

# A Systematic Approach to Course Design at Subject Level on a Mechanical Engineering Course so as to Encourage Active Learning

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*Abstract:* - This paper describes the use of cooperative online assignments in tandem with traditional lecture methods in the subject of Energy and the Environment taken by final year Mechanical Engineering students. A systematic approach to course design is presented whereby successive versions of the course were altered incrementally so as to better promote active student learning.

*Key-words:* cooperative, active learning, online learning, energy, environment

## 1 Introduction

### 1.1 Historical context

Since the appearance in 1988 of Felder's paper on Learning and Teaching Styles in Engineering Education [1] which concluded that there was a mismatch between most engineering education and the learning styles of most engineering students, there has been an increasing interest in developing teaching techniques to address all learning styles with a particular emphasis on the importance of active learning supported by pedagogies of engagement, usually involving a cooperative or problem-based approach.

Examples can be found at subject level such as Krezel and Pocknee's work [2] with project-based learning on a first year Civil Engineering course and Braga's [3] use of computer-enhanced learning to study Heat-Transfer on a Mechanical Engineering course. Vos [4] describes the implementation of active learning organisation at departmental level in the area of Electrical Engineering. Other higher educational institutions have implemented an active learning approach at a broader curriculum level: INSA-Lyon [5] offers a two-year curriculum in Technology Science and Innovation using active

learning while the Amsterdam University of Professional Education provides a competency-based program leading to a primary degree in Engineering Design and Education in the belief this approach leads to active-learning and will produce technical engineers better equipped to meet the needs of industrial enterprises [6].

In parallel with these developments in engineering education the emergence of the Bologna Process in European Higher Education has led to a growing interest in developing new ways of promoting learning from a competence-based perspective in all areas of higher education. The Tuning Methodology [7] has been developed at European level to establish reference points for common curricula on the basis of agreed competences and learning outcomes. This approach considered two broad types of competence: generic and subject-specific and attempted to identify such competences across the higher education curriculum. From 2000 to 2004, nine subject areas were studied, including Chemistry, Physics, Earth Sciences and Maths and subject specific competences were presented for each.

Although no engineering courses have been studied yet from a Tuning perspective, one possible

basis for such an approach can be found in work already mentioned at the Amsterdam University of Professional Education where Schat-Zeckendorf and Nieweg [6] describe competences (or competencies – the terms are often used interchangeably) as clusters of three essential components: skills, attitudes and knowledge elements. In the design of their Engineering Design and Education curriculum, they formulate the desired outcomes in terms of professional competencies which go to make up the competency profile of their graduates set out in the form of a matrix.

As the implementation of the Bologna Process in European Higher Education over the next four years will require higher education courses to accommodate competence-based and learner-centred curricula, for those involved in engineering education within this area this would seem to present an excellent opportunity to ally the competence-based active learning approaches being developed in engineering education with the philosophy of Bologna and the Tuning Methodology.

The present paper describes an attempt to create the conditions for cooperative learning at subject level so as to promote active learning within a higher educational institution operating a relatively traditional lecture-based system. It describes a systematic approach over a three year period from 2003/04 to 2005/06 (essentially the pre-Bologna period) whereby individual project work, internet-supported cooperative tasks and student presentations were used to encourage active learning and where the course design was altered incrementally in response to observation of student activity.

### **1.2 Classroom practice and active learning**

Various authors have described studies which show the effectiveness of cooperative learning in engineering education as an important element of course design in encouraging engagement of undergraduate students and contributing to active learning [8, 9]

Cooperative learning has been defined as the instructional use of small groups so that students work together to maximize their own and each others' learning [10].

