Constructivist Computer Assisted Learning: Theory and Techniques

Barney Dalgarno
Information Services Division
University of Canberra
barney@isd.canberra.edu.au

The changes that have occurred in accepted approaches to teaching and learning in recent years have been underpinned by shifts in psychological and pedagogical theory, culminating in moves towards a constructivist view of learning. This paper looks at these psychological and pedagogical theories and the consequences for Computer Assisted Learning (CAL). Examples will be demonstrated to illustrate the approaches to CAL that have arisen out of these theories.

Moshman has identified three interpretations of constructivism: endogenous constructivism which emphasises learner exploration, exogenous constructivism which recognises the role of direct instruction, but with an emphasis on learners actively constructing their own knowledge representations and dialectic constructivism which emphasises the role of interaction between learners, their peers and teachers. This classification scheme provides a framework for looking at the various constructivist approaches to CAL.

For example, constructivist CAL materials that draw on the endogenous view include hypermedia environments, simulations and microworlds. Materials that draw on the exogenous view include learner controlled tutorials, cognitive tools and practice modules. Lastly, materials that draw on the dialectic view are broadly termed Computer Supported Collaborative Learning (CSCL) tools.

1. Introduction

Accepted teaching and learning practices have undergone changes of revolutionary proportions in recent years. These changes are evident in situations as diverse as early childhood teaching, university physics teaching and workplace training. They have been underpinned by shifts in psychological and pedagogical theory, the most recent of which fit broadly under the heading of constructivism. This paper looks at these psychological and pedagogical theories and the consequences for Computer Assisted Learning (CAL).

1. Foundations of Constructivism
   2. From Behaviourism to Cognitivism

The recent changes in teaching and learning practices have had their roots in two broad theoretical developments. The first development, in the field of psychology, has been the demise of behaviourism in favour of a movement broadly referred to as cognitive psychology. Behaviourism is based on the premise that it is meaningless to theorise about the workings of the brain, since we can only study the behaviour of people in responding to stimuli (Leahey and Harris, 1993; Schultz and Schultz, 1992). The consequence of this premise is that there is an emphasis on strategies such as repetition that encourage 'parrot' fashion learning rather than higher order cognitive processes. The cognitive psychology movement rejects this premise, instead surmising that a person's response to stimuli is individual and depends on the person's cognitive state and on the mental processes occurring (Leahey and Harris, 1993; Schultz and Schultz, 1992). The important consequence of the cognitive position is that rather than being concerned with the best way to illicit the desired response, teachers are concerned with the learner's cognitive activity and the mental models that they form.

This development alone, however, did not force widespread changes in teaching methods to occur. There was a tendency to assume that although learners actively form a mental model of the knowledge they acquire, there is nevertheless some objectively 'correct' mental model for any given area of knowledge, that learners should acquire. Consequently the focus continued to be on designing a single sequence of instructional events, with the rationale changing from reinforcing the 'correct' responses to stimuli, to 'transferring' the 'correct' mental model to the learner (Jonassen, 1991; Rieber, 1994).
1. From Objectivism to Constructivism

The second development, which is more of a philosophical shift than a new movement in psychology, has been the gradual rejection of the assumption that there is some objectively correct knowledge representation. The alternative view, termed constructivist, is the view that rather than there being a single correct mental model of knowledge, the various knowledge representations that individuals construct may be equally valid. The focus of teaching then becomes one of guiding the learner as they build on and modify their existing mental models, that is, a focus on knowledge construction rather than knowledge transmission (McInerney and McInerney, 1994; Slavin, 1994).

There are three broad principles that together define the constructivist view of learning. The fundamental principal, is that each person forms their own representation of knowledge, building on their own individual experiences, and consequently that there is no single 'correct' representation of knowledge. This principal was articulated by Kant in his *Critique of Pure Reason* and later adopted by Dewey (von Glaserfeld, 1984; Hawkins, 1994). It is implicit within the works of both Piaget and Vygotsky. The counter view, that there is a single 'correct' representation of knowledge, is labelled by constructivists as objectivist.

The second principal, normally attributed to Piaget, is that people learn through active exploration, and that learning occurs when the learner's exploration uncovers an inconsistency between their current knowledge representation and their experience. Piaget labels the state that the learner is in when they have uncovered such an inconsistency as a state of disequilibrium. The process of changing the knowledge representation to incorporate the experience is called accommodation (McInerney and McInerney; 1994; Slavin, 1994). Bruner was the first to espouse a detailed theory of instruction based on this principal, in his discovery learning theory (Bruner, 1962; Vander Zanden and Pace, 1984).

