Who benefits from Virtuality?

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Abstract
For educational software to take advantage of contemporary views of learning, instructional designers need to employ design models that incorporate the variety of ideas that are based on constructivist frameworks for developing learning environments. These environments, if well designed, can support learner construction of knowledge, however such frameworks are based upon arguments that learners should be placed in authentic environments that incorporate sophisticated representations of context through such constructs as "virtual worlds". Within these environments the learner is supported by visual metaphors constructed to represent the information structure and how the “world” operates. This paper will discuss the framework employed in the development of several virtual solutions and the process by which they were constructed.
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Technology Supporting Reform

In today's society greater demands are being placed on education systems at all levels to produce citizens who can use knowledge in new domains and different situations. Members of society at every level are being asked to demonstrate advanced levels of problem solving to retain their utility as employees. Learning to think critically, to analyse and to synthesise information, to solve problems in a variety of contexts and to work effectively in teams are crucial skills for modern employees, and yet there is little evidence that our education systems are developing these skills in our children (Bransford, Goldman and Vye, 1991).

Schank and Cleary (1995) have argued strongly that our educational systems are not developing these essential skills, the Cognition and Technology Group at Vanderbilt (CTGV) (CTGV, 1993) have outlined what they claim are the flaws in the conventional approaches to schooling and teaching, based on Whitehead’s (1929) notion of "inert" as opposed to "active" knowledge. Berryman (1991) has delineated several erroneous assumptions on which much of the teaching and schooling process is based. Calls for the restructuring of the schooling process have also come from institutions such as the American Association for the Advancement of Science (1989), the National Council of Teacher’s of Mathematics (1989) and have been called for in Australian reports such as the Discipline Review of Mathematics and Science (DEET, 1989). However, not all calls are for development of problem-solving skills and higher-order thinking.

Recent curriculum documents in many western countries emphasise the skills of investigation, reflection and analysis to generate or refine knowledge. The appeal of cognitive process training to support this development is obvious, and it seems far more efficient to provide the student with general-purpose problem solving than instruction on specific solutions to specific problems. Jonassen and Tessmer (1996/7) have also questioned the commonly used taxonomies of learning that are the basis of our curriculum documents, proposing that engaging in a greater range of learning outcomes than isolated intellectual skills is essential for meaningful learning.
Significant efforts being made to develop and implement alternative frameworks for learning and much of the current effort for renewal is based upon a class of theories referred to as constructivism. Fundamentally, constructivism asserts that we learn through a continual process of constructing, interpreting, and modifying our own representations of reality based on our experiences with reality (Jonassen, 1994). At the same time, the convergence of technologies that enable the representation of ideas in many different media forms through information and telecommunication technology, offers designers unique opportunities to customise learning environments, place learners in open ended student–centred investigations, and to support the shift in traditional instructor roles to mentor and co-learner.

The development of software that supports modes of instruction with alternative frameworks is an issue that is now being addressed by researchers, but it is largely not being realised by developers of educational software.

Constructivism: implications for the design and delivery of instruction

There have been a number of researchers who have written about the challenge of how designers can implement the class of theories referred to as constructivism within technology-supported learning environments. Initial support for designers has generated some proposed sets of design guidelines and instructional design goals that attempt to incorporate social constructivist frameworks. For example, Cunningham, Duffy and Knuth (1993) devised a set of pedagogical goals for designers of constructivist learning environments. More recently, they (Duffy and Cunningham, 1996) reinterpreted their original list to develop a list of seven “metaphors we teach by” as basic assumptions for design.

1. All knowledge is constructed: All learning is a process of construction
2. Many worldviews can be constructed: hence there will be multiple perspectives
3. Knowledge is context dependent, so learning should occur in contexts to which it is relevant.
4. Learning is mediated by tools and signs.
5. Learning is an inherently social-dialogical activity
6. Learners are distributed, multi dimensional participants in a sociocultural process
7. Knowing how we know is the ultimate human accomplishment

These basic assumptions have taken account of the sociocultural interaction of constructivist theory and incorporated learner ownership and voice in learning into the construction process. A new element “learning is mediated by tools and signs” has been added to imply that the
tools (technology) and signs (semiotic tools) we use change the form, structure and character of activities and thus our knowledge.

