Developing Professional Consultancy Skills for Engineers Using a Web-Based Simulated Consultancy

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Abstract

This paper reports on the development of an online, problem based learning (PBL) environment (the Virtual Engineering Consultancy Company - VECC) in which students develop and practice engineering consultancy skills in a 'risk free' simulated consultancy. Traditionally, many engineering students are not afforded the opportunity to develop and practice the essential skills of professional practice before taking up positions within the profession. Well designed virtual learning environments such as the VECC, can assist and support students in building heuristics that will enhance their ability to solve problems in the real world. The problems are situated in the context of a meaningful 'real world' based environment which draws on 'real variables'. The VECC models the skills and processes of an 'expert consultant' 'a professional engineer' in the field of Heat Transfer within a supported learning environment. The power of a web-based environment to provide a platform which supports both synchronous and asynchronous computer mediated communication enables students to interact with a virtual client in an environment which is 'safe', cost effective and highly flexible. This feature is particularly important as many student engineers have limited time and resources and must often fit their training into existing work schedules. Evaluation of the pilot implementation with 3rd year Engineering students at the University of Wollongong is also briefly outlined.

Keywords

Problem based learning, Virtual environments, Flexible delivery, World wide web, Problem solving, Consultancy, Virtual client

Introduction

The training of engineers must provide them with a sound grounding in the theoretical aspects and the skills and ability to solve problems. It must also provide students with a basic grasp and understanding of ‘field practice’ skills. Successful field practice depends on the mastering of specialised problem solving and ‘client handling’ skills which allow the professional engineer to operate effectively in a dynamic work environment.

Many institutions do not provide this opportunity for reasons of financial, time or resource constraints, or the ‘traditional’ pedagogical approach of the institution to training its engineers. Generally, students graduating from engineering courses have had limited exposure to the wide range of practical skills centred on ‘real world’ contextualized problem solving and client contact, needed for successful practice as an engineer.

The Virtual Engineering Consultancy Company (VECC) represents an attempt to provide a solution to this impasse by simulating such opportunities through a web-based virtual Engineering Consultancy. The resulting learning environment is risk free, time and cost efficient. It is flexible, providing opportunities for collaborative group work and structured activities that allow the possibility for each student to assume an active and central role.

Universities and other tertiary institutions throughout the world are rushing to embrace alternative delivery methods, particularly those that utilise the versatility and power of the World Wide Web. Flexible modes of delivery such as the web can provide an effective means of addressing the problems associated with providing opportunities for students to acquire and practice essential skills. The scope of such environments is limited only by the imagination of developers and the limitations of the web in its present form.

Further, suggests Burnett (1997), the use of the Web will continue to expand as it becomes more stable, easier to use and more accessible to everyone. What we are learning from using the Web today will provide the confidence and expertise to take advantage of the advances in its technology. Now is the time according to Alexander (1995) to stop focussing on the technology itself and to start focussing on what students are to learn, and the best way for them to achieve these learning objectives

In recent times many of these institutions have experimented with the use of on-line delivery with the purpose in mind of extending the access to educational experiences to a wider audience. In many cases, the results have been less than satisfactory and have fallen short of student expectations for a number of reasons. The problem is exacerbated by a number of factors. These include: time and funding restraints; the often unjustified self perception of expertise in the field and the mistaken belief by many that, putting a subject or teaching resource on-line involves little more than providing content as a web based document.

"An understanding of the techniques and protocols of on-line teaching and learning and the processes of both the design of new and the conversion of pre-existing resources has become essential for academics, as universities throughout the world embrace alternative delivery methods in response to the globalisation of education."(Corderoy & Lefoe 1997)

Developing the VECC

The VEEC has been developed on a sound pedagogical basis using a team approach, utilising the specific skills of each team member. The Faculty of Engineering and the design/development team at the Centre for Educational Development and Resources at the University of Wollongong, Australia, have been involved in the development of a prototype over the past 18 months. The VECC is a highly interactive and innovative web based simulated consulting environment, based in the area of Heat Transfer. It provides an environment which models the 'experts' heuristic's for solving the problem, facilitating the development of an appreciation and understanding of the application of the skills and processes needed in a real world consultancy in the 'novice' student. The result will be a graduate engineer who is better prepared for the 'real world' engineering practice.

This flexible, web delivered, student-centred resource provides not only training in a specific technical area, but also orientation and experience in professional practice. This type of advanced training has been demonstrated to have significant benefits to students entering the workforce (Ryan *et al.*, 1996).

The framework of the VECC package is modelled on the resources that one finds in a real engineering consultancy office. The consultant in such an office will have developed an expertise in their chosen field - in this case Heat Transfer - and will also undertake continual professional development. This CAL learning environment will therefore foster a positive attitude in students towards lifelong learning (Candy *et al.*, 1994).

