Problem-based learning and educational technology: Exploring new horizons

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Abstract: Problem-Based Learning (PBL) is an approach to education for the professions that is characterised by a focus on authentic problems likely to be faced by future professionals, organization of knowledge around problems rather than disciplines, and active learning in small groups rather than lectures. Students are motivated by the focus of PBL on problems with clear links to the target profession and the opportunities for group work appeal to the current generation of highly connected students. Thus PBL is a strong design for learning that can be supported by appropriate application of educational technology. Early applications of educational technology in PBL included the use of multimedia to present problems in ways that enhanced their authenticity, the development of software systems that supported the problem solving process, and the use of computer mediated communications to support the group interaction characteristic of PBL.

Because PBL typically includes collaborative group work its use by learners working individually, whether because of separation by distance or for other reasons, presents challenges. However, by drawing on research into the operation of PBL, multimedia products capable of constructive use by individual learners have been developed using PBL as the underlying design.

Students currently entering university to prepare for the professions are likely to have grown up experiencing high levels of connectivity through the Internet and mobile phones. They are also likely to have substantial experience in computer games. PBL is one learning design that can make effective use of learner connectivity to support collaborative group interaction and of 3D online environments such as Second Life to provide spaces for collaboration and presentation of authentic problems.

This presentation will trace some applications of educational technology to PBL, with an emphasis on identifying how technology supports key characteristics of PBL. Particular emphasis will be given to the use of PBL as a basis for design of interactive multimedia and to the potential use of 3D online environments as venues for PBL.

Why Problem-Based Learning?

Problem-based learning (PBL) had its beginnings in medical education at McMaster University in the 1960s (Norman & Schmidt, 1992). It was a response to concerns that a focus on academic disciplines might not be the most effective preparation for future professionals who must integrate knowledge across disciplines (Boud, 1985). Since it first appeared, PBL has spread to many countries and different fields of professional education including nursing, engineering, law and business (Boud & Feletti, 1991).

The rationale for PBL included addressing the perceived irrelevance of some knowledge which students had to acquire in traditional medical curricula, the lack of integration of subject matter from different disciplines, the need for an orientation towards continuing professional education, and the desire to prepare students who could make appropriate use of their knowledge in professional practice (Schmidt, 1983). It addressed four objectives that were not well served by other educational methods, namely, structuring of knowledge to support practice, developing effective clinical reasoning, developing self-directed learning skills, and increasing motivation for learning (Barrows, 1986).

Compared with conventional instruction, PBL has been found to be more nurturing and enjoyable for students and teachers, and PBL graduates perform at least as well on clinical examinations although they may be less well prepared on basic sciences (Albanese & Mitchell, 1993). Another study of students undertaking a nursing course that used PBL found significant changes in perceptions of both the importance of, and personal ability for, self-directed learning (Ryan, 1993).

PBL emerged in an era before the invention and popularisation of the World Wide Web, when the principal information challenge in most contexts was access. Information was mostly available from books and other printed materials, less often from broadcast or recorded media. Mostly information moved in physical form and the way to ensure access when it was needed was to commit what was considered essential to memory or some other form of personal record. Now, in the age of the WWW, professionals can have instantaneous access to more information than can be readily used and the challenge is one of selection rather than access. As connected devices such as mobile phones and PDAs become increasingly commonly available, there is less need to commit information to memory or other local records in order to have continuing access. Moreover, the rate at which new information is becoming available is accelerating and memory or other records are challenged by both volume and currency.

Twenty-first century professionals must be information literate, able to determine their information needs, locate, evaluate and apply information as required. They must also be adaptable, capable of learning as necessary and bringing together knowledge from multiple disciplines to solve new problems. PBL seems ideally suited to the development of such capabilities.

How is PBL characterised?

PBL explicitly implements three key principles of the information processing approach to learning, namely, activation of existing knowledge when learning begins, encoding of retrieval cues with learned information and elaboration of knowledge through immediate application (Schmidt, 1983). Subsequent research has found that PBL appeared to sometimes reduce learning initially but over longer periods encouraged increased retention of knowledge and appeared to contribute to improved motivation and skills for self-directed learning (Norman & Schmidt, 1992).

