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Assessment in Engineering Education—A European Perspective*

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The contents of this paper concentrate mainly on a review of papers presented at an International Seminar on Assessment held at Delft University of Technology, The Netherlands in 1999, and which was organised under the umbrella activities of the European Society for Engineering Education (SEFI). The fact that the Seminar was held shows that there is a real and widespread concern about assessment amongst engineering educators across Europe. Several themes emerge from this review and these are complemented using more recent published material. The overall message is that the education of engineers is changing rapidly from the traditional chalk-and-talk approach to one that emphasises understanding as well as acquisition of knowledge. There is an appreciable increase in project/problem-based activities. The major forcing terms for the change in paradigm are: pedagogical demands from teacher trainers, Governmental demands for more relevance, a drop in student demand for engineering programmes, the requirements of professional accreditation bodies, and the impact of individuals and small groups scattered across Europe who are experimenting in widely differing teaching environments.

INTRODUCTION

THE CORE ACTIVITIES of the European Society for Engineering Education (SEFI) are undertaken—just like the American Society for Engineering Education (ASEE)—by numerous working groups, which concentrate on specific areas of interest and organise periodic meetings, seminars and conferences. Within SEFI, the Working Group on Curriculum Development (CDWG) has been particularly active over many years. The author is currently Secretary of this group. During a business meeting held in Switzerland, the CDWG decided to organise an International Seminar on assessment. This Seminar was held at Delft University of Technology (DUT), The Netherlands, in April 1999 and was organised by the joint CDWG Chairs, Joanna Daudt and Otto Rompelman, both from DUT. Full proceedings from the event are available [1]. More recently, Rompelman has tracked the evolution of engineering educational objectives and provided a brief summary of the consequences for assessment based on a few selected papers from the Seminar [2].

Participants in the Delft Seminar came from eleven different countries; speakers presented papers from seven of them. In brief, there was wide representation and participation from Western Europe and Scandinavia. As might be anticipated, there was a strong representation from The Netherlands. The activities of the Seminar were organised into three main themes identified by a leading question: Did they learn what we promised? Do teachers use the most appropriate forms of assessment? How to assess group work? In addition, the formal Seminar events featured a few keynote speakers, a role-play session and a final interactive review session.

The first, and major, section of this paper concentrates on a review of the Delft Seminar. The review looks, in turn, at the issues raised by the keynote speakers and by successive authors within each theme. From this review it becomes clear that there are several key areas of change that, in combination, reflect a significant shift away from traditional teaching methods. These points are expanded in the final summary.

DELFT KEYNOTE PAPERS

There were two keynote presentations, one from the UK and one from Denmark.

Liz McDowell, University of Northumbria at Newcastle, UK, discussed the transformation that is taking place from the current trend away from simple written and oral assessment to more diverse methods involving problem-based tasks, design projects, group work, portfolios, on-line learning, etc. In this shift, there is an increased emphasis on competencies such as communications and interdisciplinary skills and, as a consequence, the 'old' learning model of pouring knowledge into empty containers is being abandoned. McDowell asks if this trend is no more than fashion but then provides a response from three perspectives:

- Constructivist views of learning challenge the idea that students simply absorb knowledge and methodologies out of context. Instead, it is

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asserted that they actively build knowledge structures and that subsequently they not only know more but also know differently.
- It has been noted that people often perform at a higher level than predicted by early evaluations of capability and intelligence The idea that people possess multiple intelligences is displacing the traditional notion that intelligence (or potential) is a single, inherent and largely immutable quality that needs sole attention.
- There has been increasing disquiet from teachers, parents and employers that education must be concerned with more than simply a reproduction of knowledge. Whilst knowledge is important, students need the cognitive abilities to solve problems, evaluate, criticise and create; they also need to act independently, be self-motivating and cope flexibly with new situations.

