Chemistry online in a constructivist environment

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Abstract

This paper reports on the use of a constructivist approach to the online design and delivery of a first year chemistry course at Swinburne University of Technology during 2004. The transition to tertiary education for most students is difficult but particularly so for those that come to higher education with diverse and disparate backgrounds. Students often have unrealistic expectations of university life, their learning environment and the skills they require to succeed. The engagement of such students presents a continual challenge for teaching academics. In this case study the delivery approach used employed a mixture of both online and face-to-face delivery. Lectures were pre-recorded and delivered using video streaming via the universities Learning Management System, Blackboard™, and CD-ROM. Theoretical concepts and practical skills covered in the lectures were reinforced via face-to-face tutorials and laboratory sessions. Online discussion forums were established to encourage scientific debate and help build a student centred learning environment. Evaluation of the targeted outcomes indicate that issues such as social dynamics, and staff's inexperience with technology, impacted on the student's learning experience more than the diversity of learning backgrounds students came to the course with.

Keywords

flexible delivery, chemistry, social constructivism, online design, online delivery

Introduction

At Swinburne University of Technology, Chemistry is taught as a core first year subject to a large cohort of students entering a variety of science courses. Most students are required to pass this semester one subject to satisfy the prerequisite requirements for latter subjects in their respective courses. As a result, the students come into the subject with a wide range of chemistry backgrounds and experiences: VCE (Victorian Year 12 Certificate) level; middle school level; or as mature aged learners returning to study after a lengthy period away from learning. This diversity of backgrounds makes it difficult to engage students in traditional theory components, as well as the more practical components, of the course. Maintaining student interest in learning throughout the semester is a constant challenge for the academics involved. First year students often experience transition pressures as they move into the unchartered waters of tertiary learning and new social environments. Many students, young and old, travel long distances on a daily basis to attend classes. As timetabling issues becomes more complex in response to the popularity of specialised courses, so do the demands for flexible delivery. Building learning communities that engage learners in difficult content and theoretical models, which are flexible in their delivery mode, and based on student centred learning theory are often seen as a possible option in meeting these demands (Bostock, 1998).

This paper looks at how a constructivist approach to the design and delivery of a first year online chemistry course at Swinburne University of Technology was able to address some of these student needs.

The delivery context

Traditionally chemistry has been taught at Swinburne University using a transmission model (Tyler, 1949). Lectures were delivered weekly, to large cohorts of students, and rarely required student interaction. The 'lecturer', in this transmission model, was seen as the 'sage on the stage' - the fountain of all knowledge. Students were required to attend the lecture, listen, and then reinforce their knowledge through practical laboratories; a model that had some measure of success when only the most committed and naturally gifted high school students were strongly represented in higher educations classrooms (Biggs, 2003). However, with an increase in the commercialisation of higher education the need to sell, market and promote courses has forced universities such as Swinburne into repackaging their traditional science courses. In recent times science courses have moved away from 'pure' chemistry to the more specialised fields of biology, biochemistry and environmental science. This commercial shift, along with growing numbers attending universities, has dramatically changed the profile of students undertaking science courses in higher education. In response to these pressures universities have increasingly looked to constructivist principles, along with increased usage of technology for answers (Bostock, 1998).

Constructivist approaches to delivery and learning are seen by Swinburne as particularly relevant to its learners, as its student-centred focus promotes higher-order cognition among university students (Entwistle, Entwistle, & Tait, 1993; Jonassen, Mayes, & McAlesse, 1993); the last 10 years has seen an increased move towards these philosophies in face to face delivery, and more recently they have begun to impact on online contexts within the university. Particularly as communication tools such as video conferencing, audio conferencing, real time chats and discussion forums have become easier to use and implement. Such technologies have allowed staff to move the emphasis away from delivery to resource development; resources which can be utilized in a variety of ways to meet student needs. In this context 'online lectures' can take on a whole new meaning. Students are increasingly being given choices in regard to time, place and pace of study as well as their style of learning and forms of assessment (Swinburne University of Technology, 2005).

