Theory, Tools & Teaching - Making learning fun

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Abstract

Successful integration of computer technology into the classroom requires a shift away from instruction towards the creation of constuctivist learning environments. This paper briefly discusses some of the theoretical principles that play an important role in the use of software tools by students. A number of examples are presented that illustrate different ways in which computer technology can be used as a learning tool. Also, the use of different types of software (off-the-shelf, Web-based and game) is described. Students appear to enjoy using different types of technological approaches to solve learning problems and report that computer technology provides new ways for them to explore knowledge. The combination of Internet and game technologies may provide researchers with a tool to develop virtual learning communities.

Introduction

The use of technology has often been acclaimed as offering a way to solve all educational problems. Yet, many past experiences show that technology has had little, or no, effect on the ability of students to understand new concepts or to develop critical problem-solving skills. However, technology has been successfully used in training programs where participants learn narrowly defined, task-orientated functions. What is apparent from world-wide trends is that the introduction of computer technologies into curriculum design and teaching practices can succeed only if there is a move from old ‘didactic’ models to more modern styles of 'constructivist' teaching. Therefore, to understand the relationship between types of technologies and educational systems, it is necessary to explore some relationships between education theory and information technology. In this paper I shall explore the relationship between educational theory and Computer Based Education (CBE), discuss and evaluate a number of courses that include computer technology and consider future developments.

Computer Based Education

Thre are a number of reasons for the failure of CBE, including:

- Technical difficulties in building suitable networking and administrative structures to facilitate CBE;
- Deployment of inappropriate user-interfaces and the inadequacy of artificial intelligence to provide mechanisms that could make computers more responsive to individual needs;
- Introduction of CBE into all levels of education has been extremely slow and in many countries non-existent;
- Limited research into the use of CBE;
- Failure to implement appropriate educational pedagogies that could support CBE; and
- Failure of extrapolation from successful implementation (for example, in algorithmic disciplines) to disciplines which are epistemologically different. What works in one area does not necessarily transplant, without modification, into another.

Thoughts on Pedagogue

Reeves (1995) believes that the major contribution to the failure of CBE is related to the pedagogical

structure underpinning current CBE practices. He proposes a model (Table 1) that could provide a better foundation for the development, implementation and evaluation of CBE.

Each of the 10 dimensions the model, taken from diverse educational theories, is presented as a two-sided continuum with contrasting values at opposing ends. These continua are not meant to be seen as just linear ranges. The interaction between each can be used in development, delivery and evaluation of CBE. While it may appear that educational scenarios developed to integrate computer technology should favour the right hand side of Table 1, this is not always the case. For example, teaching-reading skills to young children may be more didactic (i.e. characterised by a pedagogy more closely related to the philosophical elements listed on left-hand side of the Table 1) in nature rather than developing more cognitive skills (integration of information using mind-mapping software).

Table 1. Reeves' pedagogical dimensions.

	Pedagogical Dimension	
___ Instructivist	Pedagogical Structure	Constructivist
___ Behavioural	Psychological Structure	Cognitive
___ Sharply defined	Focus of Goals	Loosely defined
___ Abstract	Experiential Value	Concrete
___ Didactic	Teacher Role	Facilitative
___ Extrinsic	Origin of Motivation	Intrinsic
___ None	Accommodation of Individual Differences	Multi-faceted
___ Program-controlled	Learner Control	Learner-controlled
___ Unsupportive	Collaborative Learning	Integral
___ Offensive	Cultural Sensitivity	Supportive

To link educational theory and computer technology, different models have been proposed. One such model was developed by the North Central Regional Educational Laboratory (Council for Educational Development and Research, USA) and consists of a number of classroom variables that promote effective teaching and learning. This framework was expanded and reorganised by Jones, *et al*. (1995) of NCREL. Their variables and indicators are presented in Table 2.

Table 2. Indicators of engaged learning from Jones *et al*.(1995).

Variable	**Indicator of Engaged Learning**	**Definition**
Vision of Learning	Responsibility of learning	Learner involved in setting goals, choosing tasks, developing assessments
	Strategic	Learner actively develops repertoire of thinking or learning strategies
	Energised by learning	Learner is not dependent on reward from others; has a passion for learning
	Collaboration	Learner develops new ideas and understanding in conversations Work with others

Table 2 continues.