The third principal, normally attributed to Vygotsky, is that learning occurs within a social context, and that interaction between learners and their peers is a necessary part of the learning process. Vygotsky (1978) describes those capabilities that are beyond the learner on their own, but are able to be carried out with the assistance of more knowledgable peers, as capabilities in the zone of proximal development (Dixon-Krauss, 1996; McInerney and McInerney; 1994; Slavin, 1994).

1. Constructivist Teaching and Learning

Although there is general agreement on the basic tenets of constructivism, the consequences for teaching and learning are not as clear cut. It is generally agreed that learning involves building on prior experiences, which differ from learner to learner. Consequently, each learner should have a say in what they are to learn, different learning styles must be catered for and information must be presented within a context to give learners the opportunity to relate it to prior experience. It is also generally agreed that the process of learning is an active one, so the emphasis should be on learner activity rather than teacher instruction.

However, from here there is significant disagreement about the details of how to implement these broad principles. The differing views tend to be on a continuum from the moderate to the radical. Radical constructivists claim that the only way to learn is for learners to be placed within the environment they are learning about and construct their own mental model, with only limited support provided by a teacher or facilitator. More moderate constructivists claim that formal instruction is still appropriate, but that learners should then engage in thought oriented activities to allow them to apply and generalise the information and concepts provided in order to construct their own model of the knowledge (Perkins, 1991). A third dimension to this disagreement is the view that knowledge construction occurs best within an environment that allows collaboration between learners, their peers, experts in the field and teachers.

These different interpretations of constructivism have been labelled by Moshman (1982) as endogenous, exogenous and dialectic, as follows:
Endogenous constructivism emphasises the individual nature of each learner's knowledge construction process, and sees the role of the teacher as being merely to facilitate disequilibrium occurring by providing appropriate experiences.

Exogenous constructivism is the view that formal instruction can help learners to form knowledge representations which they can later accommodate to their subsequent experiences.

Dialectic constructivism is the view that learning occurs through realistic experience, but that learners require *scaffolding* provided by teachers or experts as well as collaboration with peers.

Rather than looking at these categories as being mutually exclusive, it is more informative to think of them as being points on a triangle, with any particular view of constructivism drawing on influences from all three, but positioned nearer to one point than the others. The diagram below illustrates this idea, showing where a range of constructivist pedagogical theories lie in relation to these categories. The theories shown in the diagram are Wittrock's *Generative Learning* (1974), Bruner's *Discovery Learning* (1962), Brown, Collins and Duguid's *Situated Cognition* (1989), Cognition and Technology Group at Vendarbilt's *Anchored Instruction* (1991), *Whole Language Teaching* (Goodman and Goodman, 1990), Spiro, Feltovich, Jacobson and Coulson's *Cognitive Flexibility Theory* (1991), Ausubel's *Expository Learning* (McInerney and McInerney, 1994), *Metacognitive Strategies* (Wittrock, 1994), *Scaffolding* (Bruner, 1986) and *Cooperative Learning* (Johnson and Johnson, 1994).

### 1. Computer Assisted Learning

Having looked at the origins and the various interpretations of constructivism, we can now look at approaches to Computer Assisted Learning (CAL) that have grown out of constructivism. In doing so, Moshman's three interpretations of constructivist theory again provides a useful framework. Before looking at the CAL techniques that are consistent with each of these interpretations of constructivism, it is appropriate to look at the nature of traditional CAL resources based on behaviourist views of teaching and learning.

#### 1. Pre-constructivist Techniques

Traditional CAL resources consisted primarily of tutorials, which were essentially computer based forms of Programmed Instruction (PI), drawing heavily on the behaviourist views of Skinner. (Rieber, 1994). These tutorials typically contained sequences of content broken into sections, with end of section questions to determine whether the learner required remedial content or was ready to go on to the next section. They also included drill and practice materials, consistent with the behavioural psychology emphasis on producing automatic responses by repeated reinforcement. (Rieber, 1994). Examples of resources that are consistent with a behaviourist view of learning...
include the series of language tutors produced by HyperGlot, such as *French Word Torture* (Rice, 1989) and Webster's Computer Based Training (CBT) resources for learning how to use specific software packages.