It is clear that all three points are important from an assessment perspective and illustrate a paradigm shift in the assessment of learning. McDowell develops this theme by comparing of the 'old' system (a so-called *Testing Culture*) with the 'new' one (a so-called *Assessment Culture*) through three questions: What is assessed? How is learning assessed? To what purpose is learning assessed? The paper provides a short but informative reading list, which covers some of the latest research and educational development publications.

Camilla Rump, Arne Jakobsen and Torkil Clemmensen of the Technical University of Denmark presented the second keynote paper, which described a three-year project established to determine the source of students' apparent lack of conceptual understanding and, if possible, develop means of improving the overall quality of the teaching/learning process. The project concentrated on the use of qualitative tests of student understanding designed in co-operation with the teachers, and combined with interviews with students. Ten undergraduate engineering courses were evaluated over the three-year period of the study. A basic premise of the project was that the content of engineering courses made it possible to identify a number of elements—concepts, principles, models, and ways of reasoning—which are central to an understanding of the field. The study examined several interlinked areas: students' understanding, students' prior knowledge, calculation skills versus understanding, and understanding versus examination performance.

The results of the study were both detailed and informative. Some of the key observations were as follows:

- Formal examination papers did not assess students' conceptual understanding of the course material even though the teachers, who also wrote the examination papers, thought they did. Instead, what was examined was the mathematical/computational ability. Further, examination papers specifically designed to evaluate conceptual knowledge produced very high failure rates.
- Students generally fail to find any correspondence between concepts and principles covered in basic science courses and those they meet in applied engineering courses.
- There was a significant lack of integration between computational skills and theoretical knowledge, and a corresponding lack of ability to assess assumptions.

The authors highlighted three principle areas for change:

- Examinations (or assessment) must be changed to promote increased understanding. Without a change in this area, there is little scope for improvement elsewhere.
- Students must be challenged to work more intensively with the most important elements of the curricula through reading, exercises, and projects.
- The structure of course content is often deductive and must change to a more constructivist view of teaching by allowing students to advance from intuitive understanding before advancing to more abstract topics.

These two keynote papers dramatically illustrate (and support) the change in paradigm that is moving through higher education in Europe. From one perspective, it is stated that an acceptance of a constructivist view of learning and a consequent move away from tradition chalk-and-talk teaching methods will benefit the student (and society) through a recognition and development of his/her multiple intelligences. This view is supported from the second perspective, which simply states that traditional teaching methods are ineffective and, in any case, neither encourage nor measure student understanding even when teachers think otherwise.

It might reasonably be asked just how the teachers in higher education managed to get themselves in this predicament? In the paragraphs that follow, however, we will see some evidence of just how some educationalists are getting out of the mess they find themselves in.

THEME I: DID THEY LEARN WHAT WE PROMISED?

This theme comprised seven papers, six of which were from The Netherlands the seventh from France.

André Beraud, INSA, France, was interested in how engineers perceived the relevance of their own learning experience at University to the requirements of their profession some five years after graduation. The paper presented a brief summary of results of four annual surveys conducted between 1995 and 1998 of all INSA graduates, i.e. about 800 graduates each year. Whilst the exact

content of each survey differed slightly from year to year, the survey provided some unexpected (to the survey team) feedback. The main surprise was that graduates ranked non-technical competencies very highly: communications, teamwork, project management, languages, etc. were ranked far more highly than, for example, mathematics. For INSA, the main and difficult task is to convert this feedback into meaningful changes in curricula.

Three papers were concerned with assessment within problem/project-based learning (PBL) environments.

David Goldsmith, Van Hall Institute and Rien Kolkman, University of Twente, The Netherlands, summarised their experience with teaching through a course that involved both simulated computer modelling of real life engineering problems and role-play. The authors found that their approach could adequately cope with student group sizes of between 12 and 32. It was found that students were generally keen to become involved in role-play settings provided adequate time and structure were allowed for students to assimilate the necessary knowledge and information base.