Chemistry, as a subject, was seen as an ideal choice to trial constructivist design principles with new technologies in an online delivery environment as the teaching team were committed to the delivery methodology, had prior experience in teaching online and felt the subject would benefit from technological enhancement. However, as always, one of the major considerations was managing the human resource requirements of the project with the time constraints of the delivery. It was hoped the time and personnel resources of the teaching team would not be needed beyond the planning, design, delivery and support phases (6 months). The project was seen as a 'practitioner led' project rather than as a centralised flexible delivery project developed by the Teaching and Learning Support Unit. Prior experience in online delivery by the teaching team meant there was a relatively small workload required in the adaptation of subject material and integration of the technologies such as discussion forums and quizzes into lesson plans. However, challenges such as online verbal and written scientific communications were still difficult to achieve given the online context.

The move from a transmission model to a constructivist approach was introduced to enable students to have a greater input into their learning environment and to increase their interaction with teaching academics. However it is important that a fine balance is achieved in any online environment between:

Student input and knowledge construction	&	rigorous academic content
self-direction	&	academic direction
student ownership of learning	&	academic facilitation
student-to-student communication	&	academic-to-student communication
student-to-student support	&	academic-to-student support

A shift away from teacher-centeredness to student-centeredness was adopted in this subject in an effort to enable greater flexibility in how the students engaged with the learning materials, as well as how they communicated and worked with each other in an informal sense. The central question for academic developers which Redish, Saul and Steinberg (1998) poses is: "What are the students learning and how we make sense of what they do". To address these needs, a social constructivist approach was taken in developing the components required for a more flexible delivery approach. A range of methods was made available to:

- gain the students' interest
- enable them to question and discuss complex issues amongst themselves
- identify and negotiate the learning pathway they wished to follow

- analyse, develop and apply difficult scientific concepts
- provide effective two way communication between students and the academics.

The teaching team did recognise that proficiency with the technical skills and their appropriate application within a constructivist environment would take a protracted period of time to refine. The key goal of the project was to produce a learning environment that would act to stimulate and facilitate discussions amongst students and their tutors. The evaluation was based on the suitability of the approach, the chosen technologies, the engagement of students in consideration of their prior knowledge and varying learning styles.

Mapping Jonassen's Constructivist Learning Environment Model to the online design

Jonassen's (1999) Constructivist Learning Environment Model was used to underpin the design of the subject by promoting active participation in the delivery by students and to provide learners with the opportunity to develop, compare and understand different perspectives and approaches. Linkages between labs, tutorials and discussion opportunities provided the context for activities within the learning environment. The approach included provision of scaffolding in the construction of chemistry knowledge through support from tutors as well as peers. Table 1 compares Jonassen's constructivist learning environment model with the Swinburne course components.

Table 1: Jonassen's constructivist learning environment model compared with the Swinburne course components

Jonassen's Constructivist Learning Environment Model	Swinburne course components
Create real world environments that employ the context in which learning is relevant.	Student knowledge construction to be built through communication and the use of a variety of contextualized resources; video, animation, modeling, personal communication, group communication, quizzes, laboratories, online delivery and face to face contact.
Focus on realistic approaches to solving real-world problems.	Technological and face-to-face communications to be the keystone to problem solving activities that are contextualized to authentic examples. Student participation and communication to direct the learning. Theoretical models developed by students were then tested in lab environments.
The instructor is the coach and analyzer of the strategies used to solve these problems.	Tutor involvement was predominantly focused on moderation and facilitation of student learning through communication. Students drew upon the resource (tutor) as and when they needed them. Tutor analysis of online communications identified students at risk or in need of guidance.
Stress conceptual interrelatedness, providing multiple representations or perspectives on the content.	Using an online medium optimized student communication and opportunity for input to modeling. Multiple perspectives were encouraged through the use of student centered examples and interpretations.
Instructional goals and objectives should be negotiated and not imposed.	Negotiated outcomes were established at the beginning of the semester. Students had choice in regard to time, place and pace of study. Students were also able select study groups and mode of study either online or face-to-face — or a combination.
Evaluation should serve as a self-analysis tool.	Quizzes were generated not only to test knowledge but provide detailed feedback on a given topic and resources that would support further learning. The key focus of the quizzes was to enable the student to evaluate the individual progress against the negotiated outcomes.
Provide tools and environments that help learners interpret the multimedia perspectives of the world.	Student were familiar with the Internet as a resource and communication tools such as chat rooms but the development of an online learning environment extended students technical perspective of the world through the use of multiple communication tools.
Learning should be internally controlled and mediated by the learner.	Student learning was self-directed but still goal orientated. Negotiated outcomes were established to maintain timely completion.