Because of the gradual adoption of constructivist principles by designers, there are many examples of resources that are structured primarily on the traditional tutorial model, but which include discovery learning components or practice exercises that are consistent with the constructivist principles of active learning. Examples of such resources include *Alge Blaster Plus* (Hertz, De Witt and Ely, 1990), an algebra tutorial and *Understanding the Unobservable* (Cheetham, Raynor and Bennet, 1996), a tutorial on quantum physics.

One approach that attempts to address the linear nature of traditional tutorials is Intelligent Tutoring Systems (ITS). They typically consist of internal models of the expert's knowledge, the learner's current knowledge and pedagogical principals. As the instruction proceeds, the model of the learner's knowledge and the model of the expert's
knowledge are compared, and using Artificial Intelligence techniques, the sequence of instruction is dynamically generated to suit the needs of the learner (Orey and Nelson, 1993). Although these systems are consistent with the cognitivist view that the instruction should depend on the learner's current cognitive state, they are nevertheless objectivistic, because they have an implicit premise that there is some objectively correct cognitive state that the learner should acquire (Jonassen, 1992a). Examples of Intelligent Tutoring Systems include Lisp Tutor (Weber et al., 1996) and The Intelligent Physics Tutor (Mueller et al., 1996).

Figure 4.
*The Intelligent Physics Tutor*

1. Endogenous Constructivist Techniques

Endogenous constructivists emphasise the importance of learner directed discovery of knowledge. Constructivist CAL materials that draw on this view include hypertext and hypermedia environments allowing learner controlled browsing of content, simulations allowing exploration of an aspect of the world that is inconvenient to experience first hand and microworlds allowing exploration and construction within a concept space or highly simplified representation of reality. Another element of the endogenous view, is an emphasis on the learner carrying out realistic tasks and solving real problems. Consistent with this emphasis is the use of support tools that provide scaffolding to learners as they attempt to solve such problems.

1. Hypertext and Hypermedia

The term hypertext was first coined by Ted Nelson in the 1960s, but the concepts are normally traced to Vannevar Bush in 1945 (Gygi, 1990; Rieber, 1994; Park and Hannafin, 1993). Hypertext consists of chunks of textual information (nodes) with certain words acting as an automatic link to another chunk (McKnight, Dillon and Richardson, 1991). Hypermedia is a more general term, indicating that the nodes can be composed of a variety of media and that screen objects such as icons, 'hot areas' within pictures and graphical buttons can act as links in addition to words within text. (Gygi, 1990; Seaman, 1993). As well as becoming popular for use in instructional systems, hypermedia has also found widespread application as a way of organising and accessing large information databases, typically delivered on CD-ROM (Vaughan, 1993). Most recently the Hypertext Markup Language (HTML), a standard file format for hypertext databases has become the information delivery standard for the World Wide Web (Dalgarno, 1995a; Eklund, 1995).

Because hypermedia information databases typically allow browsing under complete learner control, with learners following a sequence of links that makes sense to them, it is suggested that they facilitate the formation of individual knowledge representations (Rieber, 1994). This freedom to browse through the content, is consistent with the constructivist principle that learners should be given the opportunity to discover knowledge through their own active exploration. *From Alice to Ocean* is an example of a hypermedia system, which allows learners to explore aspects of a journey across the outback of Australia.
Hypertext has been advocated as a mechanism for applying cognitive flexibility theory, a theory that focuses on advanced knowledge acquisition in ill-structured or complex domains (Spiro, Feltovich, Jacobson and Coulson, 1991; Jonassen, 1991). The use of hypertext links allows the learner to choose from a range of relevant examples of the theme or concept being illustrated. It also allows for a particular area of the content to be examined a number of times, from different perspectives.

1. Simulations and Microworlds

There is no accepted definition of simulations and microworlds that allows for a clear distinction between the two. Most simulations include features of microworlds and most microworlds include features of simulations regardless of which definition is chosen. Typically a simulation is defined as a model of a real world environment, usually with the facility for the user to interact with the environment (Thurman, 1993; Rieber, 1994). A microworld is typically defined as a model of a concept space, which may be a very simplified version of a real world environment, or it may be a completely abstract environment. Normally, a user can create some sort of constructions within the microworld which will behave in a way consistent with the concepts being modelled (Papert, 1993; Rieber, 1992; 1994).

Simulations and microworlds are popular with constructivists for two reasons. Firstly, simulations (and some microworlds) provide a realistic context in which learners can explore and experiment, with these explorations allowing the learner to construct their own mental model of the environment. Secondly, the interactivity inherent in microworlds (and usually in simulations) allows learners to see immediate results as they create models or try out their theories about the concepts modelled. (Rieber, 1992; 1994).