The Industrial Problem Solving Assignments are the main educational vehicle for building students' confidence in tackling real world situations and complex tasks. This feature differentiates the VECC from other engineering CAL packages. To quote Laurillard (1993), "we cannot separate knowledge to be learned from the situations in which it is used". In the VECC, students will immediately see the relevance of the engineering theory to be used, since they must actively search for the appropriate theoretical model. That search is the same process the student will eventually use as a practicing professional engineer.

When using this resource the student role-plays a consultant who carries out all the managerial and technical tasks required to expedite a number of high-level Industrial Problem Solving Assignments. This problem-based learning approach "confronts the students" (Boud *et al.*, 1991) with 'real world' based ill-structured problems and scenarios which provide a stimulus for learning and in so doing "encourages the students to take a deeper approach to learning" (Ramsden, 1992). The PBL approach enriches the learning outcomes by simultaneously developing higher order thinking skills and disciplinary specific knowledge bases and skills. It promotes the student to the active 'practitioners' role in the process. The consultant's activities include:

- negotiating with the client on cost and timetabling of the consultant's services
- obtaining the client's technical brief and tendering for the project
- sourcing technical information such as plant dimensions
- making on-site measurements of temperatures or other parameters
- student-centred learning through the Computer Aided Learning (CAL) module integral to the Virtual Engineering Consultancy Company
- simulation of real-life problems using a toolbox of simulation resources.

Expected outcomes

The most significant expected outcomes for students using this package include:

- A PBL based CAL resource that provides Engineering students with training in professional practice as consultants in Heat Transfer Engineering.
- Improved effectiveness of delivery to a diverse student population of full-time, part-time and off-campus students.
- Improved attractiveness of University of Wollongong Engineering graduates to potential employers.
- Improved skills in collaborative working and negotiation.

- Improved attractiveness of Wollongong Graduates to potential employers.

The pilot Virtual Engineering Consultancy Company (VECC) prototype

To date the fundamental structure of the VECC and a substantial number of software resources, including interactive Heat Transfer simulations (examples shown in Figures 1 and 2) have been developed.

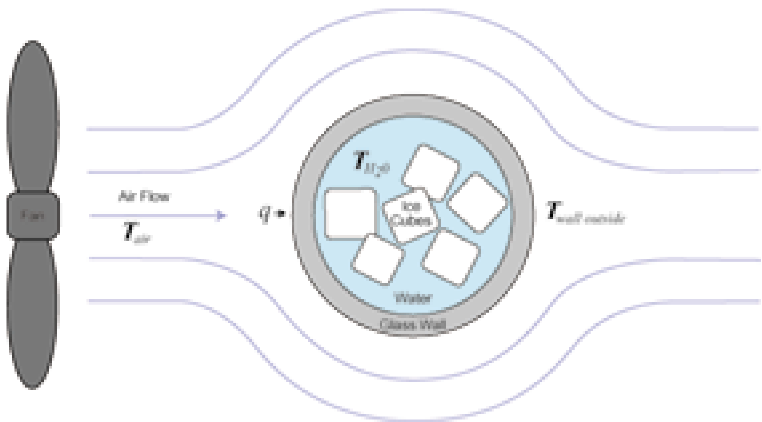

*Figure 1: Simulation of heat transfe*r

The complete package will eventually contain in excess of 30 simulations which will support and develop the students understanding and proficiency in aspects of Heat Transfer including: furnace insulation; steel quenching; conduction and boiling heat transfer. In summary, the VECC resource will eventually comprise three main Modules:

Training (CAL) Module: The student uses resources such as simulations, text-based material, videos, animations, etc to learn the fundamentals of Heat Transfer theory.

