Impact of Curriculum Decisions on Computer Assisted Design

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Abstract

This paper reports on educational outcomes from a project conducted at the University of Newcastle with Chemical Engineering students using computer assisted design (CAD) software. A number of curriculum decisions were made to improve the learning outcomes for students and to increase their productivity. The project involved curriculum change encompassing the considerations of technology, content, student needs and teaching strategies. The project outcomes revealed very convincing support for the chosen learning methodologies.

Students responded positively to the challenge of the project and by example soon endorsed approaches to learning such as student-centred, problem-based, challenge-inspired motivation and critical thinking. Central to all activity was an applied approach to learning in that students were tasked with devising a real solution to a real problem using industry standard software. Students appeared intrinsically driven and the learning that took place is best described as deep learning rather than surface learning.

Tasks completed by students for assessment were well in advance of previous assessed tasks based on traditional approaches to learning. The project’s success is largely the result of the curriculum change that was introduced.

Introduction

In recent years there has been a great deal of interest shown in the training of engineers demonstrated in the 1993 Report (Moses, I. & Trigwell, K., 1993) ‘Teaching quality and quality of learning in professional courses’. Such reports identify a large range of issues associated with the preparation and training of engineers and some of these issues include:

- the ever changing technology landscape,
- the need for engineers to be more representative of society in cultural and attitudinal attributes,
- having better communication skills,
- being more effective in teams, and
- having highly developed problem solving skills.

Engineering courses across Australia are in the process of implementing initiatives that will address these as well as other issues. In the Chemical Engineering Course at the University of Newcastle one initiative was the introduction of a subject into the core curriculum which specifically addressed the issues of:

- better communication skills, and
- problem solving skills.

This subject provides the students with the opportunity to problem solve in the manufacturing domain thus providing experiences that replicate industry.

The subject covers, among other topics, the skills associated with communication, primarily in the graphic domain. Students work in both freehand graphics and Computer Aided Design (CAD) and the subject has been well received by students. In a review of the subject carried out in 1998, the content and the methodology of delivery of one component was modified. This paper looks at the issues that motivated change, the changes that were made and the outcome of that change.
Engineering Education Practice

There are a number of pressures on engineering curriculum developers to individualise pedagogical and general instructional techniques. One is the trend to move from a teacher-centred approach to a more student-centred approach. This is evident in many aspects of teaching including the types of activities in which students engage and the methods of assessment used in the evaluation of student attainment of objectives. This concept of subject individualisation and the encouragement of autonomous learning have become increasingly important issues in the tertiary sector as Knowles acknowledges:

There is an urgent need for all programmes of higher education... to be geared (from the start) to develop the skills of autonomous learning... This is to say that the new emphasis in higher education must be on the process of learning, with the acquisition of content being a natural result (1981, 8).

Or as is encouraged in the statement by the National Foundation for Education Research:

The shift in focus implies a shift in teaching and learning strategies away from the traditional transmissive mode of formal lectures towards an emphasis on students’ responsibility for their own learning.....students would construct knowledge rather than receive it; would do so with greater independence and opportunity to work in small groups and be assessed by procedures which acknowledged the nature and context of their learning (1991, 93).

A number of educational systems are moving toward variations of outcomes based curriculum design and assessment, and this impacts on engineering education. As students are assessed in terms of outcomes, the assessment that is done is essentially individualised, as students in the one class may be performing at different levels. The impact of an outcomes orientation on curriculum design and specific student classroom activity is that activities will be designed to assist students to progress toward the next level of outcome attainment, which may of course be different for all students. This implies that each student may be working toward different outcomes, or a different level of the same activity in any class. So the incentive is to both design activities, structure the curriculum, and assess students based upon the different outcomes.

The desire is to expand the notion of engineering education from its past focus on teaching skills to an emphasis on both the cognitive and affective development of students. This combined with the need for subjects to be more individualised, has also encouraged teachers to implement methodologies aimed at the development of the individual. For example, in a situation where skill competency development is paramount, all students are expected to master the same skills. If they do not, then the pass-fail division is very clear. The development of cognitive and affective abilities is less clear cut, both in teaching and assessment, and must be individualised in order to be successful.

Problem Solving and Design

It is important then to include in the curriculum for engineers the practice of problem solving, especially in the context of design. The relationship and distinctions of the processes of design and problem solving are often unclear in discussions about technology among educators because, in some cases, it is taken for granted that the two are synonymous. For some (eg. Staudenmaier, 1985), design is the central process of technology, whatever the specific technological field, and there is a large literature on design and on design methodology (eg. Cross, Dorst and Roozenburg, 1992).

It is possible to identify three major views of problem solving in technology (where it does not overlap with design):

- a general problem solving approach,
- the focus on the global problem, and
- emergent problems created from dilemmas during an activity.
But the concept of problem solving is more universal. Within the engineering context problem solving processes are likely to be a collection of specific techniques such as fault finding and optimisation or enhancement of outcomes.