Erik de Graaff and Pieter Kruit, DUT, The Netherlands, concentrated on the assessment of learning outcomes within an introductory PBL-based course in Applied Physics for engineering students. Group size was smaller than in the previous example (about 8 in this case) and students were expected to follow a broad five-step methodology, which should lead to successful achievement of the desired learning outcomes. Assessment is split equally between 'participation in group work' and a written examination. Details of the marking schemes were not presented. The authors found that this split between two different methods of assessment resulted in fewer overall failures: 'Eventually, only students who failed to show up at the examination failed the course'.

Hetty Grunefeld, University of Twente, The Netherlands, examined the assessment methods employed in the evaluation of 'complex skills' in two undergraduate degree programmes. In this context, 'complex skills' are defined as competencies demonstrated through problem solving, modelling, designing, discussing, etc. The two programmes are of three-year duration and PBL features in each year of study, thus permitting the gradual development of complex skills (and their assessment) over the three years. Assessment in this PBL environment is entirely through written and oral presentations. Grunefeld makes the observation that the development of 'complex skills' requires a gradual increase in the difficulty of tasks over a number of years and that these extra competencies need to be added to the learning goals as students progress from year to year through their programme of study.

Agnes de Haan, DUT, The Netherlands, begins with the observation that courses provided at University level still tend to be assessed by traditional means, i.e. written examinations, despite the fact that many teachers are moving increasingly away from traditional teaching methods. The main thesis that de Haan wishes to expound is that each teaching method—and corresponding learning outcomes—demands specific forms of assessment.

In regard to overall learning outcomes, the typology of Romiszowski [3] divides these into four broad areas:

- *Cognitive skills:* knowledge and information
- *Psychomotor skills:* physical and motor actions
- *Reactive skills:* effective responses to individuals, events, and situations
- *Interactive skills:* social and communication effectiveness

The well-known taxonomy of Bloom provides a more detailed and hierarchical structure in the cognitive domain, Table 1.

The paper provides a fairly comprehensive table illustrating the most suitable forms of assessment for specific teaching methods, but which is too lengthy to reproduce here. The paper concludes with an observation that educationalists need to pay more attention to actually measuring what they want to know, i.e. whether the students have, in practice, attained the teaching objectives.

The final two papers in this theme make some attempt to address de Haan's final observation. **André van Peppen, DUT, The Netherlands**, maintains that testing should be a reflection of what the institution claims its education will provide. Using Bloom and Romiszowski as a base, van Peppen presents a 14-step flow chart to aid curriculum development and proposes a quality management system that is relevant to an educational environment and which pays particular attention to internal consistency. An important feature of this quality management system is that it involves external as well as internal consistency, i.e. it seeks input from all stakeholders—students, teachers, administrators, (potential) employers, and funding agencies.

Finally, **Liesbeth Smulders, DUT, The Netherlands**, addresses the issue raised by students that examination methods often differ from what they expected. Smulders agrees with van Peppen that students should be told exactly what to expect as an integral part of a quality management system.

Table 1. Hierarchy of the cognitive domain [4]

6 Evaluation	Ability to make a judgement of the worth of something
5 Synthesis	Ability to combine separate elements into a whole
4 Analysis	Ability to break a problem into its constituent parts and establish a relationship between each one
3 Application	Ability to apply rephrased knowledge to novel situations
2 Manipulation	Ability to rephrase knowledge
1 Knowledge	That which can be recalled

THEME II: DO TEACHERS USE THE MOST APPROPRIATE FORMS OF ASSESSMENT?

This second theme comprised six papers in total, three from The Netherlands and one each from Sweden, Ireland and the UK.

Anders Bergland, Uppsala University, Sweden, reported on the interim findings of a study aimed at finding out how study habits are influenced by changing the method of assessment. The study concentrated on three separate courses within a Systems Engineering degree programme. In general form, the changes involved a move away from traditional class teaching and formal written examination towards more student/teacher interaction, better utilisation of laboratory sessions, and alternative assessment methods such as weekly assignments. Once again, the taxonomy of Bloom surfaces as a reference in the development of methods that assess the higher cognitive levels of achievement. In order to track any changes in study habits, students were interviewed at regular intervals during the course duration. Provisional, quantitative feedback indicates that students are indeed motivated to learn through means other than a final examination but that the workload for each course as a whole may increase substantially by a move from traditional teaching and assessment methods.