Source: Jonassen, 1999.

Although the transmission model and constructive approach to delivery differ radically, in practice in early iterations of the learning environment there was a mix of the two. Particularly as lecturers and tutors came to grips with the learner centred approach and the technology opportunities provided. Davidson (1998) highlights that in practice circumstances surrounding the learning situation frequently dictate and aid in the decisions in terms of which learning approach is most appropriate. It is important to recognise that some learning environments require prescriptive solutions, and others, learner control of the environment.

In this subject, the academics played a more traditional role, taking responsibility for labs but were also responsible for maintaining additional interaction points. The traditional large lectures (70–80 students) were replaced by a video-lecture resource package obtained either by streamed video through the subject web site (Blackboard) or from a resource CD. Asynchronous communication was introduced to stimulate student engagement, provide opportunities for knowledge construction and facilitate social interaction outside of the classroom. The lecturer, with tutor involvement, initiated the online discussion forums by posing a question or submitting a thought for each lecture topic to encourage weekly reflective and scientific discussion amongst virtual tutorial groups. In addition, further points of engagement were set up to facilitate and foster tutor-student communication: email contact, weekly feedback on assessment items using online lab results postings and practice maths skills quizzes. Muirhead (2000)in his work found both students and teachers need to be active participants if interactivity is to be effective. It was expected that this aspect could significantly influence the experience of students, and also that of fellow academics. Effective communication between teacher and learner is essential and influential on the learning experience according to Rowntree (1995) who holds that an active academic collaboration is the vital integrating factor that helps learners to successfully negotiate the subject in question. The aim of fostering active rather than passive learning was likely to place additional demands on the teaching staff involved, and this aspect was evaluated.

The major change to the delivery and learning environment was the replacement of the face-to-face lectures with the video resource package, which acted as a theoretical alternative to a face-to-face lecture; and was made possible through the availability of new technologies such as Producer (Microsoft). It enabled a package to be recorded and assembled that consisted of lecture resource material via video, a PowerPoint (Microsoft) presentation embedded and displayed on the screen simultaneously with another window containing the main objective points. This enabled students to skip or backtrack through the video recording as they needed. This design gave students the opportunity to take a systematic or holistic approach to working through each video resource in accordance with their own learning style. Importantly it gave students with minimal prior chemistry knowledge the option to: view each lecture resource package many times, pause the video to allow notes to be made on their own copy of the lecture handouts, and to work through the sample problems embedded within the resource package. This process could then be revisited to allow students the opportunity to review the topic material. Other students with a sound knowledge of chemistry concepts from prior learning could skip through various topic objectives, attempt the problems separately and check the video presentation for confirmation and feedback. The intended advantage of this technology was, from an academic perspective, to assist students to develop attributes such as independent and self-directed learning, self-motivation and time management skills.