For designers to adopt these frameworks, they also need to re-examine the instructional design paradigms they are using. It is no longer sufficient to use the traditional hierarchical, prerequisite sequences (ie learning taxonomies) that concentrate on recall and application of knowledge. Jonassen and Tessmer (1996/7) have suggested a more effective taxonomy which would “elaborate structural and higher order cognitive, metacognitive and motivational leaning outcomes that are not included in the currently-used taxonomies of learning outcomes.” Thus, if we are to design learning environments on the framework proposed by Duffy and Cunningham, appropriate learning outcomes associated with this view of learning will need to be devised, and it is thus no longer appropriate to rely on the behavioural bias of commonly-used instructional design models. In particular, Jonassen, Peck & Wilson (1999) have proposed that we need to develop strategies that support:

1. Active learners to engage in interaction with and manipulation of the exploration environments that designers construct.
2. Learners to explore and strategically search through these environments.
3. Intentional learners willingly trying to achieve cognitive objectives.
4. Conversational learners engaged in dialogue with other learners and with instructional systems.
5. Reflective learners articulating what they have learned and reflecting on the processes and decisions that were included in the process.

Designers of technology-based learning environments can draw not only on these ideas, but also the work of the many other writers who have sought to develop guidelines and heuristics to support their development and to support new modes of learning. (See for example, Hannafin and Land, 1997; Honebein, Duffy and Fishman, 1993; Rieber, 1992; Driscoll, 1994; Grabinger & Dunlap 1995; Savery & Duffy, 1995; Grabinger, 1996, Squires, 1996).

**Virtuality and Multimedia**

Constructivist frameworks are based upon argument for learners being placed in authentic environments that incorporate sophisticated representations of context through such constructs as virtual “worlds”. The idea of knowledge being context dependent and learning occurring in contexts to which it is relevant is not new. Greeno (1989, p.135) in re-examining
the research on general thinking abilities argued that “thinking is situated in physical and social contexts” and that “cognition, including thinking, knowing and learning, can be considered as a relation involving an agent in a situation, rather than as an activity in an individual’s mind”.

Brown, Collins & Duguid (1989, p32) in further developing these ideas have described ‘situated learning’ as having, as its central idea, the notion that “the activity in which knowledge is developed and deployed is not separable from or ancillary to learning and cognition, but an integral part of what is learned”. This view of learning is not without its critics. A series of articles in *Education Researcher* saw Anderson, Reder and Simon (1996,1997) questioning the basis of situated cognition and the “exaggerated” claims being made from the reported research, especially the claims about lack of transfer.

However, if there is support for the notion that the learner’s understanding is developed through continuous participation in the ordinary practices of the culture (known as authentic activities), how do designers address such issues as context and related authenticity in developing technology supported learning environments? Tessmer and Richey (1997) have reviewed the role of context in learning and instructional design, proposing that one approach may be to include contextual analysis as an integral component of the design process. They have premised that ‘context has a complex and powerful influence upon successful performance-based learning, and yet is largely ignored … in most current instructional design models’ (Tessmer & Richey, 1997, p. 85).

**Defining Attributes of Interactive Multimedia and Virtual reality**

Apart from reality, the most appropriate way to generate a context based on authentic learner activity may be through the use of virtual reality. These systems are claimed to offer such qualities (Winn & Bricken, 1992) through aspects of the defining features of virtual reality ie immersion, fidelity of representation and active participation by users.