Ivan Gibson, National University of Ireland, Galway, writes about assessment of group project work in the area of engineering design. The paper describes comprehensive marking criteria, which have been developed for the assessment of a three-element course based almost entirely on group project work; a strong emphasis is placed initially on oral and written communications skills. The course comprises three elements: oral and written communications, instruction in AutoCAD, and an engineering design project. Details of the teaching structure, learning goals and assessment methods are provided for each element. Gibson refers, as have previous authors above, to the cognitive hierarchy of Bloom. It is claimed that the assessment methods are very easy to apply and have the advantage of transparency, i.e. students know what is expected of them, and the marking schemes are there to be discussed by all stakeholders in the educational process. The assessment schemes measure a mix of individual and group performance. A slightly modified version of this paper has been published recently in this Journal [5].

The paper by **Kay Sambell and Liz McDowell, University of Northumbria at Newcastle, UK**, explores student experiences of learning and assessment during a substantial change from traditional teaching methods to PBL. In substance, the teaching approach adopted is similar to that reported by Gibson except in that the students are given more specific guidelines and intermediate deadlines. The course providers identified three key reasons why they wished to change to PBL: (i) learning placed within a context relevant to the student, (ii) to encourage the development of reasoning skills, and (iii) to promote self-directed learning. Feedback on these key issues was provided through student interviews. Overall, the experiment proved successful—the introduction of PBL enhanced the quality of learning and found ready acceptance amongst students.

Computer-based assessment is a topic that has received much attention over the past five to ten years and the paper of **N. Simon, M. Sim, and P. Kist, Bitybit Information Systems, Delft and Marcel Claessens, DUT, The Netherlands**, provides a description of a computer system established to improve the overall quality of written examinations. The software architecture described is built on the object database management system Perspective-DB and was developed to support five quality criteria: coverage of study material, accuracy of contents, friendliness of presentation, 'evaluability' of answers, and quantification of difficulty. The paper by **Maarten van den Ven, R.H.A. Staal and A.M.A. Stehouwer, DUT, The Netherlands**, provides further evidence of the expertise and experience of computer-based assessment in Delft. In this paper, a new system called ETUDE is described that is designed to replace the numerous smaller systems in use in various parts of the university. The project began in 1996 with an inventory of all computer-based courseware and assessment systems developed and used within the university. A total of 17 different computerised assessment systems were found. Since that time, a professional team of software developers in conjunction with a technical discussion group have designed and implemented the system on a pilot basis (1999). The ETUDE system runs under a Windows environment; at its kernel is a database based on MS SQL-sever version 7.0. More recent information on the project can be found in reference [6].

Finally, in this theme, **Henk Vos, University of Twente, The Netherlands**, returns to undergraduate projects and their assessment. The projects under scrutiny were generated by first-year students during a three-week period at the end of their formal coursework, and were organised so as to encourage students to apply and integrate knowledge they acquired earlier. This paper gives a description of an experiment involving a change from entirely tutor-based assessment to a dual system that combines tutor-based assessment and student self-assessment. The experiment was partially successful in that it helped generate assessment criteria from both tutors and students.

THEME III: HOW TO ASSESS GROUP WORK?

From the above summaries, it will already have been observed that several papers classified in Themes I and II are also concerned with the assessment of group work. Theme III comprises

eight papers with representation from five countries: Sweden, Denmark, Finland, the UK, and the Netherlands.

Katariina Alha, University of Oulu, Finland, uses the activity of engineering design as a motivating agent for student learning in small groups (from 2 to 10 students). An interesting feature of Alha's approach is that students are asked to choose between three different assessment options:

1. All students in a group get the same grade.
2. Group members get a grade according to their individual contribution.
3. Each group is given an overall grade; the group decides how to divide the spoils amongst each person within the group.