Simulations have been used as part of CAL materials for at least three decades. Well known examples include *Sim City* and the other Maxis products (Wright, 1989). Another example is *Bihari Farmer* (Stainfield, 1996), which simulates the life of a third world farmer. For descriptions of other examples see Johnson and Norton (1992), Alessi and Trollip (1985), Munro and Towne (1992) and Edens (1990).
Virtual Reality (VR) simulations have become possible with recent technological developments, allowing the user to feel completely immersed within the simulated environment. These simulations typically make use of three-dimensional viewing helmets with head-tracking devices along with data gloves for navigation control (Fisher, 1990). Recently interest has grown in the possibility of networked simulations, with learners positioned around the world, using technologies such as the Virtual Reality Modelling Language (VRML) and Multi-User Object Oriented Domains (MOO) (Dalgarno, 1995b; Dede, 1995).

The term microworld was first coined by Papert (1993) leading to the development of the Logo microworld for exploring and constructing within a geometrical concept space. Other popular examples include The Incredible Machine, a mechanical problem solving environment and Geometer's Sketchpad (Key Curriculum Press, 1996) a geometric exploration environment. For other examples, see Rieber (1992; 1995) and Hennessy, Spensley, O'Malley, Byard, Driver, Mallen, Mohamed, O'Shea and Scanlon (1990).
1. Support Tools

An important element of constructivist theory is the idea that learners should be given the opportunity to carry out realistic tasks, with assistance or scaffolding provided to enable them to complete the larger task without needing to learn all of the sub-tasks that they encounter on the way. Ideally as a by-product the learner will learn how to complete the sub tasks so that eventually they will be able to carry out the larger task unassisted. This scaffolding can be provided in part by the computer, through support software. The software may be designed specifically for the purpose, such as the lesson planning tool described by Wild and Kirkpatrick (1995; 1996), the process writing tool described by Lohr, Ross and Morrison (1995) and the problem solving case libraries described by Guzdial, Kolodner, Narayanan, Rappin, Hubscher and Turns (1996). Alternatively, general purpose software such as a language translator, a spell checker, a thesaurus, or a spreadsheet program can fill a similar role.

The use of Electronic Performance Support Systems (EPSS) within the workplace is another example of such support tools. The use of such tools in the workplace is consistent with 'just in time' approaches to workplace training. These systems provide the assistance necessary to allow novice employees to carry out skilled tasks, at the same time as providing tools to allow skilled employees to carry out their work more efficiently (Collis and Verwijs, 1995; Goodyear, 1995).

1. Exogenous Constructivist Techniques

The exogenous view of constructivism recognises the value of direct instruction, but not the teacher centred single sequence of instruction of behaviourists. According to the exogenous view, learners should have some control over the sequence and selection of content, should have the opportunity to actively construct their own knowledge representations and articulate these representations at all stages, and after instruction should have the opportunity to apply their knowledge to realistic tasks. Constructivist CAL materials that draw on the exogenous view include tutorials that incorporate learner control over sequence or conversely, hypermedia browsing environments that include context sensitive pedagogical guidance. The use of cognitive tools for manipulating symbolic representations of concepts and for articulating constructed knowledge, including concept mapping tools, modelling tools, and text and hypertext editing tools is consistent with the exogenous constructivist emphasis on individual knowledge construction. The use of practice modules allowing learners to get feedback on their knowledge constructions, for example quizzes, matching or grouping of pictures and symbols, and problem solving exercises with feedback, is also consistent with the exogenous view.

1. Tutorials with Learner Control and Guided Hypermedia

Tutorial systems that are consistent with constructivist theories typically provide a structure that encourages the learner to follow certain instructional sequences, but allows them to choose alternative sequences, or to use the materials as a discovery learning resource if they are so inclined. In fact, often they use a hypertext or hypermedia metaphor, but provide a clearer structure or more guidance than environments that are designed specifically for
discovery learning. Typically, these tutorials will have within them practice exercises as well as annotation tools that allow the learner to articulate their knowledge constructions. For example, Investigating Lake Illuka is an environmental education tutorial providing a hypermedia interface along with annotation tools and suggested exercises.