Tasks	Authentic	Pertains to real world, may be addressed to personal interest
	Challenging	Difficult enough to be interesting, but not totally frustrating, usually sustained
	Multidisciplinary	Involves integrating disciplines to solve problems and confront issues
Assessment	Performance-based	Involving a performance or demonstration, usually for a real audience and useful purpose
	Generative	Assessments having meaning for the learner; may produce information, product, service
	Seamless and ongoing	Assessment is part of instruction and *vice versa*; students learn during assessment
	Equitable	Assessment is culture-fair
Instructional Model	Interactive	Teacher or technology program responsive to student needs, requests
	Generative	Instruction orientated to constructing meaning; providing meaningful activities/experiences
	Collaborative	Instruction conceptualises students as part of learning community; activities are collaborative

Learning context	Knowledge-building Emphatic	Learning experiences set up to bring multiple perspectives to solve problems such that each perspective contributes to shared understanding for all; goes beyond brainstorming Learning environment and experiences set up for evaluating diversity, multiple perspectives, strengths
Grouping	Heterogeneous Equitable Flexible	Small groups with persons from different ability levels and backgrounds Small groups organised so that over time all students have challenging learning tasks or experiences Different groups organised for different instructional purposes so each person is a member of a different group; works with different people
Teacher's role	Facilitator Guide Co-learner; co-investigator	Engages in negotiation, stimulates and monitors discussion and project work but does not control Helps students to construct their own meaning by modelling, mediating, explaining when needed, redirecting focus, providing options Teacher considers self as learner; willing to take risks to explore areas outside their expertise; collaborates with other teachers and practising professionals

Table 2 continues.

Student roles	Explorer Cognitive Apprentice Teacher Producer	Students have the opportunity to explore new ideas or tools; push the envelope in ideas and research Learning is situated in relationship with mentor who coaches students to develop ideas and skills that simulate the role of practising professionals Students encouraged to teach others in formal and informal contexts Students develop products of real use to themselves and others

Both Reeves (1995) and the group at NCREL favour modern education theory and attempt to show how computer technology can be integrated into such a system. However, we need to define what is meant by computer literacy to argue the proposed model fully.

Computer Literacy

Future workers need to be problem solvers, be able to communicate clearly (both in speaking and writing), as well as being critical, creative and productive.

Using a word processor or spreadsheet program will not in itself empower students to be successful. Our interconnected world is being built on technology developed in the 1960s for universities to share research information. This technology, collectively termed the World Wide Web or Internet, has exploded

during the last two to three years and will model our social, political and cultural lives and break boundaries between countries and cultures.

Information on the Internet is radically different from any other form of publication ever produced. Publishing documents on the World Wide Web is easy, cheap and not often refereed or submitted to an editor. It is this aspect of the free flow of unregulated information on the Web that appears to trouble many parents, educators and governments. As the World Wide Web expands, so does the volume of trivia, and irrelevant information is available for viewing. Therefore, young people need to learn to evaluate Web documents critically, and develop attitudes of tolerance and understanding of all points of view. Students need to know not only how to find relevant information, but how to use search engines and other indexing technologies.

Computer technologies have developed sophisticated mechanisms for electronic communications. These include electronic mail (e-mail), conferencing, two-way chat, and group discussion programs. The power of this technology is that it frees users from the constraints of traditional communication systems and is very rapid. It, however, requires superior written and verbal communication skills.

In addition, computer literate individuals need to know how to isolate and identify causes of computer breakdowns and software problems and either correct them or know with whom to consult.

Overall computer-literate students need to acquire skills in critical evaluation, use of search engines and indices (either on the World Wide Web or on CD-ROM), be good communicators and problem solvers.

Modality

It has often been argued that the more senses we use when learning, the better our retention and understanding. Alternatively, some researchers argue that dual processing often confuses the learner (Fisher, 1984; Williams and Snipper, 1990), by placing too many demands on the viewer. Yet, the use of multi-modal processing (engagement in more than one perceptual modality at a time) does seem effective when used correctly and is ardently supported by instructional multimedia proponents. It is argued that increase in sensory input coupled with interactivity integrates more rapidly into the learner's development system and allows for deeper learning.