Option 3 was rejected immediately and aroused strong divergent opinions amongst students. Option 1 was chosen only after some discussion. Once chosen, the tutor provides written details of the assessment scheme.

Arvid Andersen, Engineering College of Copenhagen, Denmark, discusses the assessment of small cross-cultural and multidisciplinary groups of students engaged in integrated engineering and business design projects. Each group is made up of students from different European countries with a mix of educational backgrounds. Assessment comprises (i) individual submission and oral presentation, (ii) group submission, and (iii) peer assessment. Andersen presents marking schemes for each element that are easy to administer and have the advantage of transparency. Once again, engineering design forms the kernel of these group activities.

Mats Daniels, Upsala University, Sweden and Sally Fincher, University of Kent at Canterbury, UK, also describe cross-cultural project activities; in this case, two groups of equal size—one in the USA and one in Sweden—working on the same project. A pilot programme was launched in 1998 and involved a single engineering design project. Few details are provided of the assessment schemes used, although the educational settings in the two host institutions remained unchanged.

Karen Kear, Open University, UK, writes about the assessment of group work that is undertaken by a group whose members are all in separate locations. Kear maintains that a carefully designed assessment structure will not only establish what students have learned, but will encourage participation in project content and engagement with other group members. She goes on to describe details of the assessment schemes adopted in two different settings and presents data obtained from surveys and interviews, which were conducted to illicit student views on the assessment methods employed. Whilst there are obviously specific difficulties with assessing group work remotely, feedback from students was generally positive. The main points are as follows:

- A task that can be separated into an individual and group component works well. However, the balance between them needs careful consideration.
- It is important that the process of collaboration is assessed, i.e. the tutor needs some proportion of the available marks according to the student's contribution.
- Groups need to be established early if they are to perform well, and collaborative work should form part of assignments prior to major group project work.

Peter Powell, University of Twente, The Netherlands, describes a major shift from traditional teaching and assessment methods towards PBL in Mechanical Engineering. The changes came about through a concern about the rate of progression of students through their degree programme and were inspired by the experience of project-based education at Aalborg University, Denmark [7]. The new project-based curriculum was introduced in 1994 and has produced major improvements in student success-rate and performance, particularly the areas of communications, teamwork and the ability to handle real-world engineering problems. Assessment is by means of oral and written presentations. **Han Smits, Diana Vinke J.D. Janssen, Eindhoven University of Technology, The Netherlands**, also describe a major shift towards PBL—problem-based learning in the first two years, followed by project-based learning in third year. The change came about through a demand from the Dutch Government that engineering graduates must demonstrate:

- the ability to integrate and synthesise knowledge;
- the ability to function in an engineering environment;
- problem-solving skills;
- the ability to work in multidisciplinary teams;
- social and communicative skills;
- the ability to keep up with new developments.

As with previous authors, engineering design is the activity employed to encourage PBL. Since the change, about 40% of student assessment involves PBL whilst the other 60% remains devoted to more traditional methods. It is clear from the questions raised in the paper that the change to PBL can be difficult. 'The (new) abilities engineers need to have as mentioned above, are difficult to make explicit. As a consequence, the 'fuzzy' goals in the education of engineers are hard to assess.'

Ian Utting, University of Kent at Canterbury, UK, describes improvements to existing design-and-build group projects in Software Engineering. Specifically, the enhancements discussed are (i) group allocation and formation, (ii) goal setting within the context of the taught material, and (iii) moderated peer assessment. In regard to goal setting, project assessment criteria and relative weightings are decided through group discussion after students have already been introduced to

the basic principles of managing software development. Students are encouraged to critically evaluate their own work and that of another group in order to help them focus on the assessment criteria agreed and also to provide more immediate feedback on their performance. A member of staff then moderates the mark awarded. It is claimed that this system works quite well and provides a good correlation between peer and staff assessment. At the time of writing, a single overall grade was given to all individual members of a design group but this was due to change in order to allow for differences in individual input.