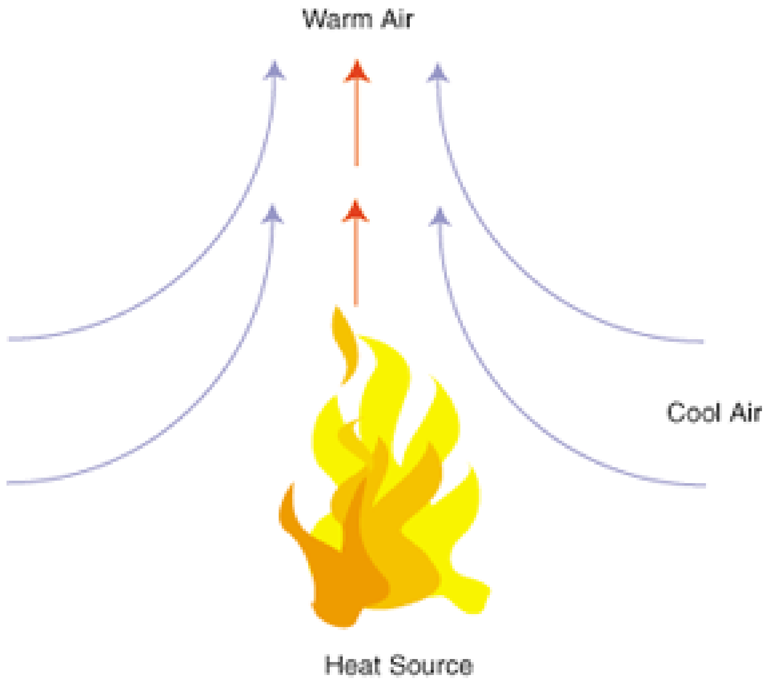

Figure 2: Simulation of forced convection

Trouble-Shooting Module: Here the student has to solve challenging real-life problems that are far more in-depth than conventional engineering assignments. In an example already developed, the student's 'virtual client' is a corporation (HeatTreat™) that has just built and commissioned a large hydrogen production furnace. The furnace is overheating and the student must find out why, suggest remedial measures and act as an expert witness in a court case. A typical brief within the package (following) would provide details of the client's needs and related data as well as suggestions for approaching the task and what additional information may be useful.

Your brief:

'HeatTreat™' requires you to:

- calculate the total heat loss from the furnace walls and roof (as a first approximation assume an outside surface heat transfer coefficient to be $20W/m^2$ including both convection and radiation heat transfer)
- calculate the interface temperature between the Zirconia Blanket and the Mineral Wool to ensure that the latter does not overheat.
- **Surface Temperatures**: The client has measured outside temperatures on the outside of the furnace to be in the range of 105 to 170^{o}C. (Table: 1) These are potentially very hazardous. You must perform the following tasks. A map of some of the surface temperature measurements is shown below. (Figure 3)

Furnace level	1	2	3	4	5	floor
Mean outside surface temperature (°C)	75	64	68	70	68	52

Table: 1 Outside wall temperatures

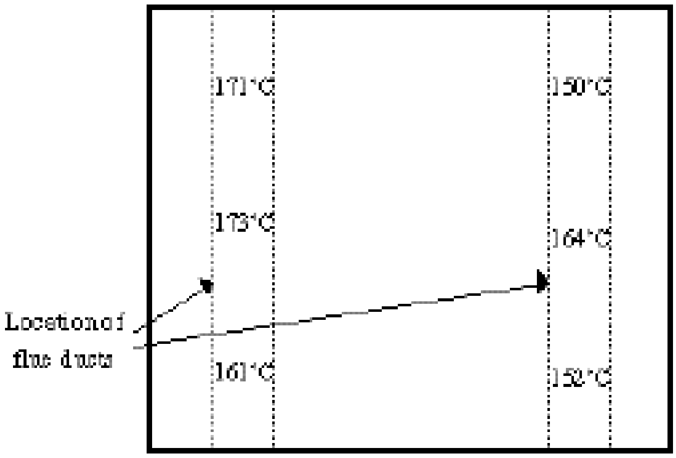

Figure 3: Outside Furnace Floor Temperatures (plan view from above)

a) Carry out a sensitivity analysis of one of the wall the surface temperatures to the outside heat transfer coefficient (calculate the expected radiation heat transfer coefficient assuming emissivity, $\varepsilon = 1$, and then vary the convection heat transfer coefficient in a range that would be expected under normal weather conditions ie between 5 and 20W/m^2 K, say).

b) Determine whether the firebrick insulation shown in the design drawings is likely to have been put in place correctly (if the insulation has not been properly installed legal action may be taken against the insulation installation sub-contractors). Assume the flue duct wall temperature is equal to the gas temperature of Section 6 of the furnace.

c) Recommend a solution to these high surface temperatures problems. Some possibilities include:

- Add extra insulation to outside of furnace (you must calculate how much must be added and whether the resulting temperature of the structural steel is within acceptable limits).
- Shut down furnace and replace internal insulation in problem areas (very much a last resort … represents a very high cost option).

Design Module: Students design a number of pieces of thermal equipment to satisfy a specification from their client. Examples will include a transistor heat sink and car radiator.

Figure 4: The VECC Consultancy Office

The centre of the VECC resource is the consultant’s office (Figure 4) that models a typical engineering office in the real world and has facilities including:

- A **project management whiteboard** that will be automatically updated as a student progresses through the study programme.

- A **laptop computer** which is the virtual gateway to the web and provides contact with the clients (the lecturer) for each project, resources external to the VECC and the brief (an example of which is outlined elsewhere in this paper) containing full technical details.

- A **video monitor** for access to video clips of site visits, illustrative fluid visualisation experiments, lecture presentations, etc.