The process of PBL typically follows a sequence described by Boud (1985). Following the presentation of a problem, students work in small groups to analyse the problem and determine what information might be required for a solution. Once the necessary areas of learning are identified, students undertake individual study and research before returning to the group to share their findings and apply them to develop a solution to the problem. The final phase involves reflective activity in which what has been learned is summarised and integrated with students' prior knowledge.

Across a variety of professional fields PBL appears to have five common characteristics:

1. The starting point for learning is a problem (that is, a stimulus for which an individual lacks a ready response).
2. The problem is one that students are apt to face as future professionals.
3. The knowledge that students are expected to acquire during their professional training is organised around problems rather than the disciplines.
4. Students, individually and collectively, assume a major responsibility for their own instruction and learning.
5. Most of the learning occurs within the context of small groups rather than lectures (Bridges, 1992, pp. 5-6).

PBL tutors "do not serve as dispensers of information. Rather, they serve as resources to the team and provide guidance and direction if the team solicits assistance or becomes bogged down" (Bridges, 1992, p. 7).

PBL & Generation Y

Students who are now entering university directly from school belong to a group frequently identified as Generation Y or the Millennials. Among the characteristics they are said to share are diversity, focus on performance, preference for group activity and fascination with new technologies (Howe & Strauss, 2000). Because they have grown up with technology in a world which is highly connected they are variously described as "IT savvy", "digitally literate", "connected" and "always on", and they prefer to learn through active participation, in teams with peers, and with information available when it is needed (Oblinger & Oblinger, 2005).

Typically Millennials are accustomed to things happening quickly, to random access rather than linear thinking, and to being constantly connected (Prensky, 1998). They have been described as "digital natives", having been born into a digital and connected world where their parents and teachers are mostly "digital immigrants", and it has been suggested that they think differently as a consequence of their brains having been wired differently by environmental influences including extensive playing of computer games (Prensky, 2001).

PBL, with its focus on authentic problems solved through group processes that require learners to decide upon and search out the information they require, appears to be a good match to many of the characteristics claimed for Millennials.

Educational technology and PBL

Hoffman and Ritchie (1997) identified a number of challenges posed by the implementation of PBL. Their list included reliance on written or verbal cases which may not adequately prepare students for dealing with problems which present in other forms; limitations on the numbers of problems of particular types accessed by students; initial adjustment problems of students inexperienced with self-directed learning; and management of learners who progress at different rates. They suggested several ways in which educational technology might be applied to alleviate the problems they identified.

One use of educational technology, specifically multimedia, to support PBL is for the presentation of "triggers" for problems. The use of multimedia including images, video and audio can make the problems that serve as the entry point for PBL more engaging and authentic than problem descriptions that rely upon text alone. Such triggers have been produced and used with success for PBL in medicine, teacher education and other fields (Keppell, 2005; Martin & Prideaux, 1994; Uden & Beaumont, 2006).

A second potential use of educational technology in PBL is to support learners through the problem solving process by providing tools and resources. A Problem Solving Assistant was used to support teacher education students undertaking PBL through access to research resources and a problem-solving heuristic (Ritchie, Norris, & Chestnutt, 1995). In a more recent study at Harvard, tutors and students reported a positive impact on tutorials following installation of large screen displays that were used for access to Internet, student presentations and course-specific postings (Price Kerfoot, Masser, & Hafler, 2005). Other uses have included networked computers to support small groups (Koschmann, Kelson, Feltovich, & Barrows, 1996) and computer mediated communication to support groups in which members were geographically separated (Pearson, 2006; Ronteltap & Eurelings, 1997).