However, VR systems are not yet available on a large scale to support these processes in school environments, but it may be still possible to address these issues through what might be termed degrees of ‘virtuality’. In examining the relationship between multimedia and virtual reality, Hedberg and Alexander (1996) have proposed that the defining attributes of virtual reality can also be considered as attributes of multimedia. (Figure 1)
They argued that the defining attributes of virtual reality environments can be considered as a continuum with interactive multimedia environments displaying various degrees of these attributes through what has been termed ‘virtual worlds’ ie varying degrees of virtuality. These types of learning environments attempt to take advantage of learners becoming immersed within a challenging and involving learning experience which intrinsically motivates the participant to work within the context, understand the objects and their attributes and how they can relate to each other.

There is little evidence available to guide designers in determining the interaction of representation fidelity with sensory, conceptual and motivational immersion that needs to be constructed to establish effective learning outcomes. There is not only a cost factor in this relationship, but the nature of the experience might impact upon the possibility of transfer of learning to different contexts. While it is always possible to create active participation in interactive multimedia contexts, (using clever instructional strategies) many interactive multimedia programs have presented information in a rather pedestrian point and click strategy. In this context, it is unlikely that such a strategy would move the learner from the periphery to the centre of the situation.
Virtual “worlds” that display degrees of the attributes of virtual reality have been designed based upon these ideas. Two such award-winning projects, *Exploring the Nardoo* and *StageStruck*, have been developed within constructivist frameworks as virtual worlds for learners. The products display varying degrees of fidelity of representation, learner immersion and active participation.

Research outcomes from use of these products in schools have shown promise in improving learning outcomes, and also improving our understanding of learner construction of problem solutions (Harper, Hedberg, Corderoy & Wright, in press, Hedberg & Harper 1998, Hedberg, Harper, Lockyer, Ferry & Wright, 1998)

**Illustrating context and Learner Active Participation- Exploring the Nardoo**

*Exploring the Nardoo*(1996) provides a rich information landscape of resources based on a geographic metaphor of a navigable river environment. The package has been designed to illustrate a context through representation of a physical space as a Water Research Centre containing a set of resources represented through metaphors such as books, clipboards, filing cabinets and computers. The context has been extended beyond this representation to include researchers as guides proposing problem-solving challenges to students, encouraging active participation in the learning process.

The data collection facilities incorporated in *Exploring the Nardoo* allow collection of a full range of media forms. Students are provided with a flexible set of tools made available through a personal digital assistant (PDA), Figure 2, to assist in the investigation process.
By providing a metaphor relating to the real world, students are encouraged to apply scientific concepts and techniques in new and relevant situations in this ecology-based application, throughout the problem-solving process. In so doing, the learner is likely to become more interested in developing questions, ideas and hypotheses about the learning experiences encountered. As an alternative teaching/learning strategy in the development of inquiry and problem solving techniques, this package incorporates high quality visual materials in the form of graphics, sound, text and motion video together with scientific measuring tools to aid in the construction of understanding.

The process of using source material within the package in support of an investigation has been enhanced to allow the student to:

- Decide precisely on the quantity and selection of text to be copied into their notes. This is either through making a selection and then 'grabbing' it into the PDA or by using a 'drag and drop' technique where the target text is selected or highlighted and 'dragged' into the notes module of the PDA.
• Use marker buttons as pointers to video, audio or picture information that can be displayed within the PDA’s viewer along with any linked information.

• Manipulate marker buttons and text within the notes areas, via ‘drag and drop’, to facilitate the re-ordering of ideas in the process of building an investigative response in the form of a report, explanation, procedure etc.

• Use text style tools, within editable text notes, providing the opportunity to use font colour, style and size as organising criteria within the notes.

The joint combination of notebook and viewer equips students to view and then critically evaluate or compare different representations of the same information. By collecting different media representations of the same topic and ‘flipping’ between these representations at their discretion, the student has the opportunity to establish cognitive links between different media forms which complement each other and support a central theme or information focus.