Meskill (1996) argues that multi-modality is the only way to teach language acquisition. Here, text and visuals aid language processing when presented with aural text. In addition the use of concurrent video not only places the learner in the correct environment, but also shows facial and other contextual information. The seeing of sub-titles superimposed on the video enhances not only the understanding of the language but also develops writing skills. Meskill (1966) argues that combined media enrich language processing and render input more direct.

There is no conclusive evidence that one sort of medium is better than another in achieving a particular learning goal. For example, the operation of an engine can be given in text, shown as animation or taught by means of a model. Different students with different learning styles respond differently to each medium. Recker, *et al*. (1995) argue that media should be classified into cognitive media types and that the type of learning be matched to the cognitive media type. For example, pictures could be used as graphical displays of relations among processes, examples or as flow diagrams. Such an approach allows the teacher to provide material closely allied to the teaching goal.

Thus, the development of interactive and multimedia teaching materials must take into account interactivity and multi-modality, while matching the media to the learning goal.

Micro-world

Constructivists define computer-based micro-worlds as a small but complete subset of reality in which one can learn about a specific domain of knowledge through personal discovery and exploration. Such

learning spaces include meaningful contexts, anticipation and nurturing of incidental learning and support intrinsically motivating and self-regulated learning (Rieber, 1992).

Play

Rieber (1996) argues that play, especially during early childhood, plays an important role in psychological, social and intellectual development; is a voluntary activity that is intrinsically motivating; involves some level of activity and often possesses make-believe qualities. Such attributes are similar to those contained in modern educational theories where learning is viewed as a self-motivated and rewarding activity (Kolesnik, 1970). Blanchard and Cheska (1985) contend that play, unlike leisure, is not the opposite of work, but is a universally accepted mode of learning.

The advent of personal computers with superior graphics systems has precipitated an explosion in game software. This multimillion-Dollar industry produces many different kinds of games ranging from simulations through to first-person adventures. Here players are immersed in virtual worlds filled with stunning graphics, compelling, if not addictive, story-lines, sound and video. McKee (1992) and Billen (1993) argue that games affect cognitive functions, motivation and remove players from the "real world". However, games appear to motivate users intrinsically by stimulating curiosity (Thomas and Macredia, 1994). This may be due to the presence of challenges and elements of fantasy (Malone, 1981a), novelty and complexity (Carroll, 1982; Rivers, 1990). Also, Quinn (1994) argues that for games to afford benefit to educational practice and learning they need to combines fun elements with aspects of instructional design and system design that include motivational, learning and interactive components.

Conclusions

Development of computer literacy skills appears to be nothing more than what modern educational practices hope to achieve with other types of knowledge domains. While the use of technology in education can take on many forms, it is the underlying educational philosophy that is important. Technology can therefore be used as an instrument to transform educational practice from the ‘old-world’ model of instruction to the more modern theories of social constructivism.

Examples

In this section of the paper I would like to highlight some of the approaches I have used to integrate computer technology into curriculum design. Each project will also describe the type of technology used and discuss student opinions and performance. Examples include the use of off-the-shelf software in courses, Hypertext Markup Language (HTML) as a viable development platform for the creation of interactive teaching tools and finally the use of cutting-edge technologies (games) to create virtual learning spaces.

The use of off-the-shelf software

Traditional courses in biochemistry often include two components: theoretical didactic lectures and practical sessions. This approach separates theory and practice and assumes that students are able to integrate these two aspects without there being any implicit links in the course. To overcome this problem a course on protein structure and enzyme kinetics was developed to integrate theory and practical work within a constuctivist learning environment. The course was also designed to test alternative form of assessments.

Students, working in groups, were required to solve theoretical and practical problems detailed in a workbook. At the end of that section of the course students (working in groups) undertook a project that was written-up as a paper for a journal (individual activity). MS Excel and Word were used to solve problems presented in the workbook and to report experimental results. Protein and amino acid visualization software (RasMol) and model building was used to help students understand the 3D structure of proteins and enzymes. Students also constructed two mind maps during the course.