As Smith et al commented in 2005 after a comprehensive review of the benefits of cooperative learning found in the Engineering Education literature: "Of the three key aspects of cooperative learning and problem based learning — theory, research, and practice — the practice piece is the least developed and probably the most difficult. The classroom practices involved with cooperative

learning and problem-based learning are complex to both design and implement, as well as to manage during the term." [8]

Smith proposes that effective implementation of formal cooperative learning groups in a well-structured learning environment requires the following elements:

- Positive interdependence
- Face-to-face promotive interaction
- Individual accountability/personal responsibility
- Teamwork skills
- Group processing

To incorporate these five elements at subject level within a traditional lecture centred institution, a course design was chosen which would incorporate individual project work and report writing, pair-work with inter-pair cooperation and individual student presentation functioning in tandem with a reduced number of formal lectures.

## **2 Background**

The students described here take Energy and the Environment as a compulsory subject over one semester in the fifth year of their degree course leading to a Portuguese Licenciatura (B Eng equivalent) in Mechanical Engineering.

## **3 Methodology**

In the previous semester (Winter 2003/04) the students taking the subject had been engaged in an individual task (Energy Audit) and a pair-work task addressing a specific theme. To encourage more autonomous learning, it was decided that for the summer semester of 2003/04, students would be set an additional task with an online component.

The following table shows the learning activities which were included in the program over the 3-year period described.

Besides the traditional lectures and readings the students are also involved in invited lectures and/or seminars and field trips. In the winter semester the subject is taken by evening-class students (attending lectures after 6 p.m.) in which case field trips are usually replaced by extra in-class seminars.

As this would be the first experience of online work for most students, it was decided at the outset to use tightly structured learning tasks and simple technology (email).

Table 1 – Learning Activities

	Individual	Presentation	Report	Online	Seminars	Field Trip
W 03/04	✓	✓	✓	---	✓	---
S 03/04	✓	✓	✓	Mailbox	✓	✓
W 04/05	✓	✓	✓	Mailbox	✓	---
S 04/05	✓	✓	✓	Discussion forum	✓	✓
W 05/06	✓	✓	✓	Portal	✓	---

W – winter semester; S – summer semester

As presented in Table 1, since Summer 2003/04 students have been expected to complete two distinct learning tasks:

- An Energy Audit of their own homes carried out individually;
- A Thematic Assignment with a cooperative online posting of information on different set aspects leading to a presentation during lecture time and a written report. Here students work in pairs, and these are expected to post about their own work and comment the post of another pair each week.

### 3.1 Energy Audit

After an introduction to the subject and studying different practical examples the students were supplied with an Excel file and a detailed explanation on procedures, measurements and goals. The file consists of several spread sheets covering Identification, Characterization of the case undergoing the audit (e.g., equipment and related characteristics, areas, etc.) and tables for measurements (electricity, gas and water). The acquired data can be automatically visualized in the last sheet of the file. Some sample results on this task are provided in Carvalho [11, 12].

At the end of the semester the students are expected to present their own study case in document form and propose actions for improvement in Efficient Energy Utilization.

### 3.2 Cooperative online posting

Both day students and evening-class students take the subject and are typically in groups of 20 to 25. As there are 10/12 distinct themes, students divide themselves into pairs and are expected to do background reading on a different aspect of their theme each week, post an informative and structured message on this and also comment on the work of a specified other pair of colleagues/group. The weekly

posts were expected to be based upon online or library research.

The specific Energy related topics covered usually changed for different semesters and included: Cogeneration, Wind, Biomass, Transport, Photovoltaic, Buildings, Geothermal, Nuclear and Hydrogen among others. Every week the students were provided with a different aspect to address, such as: Theme Introduction, Technology, Application, National issues, International issues, Future and References. The focus of each theme thus moved through different stages over a six week period: from Introduction to Future perspectives. Hence, each week the pairs were expected to work on different aspects of their specific themes and to post at least one messages describing their work in the online environment.

So, on completion of the six weeks, each student pair should have posted information about each of the above six aspects of their theme and to have commented on an aspect of each of the other themes.

At the end of this period, student pairs began their presentations during class time, assessed by the subject lecturer and at the end of the semester they submitted a structured written report on this theme which was also assessed.