Successful problem solving activities are reliant on numerous individual, social and environmental factors. From a technique perspective, *Exploring the Nardoo* endeavours to assist students by providing cognitive tools, or templates, upon which they can build their note taking or response writing activities. These are in the form of writing genre templates. Students may access the Guide book containing these templates (as well as other organisational help on note taking, presenting and filing, Figure 3) from within the Water Research Centre - a metaphor within the information landscape of the package. Genre descriptions can be viewed and a genre template can be copied into the notes and used as a scaffold upon which to build or fill-in relevant information found whilst exploring the package.

For students to ‘test’ ideas, three simulators have been incorporated: a Personal, Home Water Use simulator, a ‘whole catchment level’ water demand Dam Management simulator and a Blue Green Algal Bloom simulator. Each of these simulators is a powerful exploratory tool, which provides support for the solution to one of the embedded problems by mimicking a ‘real world process’. They enrich the ‘quality’ of the problem solving process for the user by providing unhindered access to act and become immersed in a ‘real’ situated process, manipulating the various causal parameters and testing hypotheses without a ‘real’ consequence or risk and in a time frame which is convenient and manageable for them “and enabling the learner to ground their cognitive understanding in their action in a situation” (Laurillard, 1996).

The ability to directly compare input data with output data in various forms simultaneously is a powerful feature of each of these simulators and helps the user in making connections and associations and forming an understanding of the interrelationships between ‘cause and effect’. 
As an example the Blue-Green Algal Bloom Simulator (Figure 4), is designed to provide the user with an indication of how effective their solutions are to the problem of eliminating an algal bloom in the Nardoo River.

The simulator scaffolds learners by allowing them to test their hypotheses by changing the input variables and observing the output variables, instantaneously and over time. Additionally, the simulator allows learners to link the numerical and graphic output back to the context by offering a visual representation of the river. At this level, the simulators are viewed as cognitive tools for learners, helping them to resolve a problem posed within the Water Research Centre.

In terms of a virtual world, the package overall proposes to actively engage learners so that they will participates in the problem solving process. The designers expect immersion of
learners in the context generated which represents a high degree of fidelity of representation of information.

**StageStruck: Improved fidelity to represent information with personal interpretation**

The *Nardoo* project enabled the placement of resources within a spatial framework, which was largely coded through a geographical metaphor. The inherent structure of the knowledge base used these cues to reduce the learning and searching requirements; it was obvious where you would need to seek for data and how to retrieve information from the records. The *StageStruck* (1999) project sought to move away from the narrow scientific concept of data and work with the construction of multiple meanings in a field that many would argue is highly subjective and open to numerous interpretations. *StageStruck* introduces the learner to the world of Australian performing arts by exploring a virtual performing arts venue which is organised by an architectural metaphor of adjoining spaces in the form of a navigable panorama. The virtual world is entered through the foyer of the Sydney Opera House (Figure 5). From this starting point, the user can access information that is available to the patron in a theatre foyer; the patron can view a performance read information about theatres and the Opera House. It is not until a decision to venture backstage that the user is then give a scrapbook and access to the resources required to learn about and construct a theatrical performance. Most of these spaces are presented as navigable spaces, using a virtual reality genre. The package provides two kinds of informational support, one showcases contemporary companies’ performances, processes and people, and the other elements provides tutorials to introduce theatre concepts and “tools” with which to direct performances.
Figure 5. Entry to the package is represented through the foyer of the Sydney Opera House- the initial screen of the navigable space that constitutes the virtual theatre world.