Four forms of assessment were used: ability of students to work as a group (during the course), portfolio (students were required to select five pieces of work to demonstrate their abilities), project write-up and examinations (content knowledge).

While the students found it initially difficult to adapt to the new course, they soon adjusted and reported that it was easier to study for examinations at the end of the course. They also enjoyed class activities and learned new skills.

This course demonstrated that it was easy to create a learning environment where students could acquire new skills using commercially available software.

HTML as a viable authoring platform.

The evolution and spread of the Internet as a communication protocol has resulted in the most rapid development ever experienced in the software and hardware markets. Creating documents for the Web is both easy and inexpensive. Three examples (PlantSex, Carbohydrate Metabolism and Interactive Fiction) are discussed in this section to illustrate different ways in which Internet technologies could be used to develop course work.

One of the problems associated with the use of developing teaching resources that include hyperlinks is that students often get lost in hyperspace. For a course on reproduction of fungi, algae and lower plants, an interactive resource, created using HTML, was developed to support learning activities presented to the students in a workbook. For this course we developed a shell for the display of the HTML pages that allowed the author to group the pages into chapters of book and also provided key word and global search functions (Fig. 1).

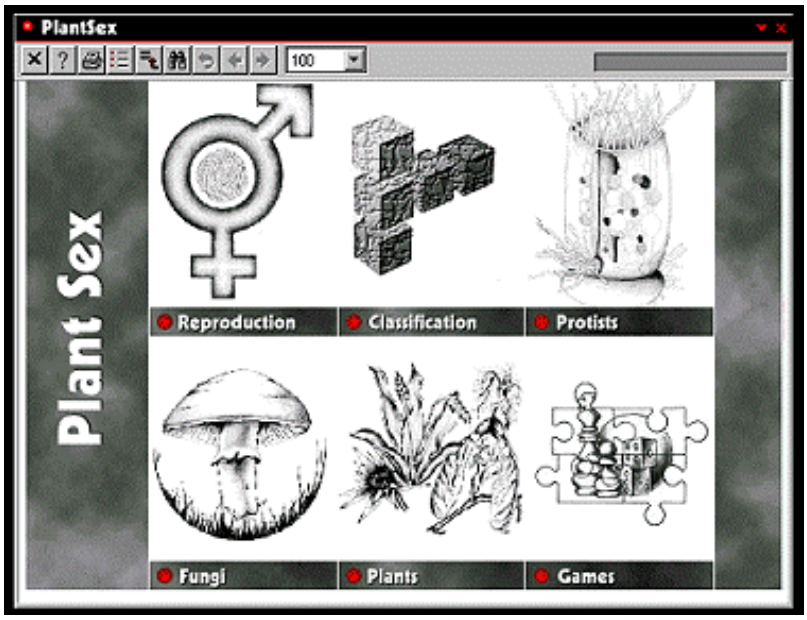

Figure 1. Interface design of the PlantSex software.

Students, working in groups, answers questions and problems posed in a workbook that integrated theory and practical work. The hyperlink document was not made available during normal contact time but could be accessed from the departmental Local Area Network at any other time.

This course was found to stimulate group discussion and was enjoyed by most of the students. Those that found it difficult to adjust to the new course were more likely from disadvantaged backgrounds. The hyperlinked document proved very useful as it allowed students to find information to solve questions posed in the workbook, increased the amount of time they spent investigating the course material and taught them basic computer literacy skills. With respect to student performance we found that outcomes

were maintained for a course where entry level requirements had decreased.