Last, but not least, in this review **Hans Vos, Frits van Beckum and Gerdy ten Bruggencate, University of Twente, The Netherlands**, describe the introduction of multidisciplinary design projects. Students from all faculties who have completed their core programmes are given the opportunity to tackle real-life problems in a group setting of 6–8 students. Some, though not all, faculties have made this project a compulsory part of their degree programme. The authors provide details of the assessment scheme, which broadly cover the areas of problem solving (designing, integrating, and quality), project management, and communicating.

FINAL SUMMARY AND CONCLUSIONS

Although of necessity brief, the above review of the Delft Seminar papers identifies a steady movement away from traditional, formal teaching and examination methods across Western Europe towards a more informal, PBL environment, which demands a variety of appropriate assessment mechanisms. Some additional background material on assessment is also available in reference [8]. This change in paradigm can also be detected in Eastern Europe (*albeit* to a lesser extent) from a selection of papers presented at a symposium organised by the International Society for Engineering Education (IGIP) held in March 2000 [9].

It is clear that the impetus for this change stems from several different sources, which vary in significance depending on the particular circumstances applying to each European country and each Institution of Higher Education. Language and other cultural differences between European neighbours can also complicate matters further. However, there seem to be five main sources of change:

- Many institutions (though by no means all) have established, or are developing, Centres for Teaching and Learning to advise and assist teachers to teach better. As examples, the two keynote papers of the Delft Seminar illustrate the vocabulary used by the teacher trainer: multiple intelligences, pedagogy, paradigm, constructivism, etc. and most of their reference material is educational in origin. Many engineering educators are unfamiliar with these terms and what they mean in practice. The case being made is that engineers need to be as familiar with pedagogical issues as they are with the technical content of their subject in order to teach and assess effectively.
- There are Governmental demands for change. It is reasoned that since the vast bulk of funding is provided by Government then it follows that institutions ought to respond in some way to requests or demands made by it, particularly in the areas of science, technology and engineering, which can have a significant impact on industrial and economic activities. In response, many institutions have developed a 'quality management systems' approach, which has involved significant changes in teaching and assessment methods.
- In many European countries there is a significant drop in the numbers of young people wishing to study science and engineering. Institutions are responding on two broad fronts: making their study programmes more interesting (through extensive use of PBL, for example) and by targeting a wider audience.
- The profession of engineering is demanding changes. Accreditation bodies are switching from their earlier prescription of the educational process and curriculum and are now demanding that educational institutions define their objectives and demonstrate just how their educational outcomes are subsequently measured against these stated goals. Similar changes are being demanded on both sides of the Atlantic. One significant consequence of these demands is that there is an increasing recognition that the activity of engineering design lies at the core of engineering education.
- There is the not insignificant impact of individuals and/or small groups of teachers who are experimenting with different teaching and assessment methods in widely differing environments. It is hoped that SEFI, ASEE and IGIP and similar organisations worldwide will continue to offer these individuals and groups a forum and a benchmark for their activities.

The overall message from Europe is that the education of engineers is changing rapidly from the traditional chalk-and-talk approach to one that emphasises understanding as well as acquisition of knowledge through an increasing involvement in project/problem-based activities. The key steps in this change in paradigm are: define learning outcomes, select an appropriate teaching method, select corresponding assessment methods and, finally, conduct regular quality reviews on the approach adopted. Also, don't forget to inform students just what is expected of them.

This emphasis on project/problem-based activities has significant resource implications; it is simply not possible to expect teachers of large

classes of students to switch wholesale to project-based activities without the provision of extra human or physical resources. In this respect, the impact of ICT on the curriculum, on teaching and on assessment is also receiving serious attention across Europe, and several institutions already have comprehensive computer-based assessment systems in place.

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