Many students have a narrow perception of how a theatrical performance is devised due to the lack of exposure or opportunity to view or take part in the performing arts. By extending the boundaries of interactivity in the context of a virtual world, we have provided learners with opportunities to express their own cultural interpretations and understandings. The project sought to:

- Reveal the diversity and range of the performing arts in Australia
- Inspire with excerpts of Australian productions
- Encourage participation in the performing arts
- Explore and learn about backstage elements and processes
- Explore the roles and career paths available in the performing arts, most importantly,
- Discover theatrical creativity through the creation of a scene

In this theatrical journey, we had the advantage of working with many visual metaphors. The world of theatre, opera, music theatre, dance and contemporary performance styles can be explored through devices such as “The Green Room” where the user can interrogate a database of the contemporary world of performing arts. The “Stage” space provides the opportunity to view sample scenes from productions which have been created by professional directors, using the same sets of resources as are available to the user. More importantly, the "Rehearsal Stage" provides direct access to the elements required to personally direct and design scenes. In this process individual users explore the processes of set and costume design, sound
development, and the concepts of direction through movement and motivation. In this project the construction tools have also been extended to enable the user not only to collect from a defined set of resources, but also to construct their own permutations based upon combinations of sets, costumes and performers.

The Stage space (Figure 6) with its database of vocal performances, movement animations and design elements provides the user with a rich set of tools to create performances. The virtual stage has a strong feeling of stage depth, transparency and shape, a rich sound accompaniment and effective, realistic animated performer movements. The creative key to directing a performance is to provide a wide range of choices. To this end we developed a variety of video-based animations of recorded movement and multiple audio recordings of each line of dialogue. The user can identify the actor’s intention behind making a movement or saying a line and this is used as the basis for selecting the recorded movement or speech. Most actions and lines have up to four different intentions for positive to negative, or what might be termed love to hate or approach to avoidance. This approach was designed to move the user’s exploration beyond the simplistic attachment of a line of dialogue or an action to a performer towards experimenting with the more realistic, complex issues associated with emotion and the underlying motivation for an action or line.

Figure 6. The construction screen for users to construct their own performance.
StageStruck thus brings together several of the Duffy and Cunningham (1996) pedagogical goals. While working with the virtual theatre, learners will be working within an environment that mirrors the world of theatre and supports the theatrical outcomes of many interpretations of each scene. Furthermore, each constructed performance can be compared with experts or other students, and learning can occur through the resolution of multiple responses to the same task. Key to the communication of the experience within this application, is the facility to save, share files between learners or re-present your constructed performance and interpretation to others located within the same classroom or across the Internet with other learners from different cultural backgrounds.

Studies with children in elementary and high schools has shown that learners perceive the virtual theatre context as a rich representation of a genuine performance environment and they are engaged for extended periods of time, actively engaged in constructing performances and performance elements (Wright, Hedberg & Harper 1998). Thus the world it creates is comprehensible and engaging and the tasks it enables are inherently challenging and motivating. The virtuality of the processes of direction and production are within the limits of acceptable stretching of the visual metaphors to make the "world" navigable.

**Discussion**

From the two examples, we have shown that learners can be placed in authentic environments that incorporate sophisticated representations of context. The process of generating the "world" requires designers to manage a complex task creating not only a series of elements that are to be learned as in traditional design approaches, but also to link the elements into a virtual "space" which is coherent and enables the elements to be manipulated and recombined into new ideas. The final product enables the learner to understand through the manipulation of the many nuances underpinning both process and concepts. The design processes require both an understanding of visual metaphor and how learning tasks can be accommodated within the metaphor. Most of these complex virtual environments require that the designer create an integration between the various component elements that Jonassen and Tessmer (1996/7) include in their taxonomy. Certainly, we are seeing researchers, such as Tessmer and Richey (1997), attempting to address these issues by advocating a context analysis processes within instructional design models. Thus the design includes inherent motivation, the tasks are linked in that they require problem solving and links between concepts, and users must create new understandings (requiring ampliative skills). All these elements are placed within the visual
melting pot, which can produce the unified outcomes we have described. Products such as *Exploring the Nardoo* and *StageStruck* illustrate these issues through increasing what might be termed the virtuality of the environment, the final product creates a "world" which is consistent and comprehensive in its ability to combine many elements and appear unified.
References

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