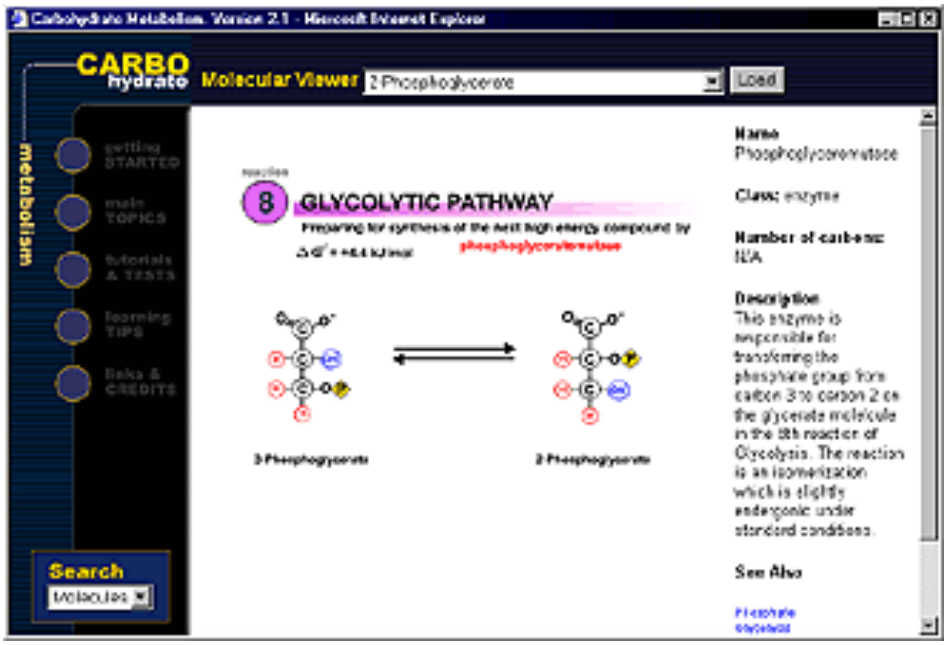

Figure 2. Web based resource for the carbohydrate metabolism course.

The course on carbohydrate metabolism was re-engineered to evaluate the use of Web-based database technology to create multiple views into a single knowledge domain. A Web site was created using Microsoft Active Server Pages (ASP) technology where the molecules, pathways and text information related to carbohydrate metabolism were stored in database tables (Fig. 2). ASP technology was used to generate HTML pages from templates and the database content. The Web site also included a search capability and automatically generated hyperlinks between the different views of the knowledge.

A constuctivist classroom was created in the departmental LAN where groups of students used the Web-based resources to answer questions posed in a workbook.

To assess student opinions we conducted a number of investigations that included knowledge tests before and after the course, opinion questionnaires and interviews. Students performed better using the Web-based resources than when they were taught the material using traditional methods (instruction). They also reported that the enjoyed the course and found the search tool very useful.

The use of database technology made it easy to create a learning resource with different, and multiple, views into a single knowledge domain. This approach allowed students to explore information in ways that made suited their learning style and offered different kinds of information to answer questions or problems.

In an attempt to evaluate the use of dynamic HTML we created an Interactive Book based on a story by Jenny Marais, a South African author of the book series for young people, "*Learning with Granny*". Her stories attempt to integrate appropriate knowledge into stories that stimulate and encourage scientific discovery in the reader. The book selected for this project is entitled *The Stars* and deals with the signs of zodiac and star constellations. To heighten the sense of adventure, readers find themselves on a deserted island at the start of the story and have firstly, to find the book, and then find objects and solve puzzles in the book, to find their way home. The player is able, at certain points in the story, to select alternative routes through the narrative.