IMM-PBL

In each of these examples, educational technology, including multimedia, was used to facilitate and enrich the experience of PBL. However, PBL is a powerful constructivist instructional design (Savery & Duffy, 1995) and it is reasonable to ask whether PBL could be used as the basis for design of multimedia learning materials (Albion & Gibson, 1998a). If multimedia materials could incorporate the essential qualities of PBL, then it should be possible to offer PBL experiences to independent learners who are isolated by distance or other circumstances. However, this approach would stand in contrast to conventional PBL which makes extensive use of small group interactions supported by tutors and would need to address these characteristics of PBL in its design.

Group processes in PBL

The key ideas of constructivism (Savery & Duffy, 1995) include cognitive dissonance and negotiation of meaning. Studies of student thinking during the initial phase of PBL (De Grave, Boshuizen, & Schmidt, 1996) suggest that during the problem analysis exposure to the different ideas of group members leads to conceptual change. The group interactions serve to encourage activation and elaboration of existing knowledge and integration of alternative views.

It is possible to design learning materials to incorporate an *activation task* that serves a similar purpose to a PBL group discussion for activating existing knowledge of a problem domain. Especially for ill-structured problems (Jonassen, 1997), it is possible to include a variety of different responses at appropriate stages in the problem solving process to stimulate *cognitive dissonance* similar to that produced by interaction among a group of learners. In these ways key affordances of group interactions in PBL may be provided by a multimedia package.

Tutors in PBL

The role of tutors in PBL groups is not to act as informants but to facilitate the group process by modelling higher order thinking and challenging the thinking of learners (Boud, 1985). In the absence of a tutor, a useful degree of support may be provided by including heuristic aids (Ritchie et al., 1995) or by breaking problems into sub-problems (Savery & Duffy, 1995).

Narrative structure

In the process of developing IMM-PBL (interactive multimedia based on a PBL design), a third area of potential tension between multimedia and PBL was identified. An attractive feature of IMM for many designers and users is the ease with which it is possible to navigate through the contents to access a variety of resources. Although PBL encourages learners to seek information it requires goal directed behaviour towards a solution for a problem.

When the PBL experience is presented in a simulated reality there may be reason to make access to certain resources contingent upon the state of some aspect of the simulation. For example, learners may need to obtain certain data or complete some activity before material that would reveal information relevant to a later stage is revealed. Such restrictions on access to part of a package are familiar to gamers but are not characteristic of open access IMM.

The approach taken to managing staged access to parts of the IMM package was based on research that has demonstrated the efficacy of story for motivating users to progress through multimedia materials and for increasing transfer of learning from the materials (Bielenberg & Carpenter-Smith, 1996). PBL experiences can be constructed around stories that scaffold solution of a problem by presenting a series of tasks that arise naturally within the context of the simulation.

Designing an IMM-PBL product

Because problems are central to PBL, the design of problems plays a key role in the development of PBL curricula and their ultimate success. Recent work in the area has presented approaches such as the 3C3R model that links context, content and connection with researching, reasoning and reflecting (Hung, 2006). The design approach described for the initial development of IMM-PBL embodied similar principles (Albion & Gibson, 1998b). Figure 1 illustrates the process of developing a problem scenario for IMM-PBL.