#### 3.2.1 Online technology employed

During the Summer semester 2003/04 and Winter semester 2004/05 the tool used for the online collaboration was a single web-based mailbox to which all were given the username and password.

During the next two semesters a discussion forum was used, as shown in Table 1. The procedure was essentially similar to the one used in the previous semesters but had some additional functionality in that it enabled more learner discussion and resource files posted by the lecturer could be downloaded but students could not upload resources directly. In addition, learners could upload their photographs and a greater feeling of belonging to the group could be achieved.

During the Winter semester of 2005/06, an online portal system was put in place for the subject which in addition to a discussion forum allowed easy access to downloadable resources and the evaluation process and weightings, useful URLs for the different thematic areas, student resource uploading, and calendar information on Seminars and Field Trips and suggestions for a specific reading related to these activities. As well making the online space more user friendly, this also meant that online resources were regularly updated by lecturer and students.

At the end of the course each group has to present the topic in a seminar-like format and the final lecture

slots of the semester are mainly dedicated to student presentations. The students present their work in class to their peers. At the end of the presentation the lecturer acts as a moderator for the discussion and provides feedback.

### 3.3 Role of the tutor

This approach involves the subject lecturer taking on a number of tasks in addition to lecturing core material and carrying out assessment:

- task organization and allocation
- covering core material during lectures
- monitoring participation during the online cooperation phase and contacting students who had not participated
- organizing the project presentation sessions and assessing them
- organizing in-class seminars and field trips and provide relevant related information in advance
- providing ongoing relevant bibliography both online and offline

### 3.4 Systematic course development

Over the years that the course has been running there has been a consistent effort to improve the student activities, online technology and learner assessment system, using observation of student activity and feedback from student questionnaires so as to encourage active learning. The approach has aimed to be one of retaining the global subject structure instituted in summer 2003/04 and altering one element of the course per semester. The gradual increase in sophistication and functionality of the online technology used was described in the previous section and in the following section the evolution of the assessment system is described.

### 3.5 Assessment

As the course evolved, different weightings of the final mark awarded to students were used, as presented in Table 2.

This year for the first time a peer evaluation component of student presentations was included. As this was the first experience most had with this type of process it required considerable explanation and close monitoring.

For the oral presentation of the thematic work (individuals evaluated) and their final written report (evaluated in pairs) the three aspects assessed were:

- Content
- Structure and Organization

- Ability to get their message across to the target audience

Table 2 - Learning Activity Weighting in the Final Assessment

	Individual	Presentation	Report	Online	Seminars and Field Trip	Total
W 03/04	30%	40%	30%	---	---	100%
S 03/04	30%	40%	30%	---	---	100%
W 04/05	30%	30%	40%	---	---	100%
S 04/05	20%	20%	40%	20%	---	100%
W 05/06	25%	20%	30%	---	5%	80%

W – winter semester; S – summer semester

## 4 Discussion

All students participated in the online component although not all of them, as in a real classroom, were equally active participants. Regular stimulation and encouragement needed to be present in the online environment. As Braga [3], working in a similar context in Brazil, has commented “obtaining an adequate balance between old style lectures and new technologies is not a trivial task” and students, for whom the majority of their education experience takes place in a more traditional knowledge transmission mode, had some initial difficulties in adjusting to a more active and autonomous role. Although initially hesitant in many cases, students tended to get more involved over the 6 weeks of the online component and become more motivated, more creative and more interactive in the face-to-face sessions (lectures).

End of semester feedback questionnaires from students were predominantly favourable on the methodology adopted although some commented on the work-load and time commitment involved. As the course design became more established within the institution, students came to know better what was expected of them right at the beginning of the semester which helped make the organisational aspect easier.