One area that has constrained the uptake of flexible delivery in science subjects has been the availability of suitable software to enable problems with mathematical or symbol content to be explained out of the classroom. The purchase of MIMIO by Swinburne has enabled the insertion of chemistry problems (worked on a physical whiteboard) to be converted to animations and uploaded into the Blackboard site. It combines whiteboard notation with audio explanations; this was an important addition to the effective use of the flexible learning aspect of the videoed lectures as a traditional lecture often uses a whiteboard to further explain concepts. Concepts that often take time to be absorbed and processed by the student e.g. balancing chemical equations, stoichiometric problems, acid-base and solubility equilibria and basic mathematical manipulations.

The integration of these technologies into the approach was to provide varied avenues of engagement and a basis to introduce and encourage scientific discussion and sharing of experiences. It also provided an element of dialectal constructivism (Moshman, 1982) into the subject delivery. This emphasised the negotiation between individual and social experiences or knowledge to facilitate learning. Solely focussing on the individual construction of learning is inadequate by itself. It became increasingly important to include technology tools such as asynchronous communication to facilitate and prompt collaboration and the sharing of experiences (Scardamalia & Bereiter, 1996). The social interaction, moderated to varying degrees by a tutor or demonstrator, enabled a sharing of ideas, difficulties and learning approaches.

As emphasised by Taber (2001) one hurdle to the successful uptake and acceptance of this type of approach by students is the lack of perquisite skills some of the students have when entering tertiary education. Academics within the subject were expecting students to be able to employ skills such as time-management and self-discipline, characteristics usually exhibited by independent and adult learners. The majority of the students entering into the course were in fact transitional learners. They had only just begun to acquire such skills and had a significant adjustment to make whilst undergoing the transition into the university teaching and learning system. As a result, the tutorials were closely linked to the lecture material, which was emphasised at the beginning and end of each video presentation and short tutorial tests were introduced. Laboratory classes were also timed to fit with the schedule for viewing topic lecture videos. This gave independence and flexibility in terms of covering theory components but also kept the flow of information succinct and continuous through the semester period.

Formative evaluation model

When considering a constructivist instructional design model, such as that proposed by Jonassen (1999), design elements such as enabling multiple paths through the material, clear identification of the learning domain and provision of tools for a learner controlled path, are considered to be central to the design of the flexible delivery approach. A schematic of the subject is shown in Figure 1 that relates the important components of the flexible delivery package. It is considered desirable to have the delivery of the material as central, while still providing several avenues for communication and practical application of the learning in an authentic context (Reeves & Reeves, 1997). In this subject this component was designed to occur through tutorials, lab sessions and discussion forums. The evaluation modes were used to obtain feedback from the inner circle components, i.e. communication, delivery and assessment, to enable adjustments to be considered and incorporated into the design of the delivery approach.