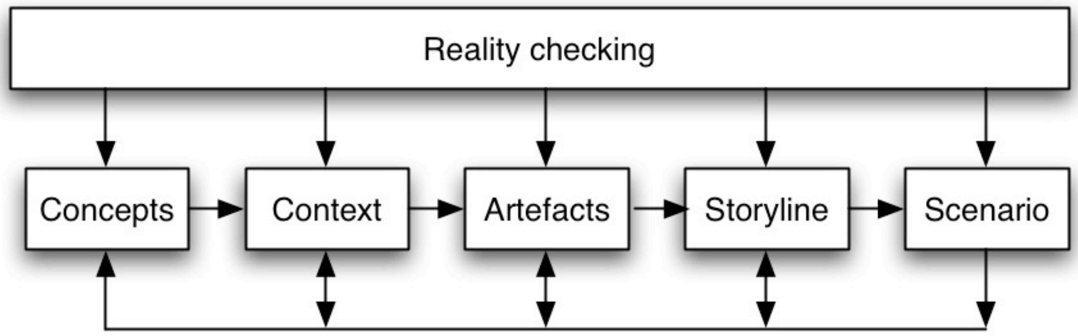

Figure 1: IMM-PBL scenario development

Development began with identification of key concepts from the content domain and a context in which those concepts might be applied. The context, including significant aspects of the environment and the problem was described in sufficient detail to permit reality checking by professionals familiar with the context. Scaffolding was planned by considering how the problem solution might be represented by a series of intermediate outcomes developed as documents or other artefacts. The scenario was completed by devising a motivating storyline that makes sense of the progress of the problem solver from initial encounter to resolution. At each stage in the design reality checking was applied to ensure the plausibility of the overall scenario and each of its components and that the expected action flows logically from start to finish. The design process is iterative rather than linear, with a feedback loop through which evaluations at each stage can influence revisions. Figure 2 illustrates the structure of a typical scenario for IMM-PBL.

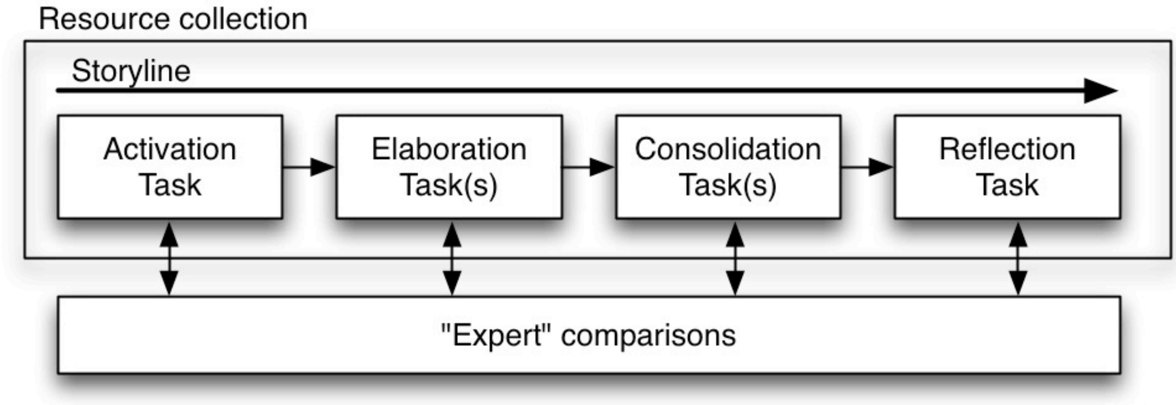

Figure 2: IMM-PBL scenario structure

Scaffolding of the problem solving process is provided by presenting the scenario as a series of tasks embedded in a storyline related to the professional context. Each task has an identifiable outcome, typically an artefact relevant to the problem. The first task situates the learner in the problem context and prompts the activation of relevant prior knowledge. That is followed by elaboration tasks that provide opportunities to recall and reconfigure relevant prior knowledge and to explore additional knowledge and experience gained during problem solution. Consolidation tasks focus on knowledge transfer, analysis, integration, synthesis and evaluation of selected, context specific knowledge and experience gained through the activity. The final task is designed to encourage reflection that supports integration of the knowledge and experience acquired while working with the scenario.

As they complete each task, learners are able to compare their responses with examples from a panel of experienced professionals. These 'interactions' are intended to serve similar functions to interactions with peers (De Grave et al., 1996) or a facilitator (Savery & Duffy, 1995). Except when the storyline requires otherwise for reasons of authenticity, learners have access to a collection of resources that include pointers to additional resources not included in the package. Because PBL relies upon learners making decisions about what knowledge they require to solve the problem, the selection of resources is such as to require learners to exercise judgement in selecting from what is provided and initiative in locating additional sources.

Integrating Information Technology into Teaching

The design principles and approach described above have been applied to the development of a CD-ROM package to assist teachers with information technology integration (Gibson & Albion, 1999). The CD-ROM incorporates resources relevant to the use of technology in classroom teaching and a series of four problem scenarios based around the common theme of integrating technology into a variety of teaching contexts.