- A **desktop computer** which represents a powerful computing resource where the heat transfer simulations are located. These already include four unique simulations of important conduction heat transfer situations. Each simulation deals with a real world problem and will be used as part of the consultant's exploration of the case studies.

- A **telephone** for initial contact with the consultant's clients achieved using an audio track.
- A **virtual library** of books which is the link into the CAL module where the student explores the topic of Heat Transfer through the problem-based learning approach of the VECC.

Pilot Evaluation

Students who took part in the pilot implementation had access to a limited prototype version of the 'complete' site. At this stage of its development, some of the segments of the VECC exist as discrete units that are independent of the overall structure. It was expected that this may cause some navigational/continuity problems for some students, however early anecdotal evidence collected from the students seems to suggest that this was not the case. The theoretical 'reference bookshelf' was not available to the students in the prototype. This material was provide in the more traditional lecture/notes method of delivery. Approximately 80 3rd year engineering students (20 groups comprising 3 or 4 students each) used the VECC to complete a major assignment during semester one. Each group consulted in various degrees with the client using the E-mail link, used the various resources available within the consultancy office to support their investigations and develop their 'solutions' to the 'posed problem'. The students were given some introductory guidance on how to use the site and what would be expected of a consultant engineer in such circumstances.

Data collected during this pilot included:
- student interviews – conducted by the lecturer as the semester progressed;
- comments and observations collected during a special forum conducted with by the lecturer, with the co-author/designer observing

and recording. During this forum both technical issues and the learning processes were discussed;
- lecturer’s observations derived from day to day contact with individual students;
- archived E-mail communications between the lecturer and students;
- comparison between the group involved in the pilot study and past groups in terms of the individual marks awarded to students and;
- the lecturer’s ‘quality of answer’ evaluation between groups.

At the time of writing of this paper, only a preliminary evaluation of the data/observations collected had been completed, however a number of significant issues have been identified.

The Students’ perceptions

Comments made by students to the lecturer include:

- convenient and easy to use;
- provides for flexibility in their study schedules;
- provides access to a greater richness of resources;
- motivating;
- use of a real world problem put the theoretical concepts learned and the analytical skills developed into the context of their future activities as professional engineers and;
- comfortable working in this delivery mode.

The Lecturers’ perceptions

Although at this early stage in development there is no longitudinal data for comparison, the lecturer is confident that data to be collected during the continued development and use of the VECC will support and re-enforce observations made so far including:

- overall performance of the majority of groups is better than past years, not just in terms of the overall mark but in the quality of the answers;
- role play appears to have contributed to a deeper understanding of the problem and possible solutions and enriched the learning experience;
- there has been no change in the completion rate, the number of students ‘opting out’ is about the same as usual;
- in this type of learning environment, support for students is essential and this will lead to an increased workload on lecturer/tutor;
- students who took full advantage of this support by contacting the ‘client’ (lecturer) performed better than those who did not;
- seems to be a time efficient way of presenting both the technical information and the processes involved in consultancy in a richer environment;

- flexibility for both students and lecturer is a ‘real plus’ and;
- the students seemed to be more motivated and this is reflected in their willingness to explore the resource base fully, developing better quality answers.

Stage Two: Full Implementation

Work is currently under way to develop the full working version of this virtual environment. Changes are being implemented based on the feedback from the pilot implementation. One of the most significant segments of the program, in terms of content, is the theory section which is being carefully structured to avoid the ‘page turning’ syndrome often seen in CAL which has a large theoretical content base.

There are several issues unique to technology based delivery which need to be investigated with respect to the VECC when the full working environment is implemented and evaluated by students. The student groups in the pilot implementation had minimal exposure to the ‘structure’ and process of the VECC in lectures. Did this add to the cognitive load placed on them so that unnecessary effort was expended on learning about the system, rather than from it? The issue of preferred learning styles and the ‘students’ fit’ to the delivery mode needs to be explored. Finally, an essential part of such complex learning environments is a ‘user support’ mechanism and it is essential that all students avail themselves of it. Ensuring that they do is one of the keys to facilitating useful student interaction with the learning environment. The developers have targeted the design and implementation of a 'help' function to ensure effective use of the virtual environment.

Conclusion

The rapid rise in the development of sophisticated and improved technologies has been the driving force behind the widespread embracing of the concept of flexible delivery and the application of the many and varied tools upon which it is based in the field of education. Flexible modes of delivery such as Web based instruction can provide an effective means of addressing the problems associated with providing cost effective mechanisms and risk free environments in which student engineers can gain vital understanding and competency in the skills and processes associated with engineering professional practice. The VECC is such a web based flexible learning tool. Early indications suggest that students are benefiting from this virtual consultancy learning environment which uses a problem based learning approach to develop the skills which are vital to every day engineering practice.

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