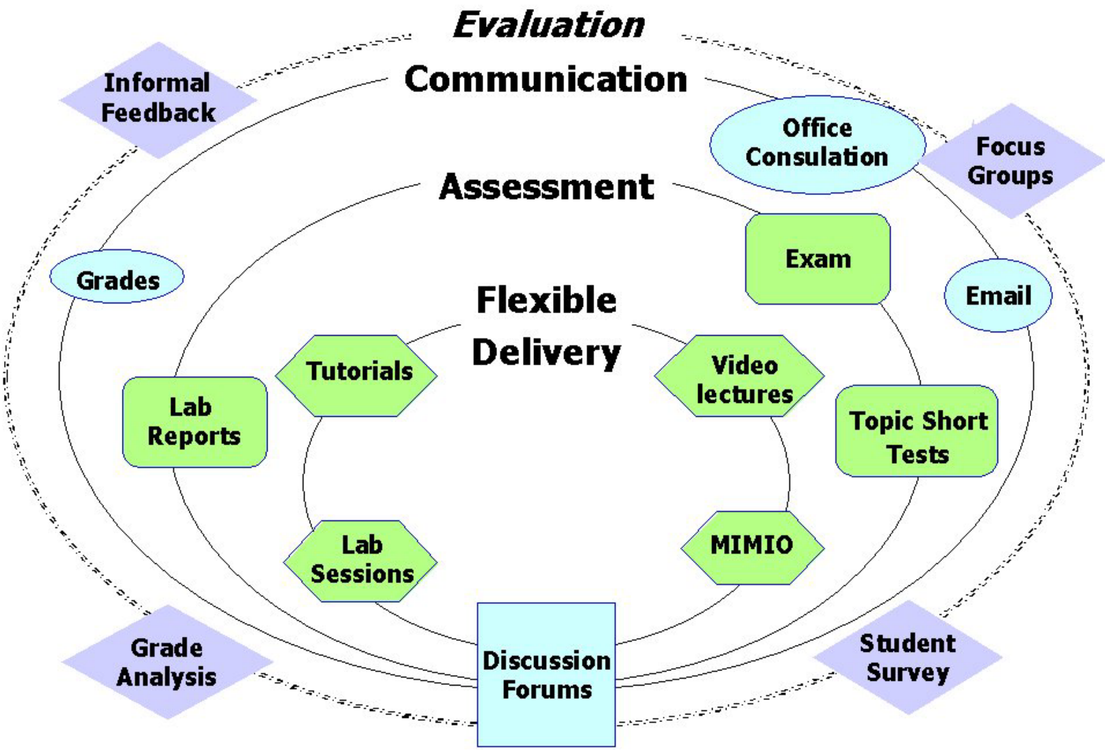

Figure 1: Schematic of the flexible delivery approach taken, its components and the relationships between delivery, assessment, communication and evaluation for the chemistry subject

Formative evaluation and results

In evaluating the approach it was anticipated that the participating students would raise several concerns, ranging from their perception of the usefulness of the delivery package and lack of engagement to difficulties with self-management and keeping to the schedule for the whole semester period. A survey was constructed and several focus groups sessions were conducted at the end of the delivery period to gain feedback from both students and the involved academics on these points. In addition data was sought relating to whether the technology and/or prior learning backgrounds were considerable contributors to any difficulties encountered during the course of the delivery period. As Salomon (2000) discussed, the use of technology can tend to be in terms of accessing information, rather that guiding the attainment of knowledge. This is an important distinction that needed to be evaluated for this project.

Interestingly each focus group (both academic and student groups) identified the main issues pertaining to the management and implementation of the flexible delivery approach were not related to technology but rather with:

- Difficulties in determining a principal contact point with the absence of a physical lecturer.
- The impact of the psychosocial environment in tutorials.
- Insufficient orientation into the subject and flexible delivery approach.

Underlying each of these issues were the major changes that the students were encountering upon entering the university learning environment. Independence and responsibility for their own learning is a new concept to many students when they begin tertiary study. One academic involved in the tutorial component of the delivery found that the greatest disruption and influence on the learning environment and acceptance of the delivery mode was the psychosocial environment in the tutorial class. The class was observed to split, not according to learning styles or prior chemistry knowledge but according to social dynamics. Comments from the academic interviews were interesting for this particular group:

> (sic) “probably split it into four…1. straight out of high school, fairly quiet people, had a science background, all they were really getting used to was the new delivery system. 2. mature aged students, little bit of problem with chemistry but not much of a problem with the flexible, learning independently. 3. had trouble with understanding chemistry, wanted to have someone face to face, fairly shy, embarrassed, wanted to be able to do it anonymously and 4. your clowns, just couldn’t be bothered”

… with the final observation that this splitting into groups was not reflected in the marks. It was just a factor of social behaviours and consequential learning environment in the tutorial class.