So as to expose learners to variations in context, the package was designed around the circumstances of a teacher applying for a series of short term appointments with different school settings, pupil characteristics and resource availability. In each scenario the activation task required learners to respond to an advertisement for the position. Sufficient details of the positions were provided to cause learners to activate knowledge relevant to each scenario.

The first problem scenario involved the introduction of a computer to a classroom and tasks dealing with location of the equipment in the room and issues of planning and management of classes. Once these tasks and the associated artefacts were identified, a simple storyline was devised and supporting materials such as school documents and correspondence were created. Reality checking was conducted at appropriate stages during the design and development process by inviting comment from relevant professionals. Expert comparisons were provided in the form of sample solutions prepared by a panel of experienced teachers. These were made available to learners following completion of each task.

Interactive software requires a consistent format for navigation to allow the learner to focus on the substantive problem rather than the mechanics of use. For this package, an integral component of the teacher's workspace, a desk, provided a natural navigational tool for users as shown in Figure 3.

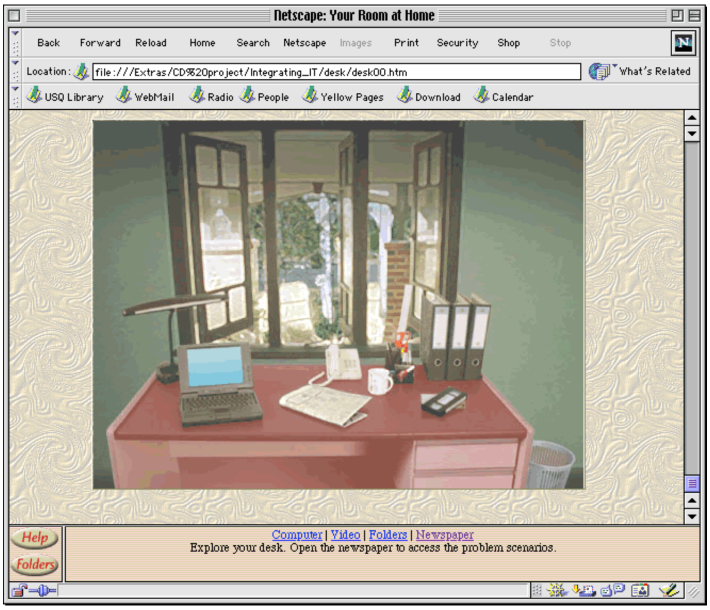

Figure 3: Typical screen layout showing desk with resources

Outcomes

The IMM-PBL materials were reviewed online by a small group of educators experienced with PBL who agreed that the materials matched the characteristics of PBL other than the use of group interaction. When the materials were evaluated in use with teacher education students, the students reacted very favourably to the presentation of the materials and perceived them as highly relevant to their professional preparation especially in relation to the authenticity of the problems and associated resources (Albion, 2000).

The particular focus of these IMM-PBL materials was to increase students' self-efficacy for teaching with information technology. Analysis of pretest-posttest data confirmed that there were significant increases in self-efficacy for users who commenced with low self-efficacy. Users with initially higher levels of self-efficacy recorded a decrease which apparently resulted from exposure to experiences which caused them to revaluate their sense of efficacy. In both cases, initially low and high, the effect of working with the authentic problems in the IMM-PBL was to develop a more realistic self-assessment of capability.

Although the original IMM-PBL materials are now outdated and have not been redeveloped, citations demonstrate that the work has had a continuing impact on other applications of educational technology to PBL.

New technological horizons for PBL

Over the past decade there has been increasing interest in the application of ICT in support of PBL. Much of the research has been directed towards the use of standard online communication tools to support PBL groups but there have been examples of environments built specifically to support PBL (Savin-Baden & Wilkie, 2006). More recently emerging technologies may offer new opportunities and challenges for PBL. Two of particular interest for their potential relevance to Generation Y learners are mLearning and 3D online spaces.

mLearning

PBL has been identified as one of several pedagogies of potential interest for the emerging field of mobile learning (mLearning) (Nie, 2006). The use of mobile devices such as laptop computers, personal digital assistants (PDAs) or mobile telephones, provides opportunities for learners to be supported while working in a realistic context. Even without network connectivity, the devices can provide convenient access to stored information such as problem triggers or reference material for learners operating in the field. With network connectivity the devices can support periodic updates of problem scenarios for purposes such as promoting time sensitive responses to problems, communication among teams of learners, access to resources and reporting to instructors.