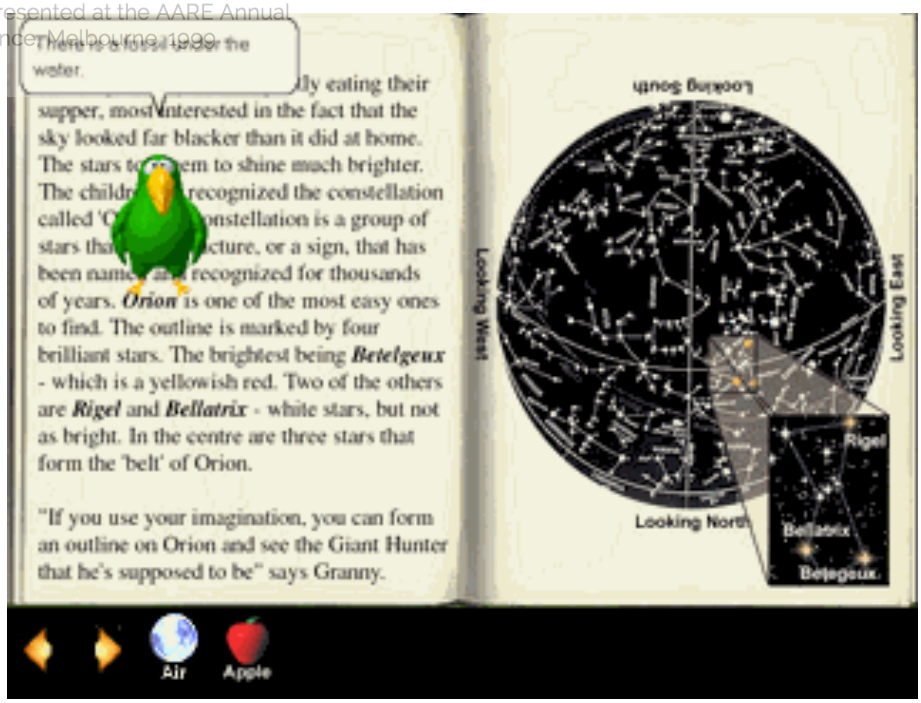

Figure 3. Interactive book created with DHTML and an interactive agent (Peedy)

The objectives of this study were to evaluate the use of DHTML and the use of interactive characters in teaching resources. Two Microsoft® technologies were used to create the learning resource: Internet Explorer DHTML version 5 and Agent version 2 (http://msdn.microsoft.com/workshop/c-frame.htm#/workshop/imedia/agent/default.asp).

The different interactions required for the interactive book were scripted using DHTML. Agent was developed as a conversational interface to enhance computer-human social communication and includes support for speech recognition (both text-to-speech and speech-to-text) allowing characters to respond using synthesized speech, recorded audio, and/or text in a cartoon word balloon. The animated characters can also respond to user input and include a number of predefined gestures. The character selected for this project was Peedy, an animated parrot. While the development of the user-interface relied on VBScript, the puzzles were coded in JavaScript (Fig. 3).

The initial testing of the interactive book was undertaken with two young people (between 10-12 years old). They found it easy to navigate through the pages and quickly learned how to use the interface. They soon solved the puzzle after we showed them how to use the drag-and-drop technique. While they enjoyed the experience and thought it was a good idea to include interactive actors into such software, they felt that the story was too simplistic and that while Peedy is cute, they thought the character was better suited to eight-year-olds. They suggested that we use a 'surfer dude' as the interactive character.

Use of DHTML to create this resource was difficult. While the technology is powerful, software companies need to develop more mature tools what will enable content authors to utilise this technology.

Web technologies are very powerful tools that can be used for the creation of learning resources. However, it is still difficult to use the most recent advances, such as DHTML. Constructivist learning environments that include resources created using HTML appear to provide students with way in which they can explore knowledge in different ways.

Playing games

a b

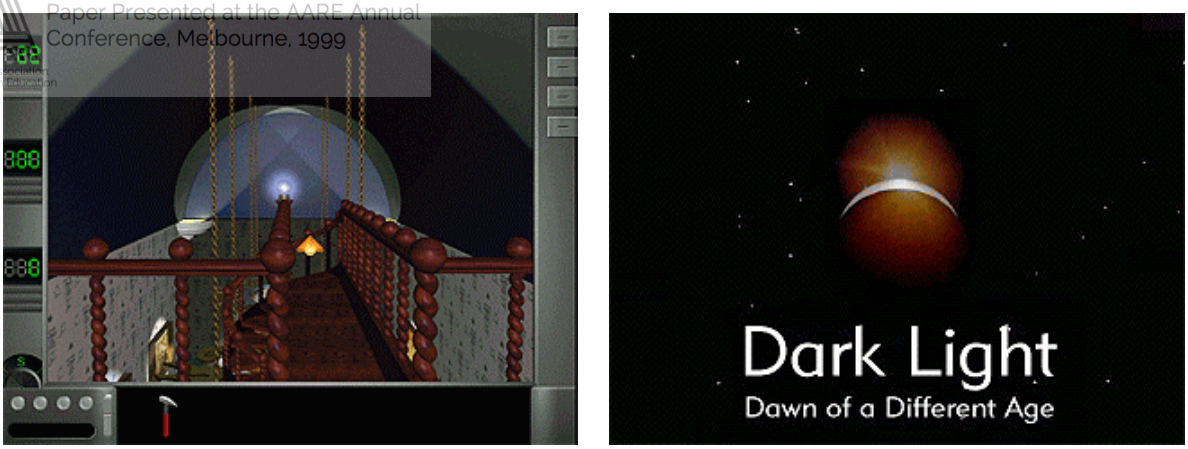

Figure 4. Interface design of Zadarh (a) and title screen for Dark Light (b).