The students’ learning environment in the classroom was greatly influenced by a disruptive social element that altered others perception of the learning environment and their confidence. This was also transferred to the virtual environment in the discussion forums set up. The composition of each of the online groups was a mirror of the classroom tutorial groups, and as a result the social dynamics were also present in the online contributions. Tally data from Blackboard showed that “lurking” far outweighed contributions. Initially this was thought to be due to the varied backgrounds causing some students to be discouraged by concerns that fellow classmates would think their postings to be less intelligent thus the tendency to be either more aggressive or to not contribute, as observed by Rowntree (1995). However, as Yeo and Zadnik (2004) note, social dynamics of a student group and how it can influences motivation and learning behaviours has just as much impact as the mode of delivery used or the subject material. Moallem (2001) also reports students are wary of contributing to the discussions due to a lack of confidence and worries that their postings may not be deemed intelligent enough by their peers and would be saved for the duration of the subject. These students were more comfortable with gaining feedback from an instructor rather than from their peers.

Acceptance of the technology was not seen to be a significant issue. Troubleshooting facilities were made available and most of the problems were sorted out early in the semester through contact with the tutors or through online discussion forums that had technical support personnel moderating them. On the other hand there was the underlying expectation that a subject, whether it was comprised of lectures, labs or tutorials, would be delivered by an academic for the published number of contact hours per week, rather than the offering of varied delivery modes. This was associated to a reoccurring expression of dissatisfaction with value for money.

For the online interaction to be successful, an almost daily interaction was required between students and tutors. This was especially so for the students who were having difficulty becoming self-directing in their learning. Daily contact was also needed to establish a positive online community. Such interactions resulted in a greater than anticipated time commitment from the tutors, who could not always meet the expectation satisfactorily.

As Flottenmesch (2000) reports, students tended to judge the quality of their experience by the level of interaction and involvement of the academic. This introduced another variable between tutorial groups. The inclusion of the online discussion groups was considered to be central to the successful implementation of the model. To successfully add an element of social constructivism, the groups needed a means to socially construct knowledge (Stacey, 1999). This became evident towards the end of the subject when the forums began to evolve into a valuable resource of knowledge, with discussion of various approaches to problem solving and communication evolving into a scientific context.

A trend analysis of grades obtained for the assessed components, whilst only for one year, showed no significant change resulting from the introduction of the flexible delivery model. It is difficult to draw any conclusions, as student groups each year can be quite variable, however it can be noted that the performance was relatively close to that of the previous delivery mode. The overall class average was slightly higher than the average calculated over the years 2002–2004, with 73% compared to 70.3%. In terms of the distribution of grades earned by the students, there appears to be a shift in the population for each category upon the implementation of the new delivery approach. One trend seen in Figure 2 is the shift of students away from the middle grades, i.e. from a Pass towards the higher grades of Distinction and above in comparison to 2003.