In Australia there has been considerable interest in the potential of mLearning from various quarters including the Vocational Education and Training (VET) sector. The use of mLearning is seen to provide advantages of access, context, collaboration and appeal in addition to supporting learning facilitators (Geddes, 2005). All of these advantages are relevant to implementation of PBL and we might anticipate that, in the next few years, many more implementations of PBL will include some use of mLearning. The capacity of mobile technologies to enable collaborative learning across the network and in contexts where it can be immediately applied should be attractive to Generation Y learners.

3D online spaces

At first glance 3D online spaces appear to have much in common with the environments seen in massively multiplayer online role-playing games (MMORPGs) and it is true that the underlying technologies are often closely related. However, 3D online spaces such as Second Life do not necessarily share the goal-directed qualities of games such as World of Warcraft although they may share many other qualities.

The potential appeal of such spaces to a generation familiar with online gaming is immediately apparent but how that appeal may be converted into affordances for learning is not so obvious. Researchers are already working to develop better understanding of how Second Life and similar spaces might support learning, including PBL.

Second Life

Among the issues identified in research about online learning more generally and PBL in online environments is that of authenticity and presence (Land & Bayne, 2006). For many educators and learners, online spaces seem disembodied and less real than the experience of traditional face-to-face classes. Second Life and similar environments may mitigate this effect by providing a more realistic experience in which learners and facilitators, represented by avatars, interact in environments that offer more than text on a screen.

Professor Maggi Savin-Baden of Coventry University and an international group of colleagues have begun exploring the use of Second Life for PBL. Figure 4 shows a meeting space established during the early development of the Coventry University island in Second Life. Learners and facilitators can gather in such spaces and interact using text and voice. It is possible to introduce and share resources such as documents, audio and video in the same space.

Figure 4: Campfire meeting space on Coventry University island in Second Life

Beyond simply conducting meetings in such spaces, it is possible to engage learners in other activities such as building and interacting with objects in the environment. As the environments evolve the range of activities possible will expand and, for some problem domains, it may be possible to provide a complete PBL experience in such a space.

Research being undertaken by a doctoral student at USQ suggests that participants can find the experience of meeting in Second Life engaging and capable of developing and sustaining working relationships. Lindy McKeown (Deckah Mah in Second Life) has developed an island, Terra Incognita, with facilities designed to support Action Learning which, like PBL, uses meetings of small groups of learners as a central element of the learning experience. Spaces like Deckah's Decks (Figure 5) support both large group presentations and breakout groups with recording of text-based conversations and other features that support and enhance the learning experience.

Figure 5: Deckah's Decks on Terra Incognita in Second Life

Second Life is just one proprietary online 3D space that might have potential for PBL. There are many others, both proprietary (e.g., Active Worlds) and open source (e.g., Croquet and Ogoglio). They are at varying stages of development and offer different feature sets. Some promise a degree of interoperability but others are virtual islands. Only time will tell which will persist and develop to be useful spaces for PBL.

ALIVE, AliveX3D and Web3DX

In addition to the work being done in Second Life, USQ has another significant research and development effort in 3D technologies with potential for PBL.

The Advanced Learning and Immersive Virtual Environments (ALIVE) project commenced in late 2005 with support from an internal USQ grant. It received further funding in 2006 and in 2007 was the basis for a successful application for funding from the national Carrick Institute for Learning and Teaching in Higher Education.

The first phase of the ALIVE project (http://www.alivex3d.org/) produced a representation of part of the USQ campus (Figure 6) within which a user could tour facilities such as the library and engage in chat conversations with embedded 'bots' and/or other users. The virtual environment was intended to support orientation of distance students but the basic affordances that it presented could equally well support online meetings such as those typical of PBL group interactions.