Research points to one very strong conclusion namely that, despite the common belief in a general problem solving process or skill, or indeed a general design process, it is difficult to show that such general strategies exist. The reality is that engineers and designers exhibit inventive and flexible approaches that are adapted to the particular situation they face (Lave, 1988).

Several basic features of pedagogical strategies need to be considered in light of the above discussion:
- self management should be developed in the students,
- students need to develop skills in generalisation so need to experience problem solving in a number of contexts,
- provision of support systems to aid students in developing problem solving strategies, and
- the development and augmentation of conceptual knowledge (technological and other).

**Support Mechanisms for Problem Solving**

If an emphasis is put on a general problem solving or the design process, then the comments on self regulation and avoiding ritual are particularly important. This will enable students to see how problem solving has to be responsive to particular conditions and show them how they have to choose when to employ particular techniques. The variation in the way the tasks are structured to show the context-specific nature of problem solving can be achieved in various ways:
- by moving through an activity in various ways, and
- by comparing different design strategies for different products or problem situations.

It is also necessary to focus upon specific heuristics or design skills if students are to learn to use them in order to allow students to develop strategies of when to use particular heuristics, ie, develop *procedural knowledge*, but they still need to develop the individual design skills. This will be achieved through:
- focusing upon the global problem;
- technological activity requiring at least two features, namely a client and an organisational setting;
- supporting students to solve emergent problems; and
- the teacher then having several strategies to involve the student in solving the problem:
  - a. demonstrating the process of formulating, reformulating or solving the problem, and doing so in such a way that the thinking process is made explicit to the student;
  - b. posing questions to the student to encourage his or her own solutions; and
  - c. giving several alternative solutions and allowing the student to choose or modify them to produce one that is satisfactory.

**Project Based Learning**

The methodology of project centred learning differs in its characteristics from the widely accepted and published Problem Based Learning (PBL) Methodology. The Project Centred Learning activity is single student centred rather than group centred as in PBL. The project and the objectives, though not the specific project outcomes of the learning module are developed by the lecturer. This methodology involves the student receiving the specific project with the expected outcomes and the assessment criteria profiled.

An important aspect of this method is the introduction of the problem or specific project. It is important that students experience the process of design and problem solving from a range of different contextual situations.
**Context of CAD Education**

Traditionally the teaching of technical drawing is based on a conventional approach centering around manual drafting techniques. The often used rationale for this approach is that it provides a grounding from first principles which provides a platform for computer assisted drawing.

When this subject was first introduced and it was decided that it should have a technical drawing content, the decision was made that it should be taught through CAD. This decision was seen as being innovative as students would not only learn the relevant technical drawing concepts, but also develop appropriate CAD skills.

The approach adopted focused on CAD skill development in a 2D environment only. This was intermixed with attention to technical drawing concepts as they arose from the CAD experiences. Skill development was focused on drafting techniques where students became competent in the basics of drawing commands, editing options, text generation and dimensioning techniques. There was little opportunity for students to apply their skills to specific problems, little chance for creative and individual application and assessment focused on generic or standard problems. Students were quite receptive to a CAD approach to technical drawing and quickly saw the appropriateness of this technology to their profession. Their status in terms of CAD understanding after the completion of the course could be described as introductory with a reasonable appreciation of 2D skills only.

A weakness with the CAD component of the existing subject was that it did not provide students with 3D experience and there was no opportunity to apply their skills to real world problems.

**Issues that Prompted Change**

The use of computers to generate 3D images has changed the way designers (including engineers) design and problem solve. Initially, because of the limited capacity of computers and software, CAD was often limited to 2D work making it difficult for people to design, draw or document in 3D. This situation has changed with further development of the software and with the arrival of more powerful hardware. Most CAD packages now have a comprehensive 3D capability integrated into the program. The CAD component needed to address the changing potential of computers and software.

A second motivation for changes to the component was the desire to apply a ‘project-based’ approach as the mode of delivery. The need to change the mode of delivery grew out of a desire to engage the students in problem solving concurrently with learning to use the software. The subject is a semester subject with three components so the time available to apply the CAD skills was limited if a problem was introduced after the software was taught. It was decided to use a project requiring both problem solving and design as the focus for learning CAD.

This change of delivery mode was needed to bring about a more relevant coverage of CAD component of the subject. Issues arising from the change were more material to cover, additional concepts to address and different organisational requirements if students were to move to individual assessment tasks. The introduction of the project-based mode included a number of initiatives. Project-based meant that learning could focus on students applying their CAD skills to finding a solution to an actual problem, it meant that there would be scope for students to employ creativity and individualism and it also meant that students would encounter some design experiences. Furthermore, the shift would promote autonomous learning and outcomes would be individual rather than group focused.