Interestingly, another observation by Braga [3] that “grading student participation is by far the most troublesome part of it all, not only due to its inherent difficulty but also because students frequently believe they participate much more actively than they actually do which leads them to the conclusion they deserve a better grade” was also encountered in some student feedback on this course. As students became involved in the activities they sometimes equated time invested in the work with an expectation of a high grade and

were disappointed if this was not the case. This may be an aspect of having this type of active learning subject operating within a more traditional system and it indicates the need to supply students with more explicit information on assessment criteria at the beginning of the semester.

## 5 Analysis and Suggestions for future development

### 5.1 Technology

In this first implementation of cooperative online work on the course, the mailbox was selected as the tool for online learner knowledge sharing because of its technological simplicity and portability: a mailbox can be created and maintained without any dependence on institutional servers or IT support and it can also be easily adopted by non IT-minded colleagues. It also gives a clear structure to student tasks: to log on at least twice weekly to post your own findings and comment on the findings of a specified pair of colleagues.

However this tool limits ongoing discussion about the issues raised. Online interaction and debate were enhanced when the portal system was adopted which justified the additional complexity of server hosting and IT support involved.

### 5.2 Grouping Methodology

Although the use of self-selected student pairs on the course has the benefit of organizational simplicity, its value in encouraging the development of the kind of teamwork competences which are important for the professional engineer is limited. On future iterations of the course, learners will work in 3-4 person instructor-formed groups and the guidelines proposed by Felder et al (for example team policy, group roles and peer ratings) will be followed to turn these groups into effective teams [13].

### 5.3 Assessment

Provision of a detailed assessment criteria matrix at the beginning of the module would help make the assessment process more transparent.

### 5.4 Integration at institutional level

Vos has described the introduction of active learning at subject level in engineering education as but one of three levels of change necessary to achieve an active learning organisation: “(...) active learning has to take place on three levels: the students, the staff, and the organisation. These three actors have each to learn from experience, and their learning processes

have to be related. Learning on the lowest level is based on the cycle of Kolb for experiential learning.”

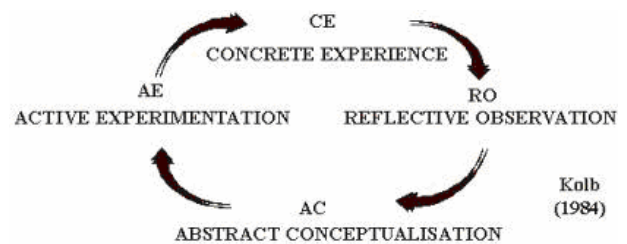


Figure 1 - Kolb cycle

Over the three year period the design of the course described here has developed in a cyclical fashion which can be said to have followed the contours of a Kolb experiential learning cycle [14].

Vos further proposes that active learning and innovation diffusion at staff level also involve a cyclical process which in this case can be represented by a Van Delden model. This model distinguishes four crucial staff “quality factors” which can be summarised as:

- a coherent central view on problems;
- giving structure to professional knowledge;
- the individual positions and competencies of employees in Knowledge Management;
- the ability to deliver products and services.

Finally at departmental or institutional level he suggests that Senge’s work on learning organisations and his five component technologies would apply: Systems thinking, Personal mastery, Mental models, Building shared vision, Team learning.

With regard to the time scale involved Vos suggests that “the formation of an active learning organisation takes a very long time, in the order of 10 years or more.”

## 4 Conclusion

Although it is possible to achieve valuable learning experiences and competence acquisition using structured cooperative online tasks and simple email technology, more enabling technology such as a dedicated portal encourages online cooperation and activity.

The blending of subject-specific and generic competences (including synthesis, analysis and problem-solving strategies) was considered by the

majority of students and by the subject lecturer, to be a major motivation and give added value of the teaching and learning process.

Given that the coming years are expected to bring about profound changes in many aspects of European higher education, we could conclude that initiatives like the present work and others mentioned in the introduction, could have a useful role to play in efforts to enhance engineering education and help institutions develop into active learning organisations so as to meet the challenge of preparing future engineers in a rapidly changing knowledge economy.

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