Figure 6: ALIVE representation of USQ campus

Unlike Second Life and some other 3D environments that require connection to a server to operate at all, the first version of ALIVE was designed to run as a standalone application with an optional connection to the network for interaction with other users. Because all of the essential content was available in the base installation, which could be distributed on CD-ROM, the bandwidth requirements for interaction were governed by the exchange of simple text and much less than for Second Life – a clear advantage for learners without broadband connection to the Internet.

The first ALIVE application with explicit educational content was a mathematics simulation based around the problems implicit in optimising the use of land and other resources to produce crops on a farm. The simulation could be used offline in single-player mode or on the network in multi-player mode. Although not designed with PBL in mind as a pedagogical strategy, the simulation demonstrated the potential for supporting presentation of authentic problems in the environment together with facilities to support interaction among users in ways that could support collaborative interactions for PBL. ALIVE clearly possesses potential for application to PBL.

Currently the focus of the ALIVE team is on the Carrick funded project to produce 3D educational materials to be shared via the Web3D exchange site (http://web3dexchange.org/). The materials to be produced as 3D virtual worlds may include social environments, simulations, and serious games. In addition the team is developing 2D/3D hybrids that embed small 3D elements in web pages (Figure 7). The latter approach is especially suitable where good quality text is required alongside the 3D content because the rendering of text in 3D environments is typically limited. Each of these approaches to working with 3D online content has potential for application to PBL through some combination of problem presentation, group interaction and problem solution. The limits of that potential will be explored as the project progresses.

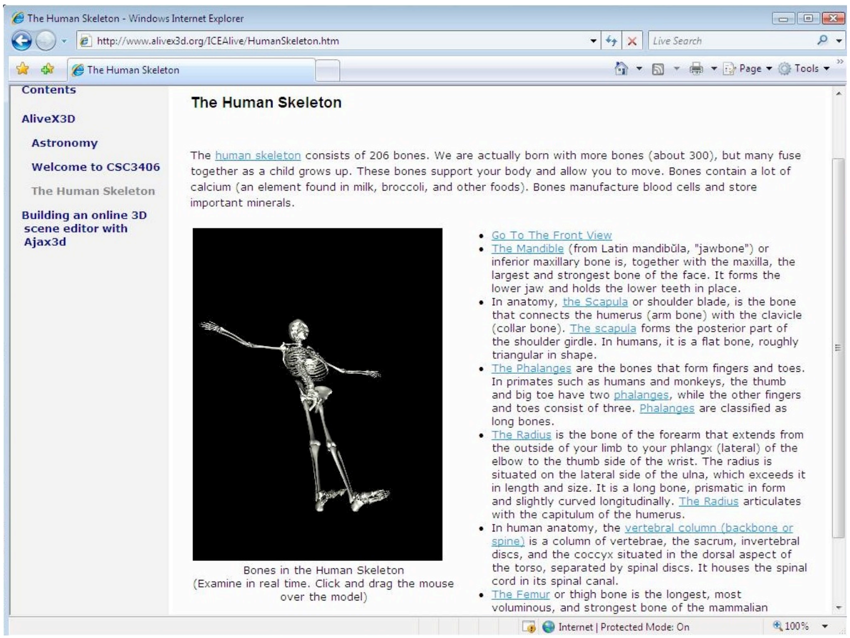

Figure 7: ALIVE 2D/3D hybrid content

Conclusion

Problem-Based Learning is a well established approach to the education of professionals. Its focus on collaborative learning through solving problems in authentic contexts rather than memorising and recalling information makes it a good match for the characteristics of Millennial generation learners in information rich environments.

Over the past couple of decades there has been consistent and increasing interest in the application of ICT to support PBL, and many successful examples of such application. Now there are emerging technologies that appear to be well matched to the characteristics of both millennial generation learners and PBL. There are exciting opportunities for educators prepared to explore these new horizons.

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