![Image of Investigating Lake Illuka](image)

**Figure 9. Investigating Lake Illuka**

Exogenous constructivists are inclined to criticise many hypermedia exploration environments, citing research that shows the tendencies for learners to become 'lost in hyperspace' (Park and Hannafin, 1993; McKnight, Dillon and Richardson, 1991; Gygi, 1990). The problem is normally caused by not being able to visualise the overall structure of the space and not being able to mentally keep track of the links that have been followed (Gygi, 1990). One proposed approach to this problem is to provide pedagogical guidance to the learner as they browse. This guidance could be in the form of intelligent monitoring of the browsing patterns of the learner or it could be in the form of more passive guidance through pop-up help.

The creation of guides which simulate the role of a personal travel guide has been proposed (Wills, 1996; Oren et al., 1990). These guides typically have a visual appearance which may be conveyed through an icon, a photograph, an animated cartoon or a video, possibly using digitised or synthesised voice. For example, Wills (1996) describes a hypermedia University Handbook, that provides a choice of student guides, each providing a unique perspective on the information portrayed in the system.

Where the guide does more than simply provide advice, and actually makes decisions on behalf of the learner, it is normally termed an agent. Oren, Salomon, Kreitman and Don (1990, p.381) describe guides as interface objects that provide "canned additions to the database rather than intelligent reformations of the content" and agents as "autonomous software entities that make choices and execute actions on behalf of the user".

The use of intelligent agents within a hypermedia environment is often referred to as adaptive hypermedia (Eklund, 1996). In order for an agent to make decisions on behalf of the learner, a model of the learner’s current knowledge state or at least a log of their browsing history is required (Laurel, 1990). The action of the agent could consist of a modification of the set of links available or the choice of a particular content representation. Where the content is modified according to the current learner model, adaptive hypermedia systems are effectively examples of Intelligent Tutoring Systems, which have an objectivist assumption implicit within them as discussed above (Jonassen, 1992a). On the other hand, intelligent guides that provide a suggested next link, can provide valuable navigation assistance without enforcing what may be an undesirable or inappropriate learning strategy.
1. Cognitive Tools

All three views of constructivism emphasise the importance of individual knowledge construction. A consequence of this is the use of metacognitive strategies, that is, strategies employed by the learner to improve their comprehension, retention and individual construction of knowledge. These strategies are considered particularly important by exogenous constructivists, who typically advocate that these strategies be directly taught to students. It has been proposed that the use of computer based cognitive tools can be of assistance with these strategies. According to Jonassen, such tools "amplify thinking and facilitate knowledge construction" (1992a, p.4), while Wild and Kirkpatrick state that these tools can "provide the means by which learners can construct, manipulate and evaluate representations of knowledge" (1996, p.414). These tools include text and hypertext editing tools, modelling tools and concept mapping tools (Jonassen, 1994).

Critics of the use of hypermedia environments for the delivery of content have often stated the view that the most significant learning gains occur when learners are able to annotate the hypermedia environment with their own ideas and their own links between concepts, or to develop their own hypermedia databases (Jonassen, 1992b). The node-link structure of hypermedia environments has been compared with the way information is stored in the brain (Warren, 1989, in Lohr, Ross and Morrison, 1995). Consequently, learners constructing their own hypermedia databases are able to articulate their knowledge representations. This has lead to the use of a hypertext environment to teach process writing skills (Lohr, Ross and Morrison, 1995). The collaborative development of hypertext environments has been proposed as an approach to collaborative writing (Bonk, Medury and Reynolds, 1994; Trigg and Suchman, 1989 in Lohr, Ross and Morrison, 1995) and collaborative learning in general (Edelson, Pea and Gomez, 1996). Tools that allow the learner to develop their own hypertext documents and hypermedia databases include authoring tools such as Hypercard and Toolbook (see Dalgarno, 1996b for a review) or HTML editors.

Concept mapping, whereby the learner draws a diagram indicating the concepts that make up an area of knowledge and the way that these concepts relate to each other, has long been advocated as an effective metacognitive strategy (Jonassen, 1992c; Fisher, 1992; Gaines and Shaw, 1995). Various syntactic guidelines for cognitive mapping have been proposed, for example by Buzan (1970 in Jonassen, 1992c) and by Novak (1977, in Gaines and Shaw, 1995). The term semantic networking, which originally was used by Artificial Intelligence researchers to describe formal representations of knowledge, is often used synonymously with concept mapping. Various computer assisted concept mapping tools have been developed, including SemNet (Fisher, 1992) and KMap (Gaines and Shaw, 1995).