Included in the change was the introduction of 3D into the delivery of this unit of work. Working in 3D was seen as a means of promoting better visualisation, improving graphical communications and assisting students appreciate conflict and design violations. As well, it was considered that improvements in understanding through better visualisation would offer a benefit of performance transfer which might flow to creative and practical aspects in mechanical design.
To further improve the quality of this component, it appeared that teaching strategies should also undergo a review. Although teaching and the content of the course (including the CAD component) had always been highly rated by students, it did seem that a new approach would be appropriate. If a move to project-based learning was going to occur, and if the workload of students was about to increase, then it appeared that different teaching strategies would be necessary. Previous teaching tended to be formal, structured and teacher-centred with an emphasis on acquiring the necessary skills through generic class exercises.

**The Strategies Employed**

Students understood from the outset that their learning would be project-based. The project was based on the design of a device to support a parallel piping system with CAD as the design medium. The scenario was conveyed to students supported by a drawing with necessary sizes and an explanation of the limitations and expectations of the project. Students were made aware of a 3D focus and some reasons for this were given. From the beginning, they understood that the approach to learning would be applied and student-centred, that more was being asked of them compared to previous students and that the 3D focus was a contrast to the conventional approach.

A feature of the methodology was that the input by the lecturer progressively modified to meet the needs of students. At the initial stage it was intensive, structured and transmissive but this changed as students took ownership of the problem. Students accepted the initial intense and direct approach realising that they needed certain skills to progress and that it was necessary to resource their needs. Once students felt confident in the CAD environment, their attention turned to the project’s design requirements. Motivation increased and appeared to be driven by the challenge confronting them while teaching moved to facilitation rather than instruction. Facilitation tended to be on an individual basis because of the varied needs of students that evolved from individual approaches to the problem.

Other initiatives were introduced and could be grouped into what might be called ‘software strategies’. CAD software is truly comprehensive. It has many features that make it possible to design, draw, plot and present the most simple objects through to the most complex. However, its comprehensiveness can also be a burden. A selective use of the software features was adopted and this came down to two things. First, it meant dealing only with the essentials of the basic commands and not going through every available option. Second, it meant that some of the complicated but extremely important 3D commands were introduced early. This approach provided students with the tools they needed to get started early in the process of autonomous learning and gave them a foundation to build on as dictated by their needs.

**Evaluation Process**

At the conclusion of the subject an evaluation was performed to establish the students’ perceptions of their learning experience. The evaluation process involved the use of a survey questionnaire addressing a range of issues associated with the subject including subject content, effectiveness of delivery. The survey was conducted by the University’s Survey and Evaluation Service with reports being sent to the lecturers involved in the subject, Head of the Department of Chemical Engineering and the Dean of Engineering.

The student’s perceptions of the subject were very positive with the subject being rated as one of the best in the Faculty. Students appreciated the fact that the subject was very practical in nature with projects being the focus of the modules. This was identified in the very high rating in the categories of the survey relating to the subject being interesting and stimulating. Students also saw the relationship of the subject objectives to their future roles as professionals identifying that they had learned a lot from the subject.
Probably of more importance to the lecturers was that the quality of student work was very high when compared to previous years. Students became very involved in the development of their design project and claimed ownership from the outset. They devoted more time than students in the past, their level of understanding was higher and their skills were more advanced. Their projects were distinctively individual, their solutions to the given problem were very viable and the self-imposed standards they aspired to were noteworthy. Assessment of projects was divided into CAD skills and design concepts making comparison with the results of previous students possible. CAD skills were assessed in terms of accuracy, features and appropriateness while design concepts considered such things as feasibility, safety and practicality. Projects were externally assessed and validated.

Conclusion

Evaluation suggests that students benefited from curriculum changes that focused on student-centred learning, individualised outcomes, problem solving in a design context and project-based learning with teaching adapting to the needs of students that moved from direct instruction to facilitation. The project gave relevance to skill development and provided an application for new learning. Students responded enthusiastically to the challenge producing good outcomes to the problem. The 3D focus gave more realism to the designing process requiring less reliance on mental conceptualisation. Students were better able to see the results of their work and check the practicality of the decisions taken.

Noteworthy was the effort of students. They were positive about the requirements and tackled the project with great commitment. It was obvious to them from the start that they were being ‘worked’ but it did not seem to bother them. Less intensive options were suggested by staff in an effort to reduce the workload but this was not an option that any student wanted to accept. Students were determined to get the result they wanted and it became a priority for them. Collaboration in terms of peer tutoring was also a feature and it was encouraging to see the student initiated teamwork which developed. Students were learning out of a need to meet the demands they placed on themselves and discovery learning was evident. Student knew the outcome they wanted and looked for the skills necessary to achieve this. Their perseverance to the task was to be admired.

It appeared that the typical traditional approach of spelling out every detail and option was not applicable to this group of students. Pointing them in the right direction was enough and their determination to meet the challenge of the project provided the momentum necessary. Credit has to be given to their pick-up rate. With the right initiators, they were able to take over and developed the skills they needed.

The project-based approach with the added 3D focus demanded more of students in terms of standard, workload and material covered. At times the authors were worried about asking too much. However, this could not be substantiated in any formal or informal evaluation. To the contrary, formal evaluation indicated that students were willing to work beyond the normal workload expected of a subject of this size.

References


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