The computer game industry is one of the fastest growing economic sectors. Both young and old appear to enjoy such entertainment. However, the use of computer games in education is often frowned upon as many educators believe that learning should be just hard work. No doubt it is sometimes difficult to learn new concepts, but play is one of the most important activities that teaches very young people about interactions with others and about the world. The two projects described here are part of a research exercise that attempts to assess the value of games as viable educational tools. These projects also strive to devise a theoretical framework that could help other developers in the conceptualisation of such learning resources. The games Zadarh and Dark Light (Fig. 4) were developed to help students understand complex issues and to overcome specific misconceptions.

These games are designed as typical adventure games where players navigate virtual spaces using the mouse as the primary mechanism to interact with the game interface. While navigating through the different game areas, players discover information and hidden objects that help them solve puzzles.

The primary objective in Zadarh is to find an anti-viral protein than can be used to stop the spread of a virulent virus infection. The game consists of a number of levels, each of which relates to a single biological concept that students find difficult to understand, or attempts to overcome misconception held by students with in specific knowledge areas. To date we have developed levels on human evolution; the relationship between photosynthesis and photorespiration in plants and animals; and Mendelian and molecular genetics.

The game Dark Light, a tribute to Stanley Kubrick and Arthur C. Clarke, was designed to allow students to practise 3D visualisation skills. The game consists of a 5x2x5 maze that consists of atria at each point in the maze that are connected to each other via passages or lifts. To gain entrance into an atrium the player needs to solve a puzzle. Five different kinds of puzzles, each linking to a level of the maze, are included: pattern matching, pattern rearrangement, 3D projection from top and front views, mental rotation of 3D objects and project from 2D into 3D objects. The maze is situated inside a black monolith (as per *2001: A Space Odessey*) and, after traversing the maze, the player is presented with a number of screens contrasting the predictions of 2001 with the communication revolution of today.

While students have not yet explored Dark Light, they have played the evolution and photosynthetic/respiration levels of Zadarh as part of their class work. While each student played the games on their own computer, we encouraged students to talk to each other and work together to solve complex puzzles. When asked why students played the game, 85% gave answers such as fun, beautiful graphics, wanting to solve puzzles (intrinsic motivation) while the rest were motivated by class requirements. Generally, students enjoyed playing the game and thought that such developments should be continued. Evaluation of performance suggested that the playing of computer games helped students assimilate new information, develop problem-solving skills and construct new ideas or corrected incorrect mental models. Games appear to provide a useful platform for the successful integration of all kinds of media into a learning environment that is engrossing and stimulating.

Conclusions

Off-the-shelf software, easy to develop Web-based learning materials and complex virtual environments can be integrated into constructivist-like classroom successfully. Students appear to enjoy using computers to solve problems, gain insights into new knowledge areas and learn new skills, such as the ability to undertake group work, computer literacy and problem solving.

What next?

Imagine a virtual world that is visually stimulating, offers many challenging problems and a number of integrated communication technologies. Such a virtual landscape teaches young adults about democracy, history and culture, and about arts and sciences.

The objective of this project is to integrate communication and game technologies to create a virtual learning space in order to develop a better understanding of the role of such technology in education. Also, the project will explore integrate our history, culture, arts and sciences into the story line to illustrate our diverse heritage.

Conclusion

The use of technology provides educators with a power-tool to manage the change from instuctivist models of teaching to more modern contructivist approaches. Many types of software can be used in the classroom where students explore information and build models that better reflect our understanding of the universe. While much of the research conducted in the use of information technology in education appears to support the idea that such tools can support learning, we do not yet fully understand how to create and manage virtual learning environments. The creation and testing of densely-layered and richly-designed virtual learning communities may give us insight to ways of harnessing the power of technology to make learning fun and rewarding.

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