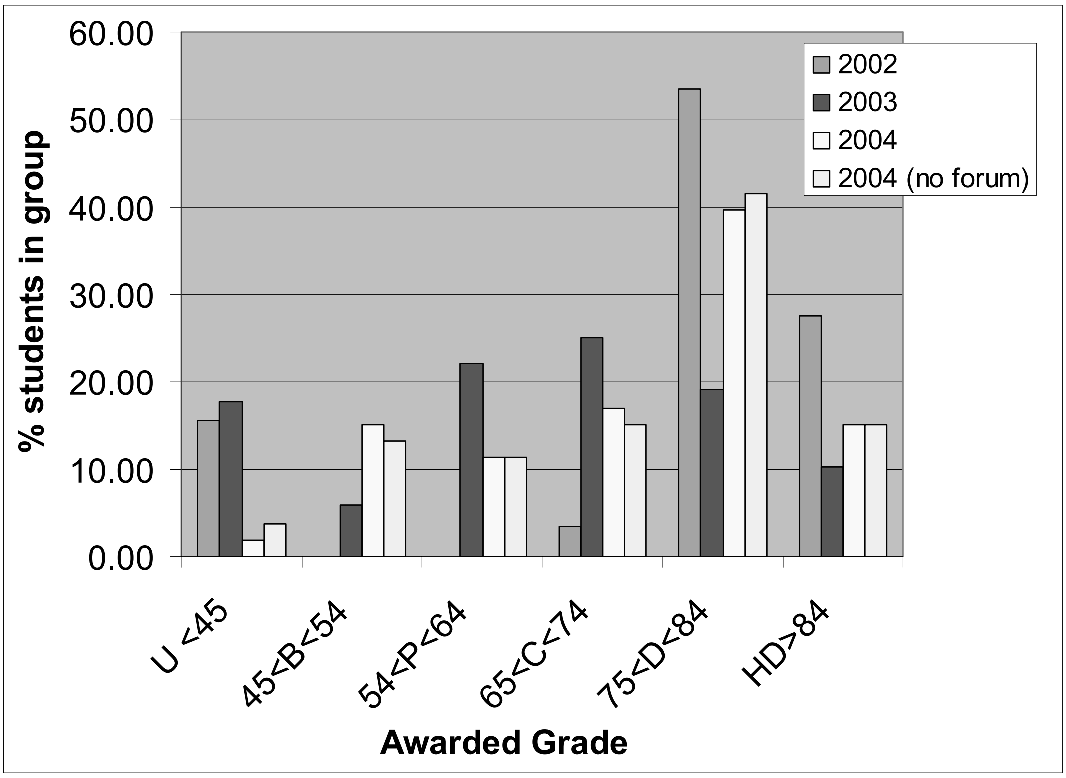

Figure 2: Trend of the overall grades awarded to students completing the chemistry subject; B = borderline, P = pass, C = credit, D = distinction and HD = high distinction. Also shown is an adjustment for the discussion forum contribution mark that had not been part of the assessment scheme in 2002 and 2003.

The distribution was also quite different to that seen for 2002. This could be linked to several contributing factors: difficulties faced by students in becoming more self-directed and responsible for their learning and the delivery being less teacher–learner centred. Given possible variables — such as exam composition, changes in tutoring staff, the intake mix of students for each course stream, the impact of inexperienced tutors on the learning environment and student engagement — no real conclusion can be drawn as to their contribution. The assessments items were constant except with the inclusion of the discussion contribution mark in 2004. The effect of removing this component was examined and the overall average for the adjusted assessment scheme was recalculated and is also shown in Figure 2. It caused only a slight alteration in the proportion in all ranges, with no effect on the Pass range. More data analysis needs to be done and further groups need to pass through the subject before any further conclusions can be drawn on the impact on grades and assessment.

Implications and conclusion

The flexible delivery model was shown to be successful from an implementation and application of technology viewpoint. It was required to engage a diverse body of students, with varied learning styles and chemistry backgrounds. Students with a prior tertiary learning history, high self esteem and confidence, and who were self-directed learners embraced flexible delivery model very favourably. Another group of students required a more teacher-learner centred approach. Although teaching was supported by tutorials and lab sessions, feedback suggests this group found it insufficient on a personal rather than academic level.

A successful transition into tertiary learning had a major influence on the students' social interaction and learning experience. The psychosocial environment for one group of students impacted on the learning environment in the classroom and their participation in communication such as discussion forums. The academics, specifically the tutors involved, spent more time establishing and interacting with online tutorial groups than was anticipated.

Considering the above, additional support for the teaching staff in terms of how to manage online communications and tutorial psychosocial influences will need to be implemented into their tutor training. Improved orientation for students into the e-learning environment should also be covered in orientation.

In summary the project used a constructivist instructional design approach to develop and implement a chemistry subject to provide flexible learning opportunities via the incorporation of new technologies. This enabled a greater element of social constructivism to be introduced into the subject through active participation in the delivery. It was shown to enable scaffolding in the construction of chemistry knowledge through support from tutors as well as peers. The cyclic evaluation, review and development process will continue, with emphasis on the assessment scheme and further incorporation of situated learning theory to expand on the constructivist approach within the learning environment. It will take time for the staff to become fully proficient in both the technology and the constructivist delivery methodology but the obvious nexus between the two bodes well for the future.

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