought, possibly not until senior levels of school or university education. The PC now becomes an extension of the brain.
- The fifth and possibly most difficult level to attain-and the one in which most research needs to be done-is related to the development of understanding of the cognitive processes of the learner and the application of this knowledge to specific tasks. At this stage we may be able to develop generic creative abilities rather than the ability to understand specific problems. When we can utilize this capability, we will begin to be able to exploit the power of ICT in the learning environment.
- While it is obvious ICT can be used to aid learning, the real breakthrough will occur when truly interactive packages provide rich learning environments.

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