Figure 10.

Sem Net

Just as hypermedia environments that allow only passive browsing, rather than active knowledge construction, can be criticised, the use of simulations, without the learner having the opportunity to modify the implicit model or construct their own model can be similarly criticised. The use of modelling tools that allow the learner to develop
their own simulation of a particular aspect of the world requires the learner to develop a very deep understanding of the concepts involved. Agent Sheets (Eden and Eisenberg, 1996) is a modelling environment designed to allow learners to produce simulations similar to Sim City. Stella, also called ithink (High Performance Systems, 1994) is a modelling tool that provides a graphical environment allowing the learner to specify the quantities to be modelled and their relationship, and will then carry out the simulation producing charts showing the changes in quantities over time.

1. Practice Modules

If direct instruction is to be used, an important element of the instructional process is the provision of opportunities where the learner can put their knowledge into practice and receive feedback on their knowledge constructions. In some knowledge domains this could occur through the learner carrying out activity within a simulated environment or a microworld. In others it might occur through the learner articulating their knowledge representation in a written form, or in the form of a hypertext database. However, in some cases, the use of simple practice exercises with feedback is quite appropriate. These might consist of multiple choice, single word or numeric answer quizzes, the graphical matching of words and symbols or the grouping of words and symbols. The prototype hypermedia tutorial system, Curry Cookery Concepts (Dalgarno, 1996b), includes a number of different types of exercises of this type.
1. Dialectic Constructivist Techniques

Dialectic constructivists emphasise the role of social interaction in the learner’s knowledge construction process, leading to an emphasis on cooperative and collaborative learning strategies. The term Computer Supported Collaborative Learning (CSCL) is typically used to describe tools to assist in this type of learning. Technologies used for CSCL can be divided into three groups, those that are general purpose Computer Mediated Communication (CMC) tools, those that are designed for Computer Supported Cooperative Work (CSCW) and lastly those that have features specifically for group learning (O’Malley, 1995).

CMC technologies can be classified according to the type of communication that they allow, that is whether they allow one to one or one to many communication and whether they allow synchronous or asynchronous communication (Bonk, Medury and Reynolds, 1994). Technologies that are helpful with asynchronous communication include Email for one to one and mailing lists, news groups and bulletin boards for one to many communication. Technologies that are helpful with synchronous communication include talk programs for one to one and computer conferencing environments such as Internet Relay Chat (IRC) for many to many communication. (Bannon, 1995; Bonk, Medury and Reynolds, 1994). The rapid adoption of the Internet has seen a number of new CMC tools becoming available, including user friendly Email tools and tools such as Netscape Navigator that integrate World Wide Web browsing functionality with conferencing functionality using Internet news groups (Dalgarno, 1995a).

Figure 13. Netscape Internet News Reader

CSCW tools, commonly known as groupware, typically include CMC tools along with shared workspaces for collaborative work, scheduling tools and workflow organisers (Grudin, 1990). Although designed primarily for use within the workplace, groupware tools have been found to be useful in a learning context for group projects (Collings, Richards-Smith and Walker, 1995).

Systems designed specifically for collaborative learning typically include a CMC component as well as tools for group learning tasks. These may include tools for group writings, tools to facilitate discussions (such as allowing role playing within the discussion), tools for shared annotation of hypermedia spaces or tools for shared problem solving (Bonk, Medury and Reynolds, 1994; Scardamalia and Bereiter, 1996; Harasim, Hiltz, Teles and Turoff, 1995; Edelson, Pea and Gomez, 1996; Trigg and Suchman, 1989 in Lohr, Ross and Morrison, 1995).

1. Conclusion

This paper has summarised the recent psychological and pedagogical theories that have lead to significant changes in accepted teaching and learning strategies. It has outlined the consequences of these theories for Computer Assisted Learning, showing that the range of proposed CAL techniques incorporating constructivist theory has been
broad and varied. The number of packages described that make use of these techniques, indicates that there has been significant progress made by developers in incorporating constructivist theories into their resources. However, these packages represent a small proportion of the products that are available to educators. There are still numerous packages available that are built on behaviourist assumptions about teaching and learning, or worse still, are built on no assumptions at all except the view that if there are lots of moving pictures and sound then people will buy the product. It is hoped that as educators become more knowledgable about Computer Assisted Learning they will become more discerning about their purchases, which ultimately will create a market for products that are based upon sound pedagogical principles, and most importantly, products that really do facilitate learning.

1. References


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