Control Engineering Laboratory
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Continuous Assessment in Process Engineering Education
–
Two Case Studies

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BACKGROUND. Development of higher engineering education requires understanding on teaching, learning and assessment. The content being taught and boundary conditions, such as available resources, must be taken into consideration. In practice it is not possible to implement everything that is presented as desirable in educational research and a compromise is needed, where such a teaching, learning and assessment environment is created that is both theoretically sound and useful in practice.

PURPOSE. The purpose of this report is twofold: Firstly, to present a teaching, learning and assessment environment which can be used as a base for educational practice and development. Secondly, we present two cases, in both of which the implementation is based mainly on the ideas of constructive alignment and the key element has been to find those assessment procedures that are most useful for the attainment of learning outcomes.

SCOPE/METHOD. The report begins with a discussion on research about suitable teaching, learning and assessment environment with special emphasis on constructive alignment. Continuous assessment with its pros and cons and uses in our environment is also covered. Our report ends with our two educational cases and discussion.

CONCLUSION. Based on quantitative (pass rate, grades) and qualitative data (student feedback) obtained from our cases, we claim that the use of continuous assessment, which can also be justified by learning and assessment research, is an efficient approach in creating a well functioning course. Continuous assessment also provides us with real-time information about student learning and this enables us to make well founded changes even during a course.

KEYWORDS. engineering education, constructive alignment, continuous assessment

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1 Introduction

In the beginning of our teaching careers teaching and assessment was easy: we gave lectures, produced an exam paper, students took the exam and we graded them. It seemed so simple but, as it turned out, teaching methods and student learning were far from optimal. Reading a book (e.g. Wankat and Oreovicz 1993) about teaching in engineering or a book about assessment practices in higher education (e.g. Miller *et al.* 1998) is one thing, but to actually implement successfully results of educational research into your own courses or into the curricula of your department is something very different and requires that one has at least basic understanding of educational sciences, teaching, learning and assessment.

Our report concentrates on the central role of assessment in higher engineering education. Student assessment is usually done by taking a sample of what students do, making inferences and estimating the worth of their actions (Brown *et al.* 1997). There are also several purposes why assessment of students is done (Trotter 2006):

- to provide feedback to students to improve their learning,
- to give the teacher feedback on how effective and successful students are at promoting learning,
- to motivate students,
- to enable students to correct errors and remedy deficiencies,
- to consolidate student learning and
- to convey to students what we want them to learn.

As Trotter (2006) points out, these purposes can be condensed into three main topics: feedback, motivation and student learning. Feedback is most useful when it is at its greatest *before* the end of a course. The timing of traditional end-of-course exams is usually too late for effective use of feedback, so other assessment approaches, such as continuous assessment (Miller *et al.* 1998, 87-93), are more effective. Using assessment positively, i.e. to encourage and motivate students to learn (Rowntree 1987) and to use deep approach (Marton and Säljö 1976a, b) in learning, leads to assessing students' learning process instead of the end product. Using results from learning research has paved way to approaches which use the fact that, since students learn in part to be assessed, their learning should be assessment led, i.e. assessment can be used as an instrument of coercion (Trotter 2006). Aspects of practicality and realism support such assessment approaches where demands on student and teacher time and resources are not excessive (Lines and Gammie 2004, 72).

Our work on assessment began as a teaching development project, but it soon transformed into action research where one looks to foster change in social practices in the social situations in which they take place (Cousin 2009, 150). The aims and benefits of action research are strategic improvement of practice and improvement occurs through the active engagement of the practitioners (Case and Light 2011). Another approach used by us is case study, which can be described as an in-depth study or examination of a distinct, single instance of a class of phenomena. Case study as a methodology can be used as motivation for the validity of findings emerging either from an analysis of a single case or across multiple cases (Case and Light 2011). In this report we present two cases: case A, process optimization course and case B, engineering thermodynamics course).

With this on our mind we come into our specific research questions (see Maxwell 1996):

- Question 1: Is it possible, by using educational research results, to create an assessment-centred teaching/learning environment in higher engineering education?
- Question 2: Is it possible to show, qualitatively and quantitatively, that the assessment-centred learning environment thus created is advantageous in educational terms?

When creating our teaching/learning/assessment environment we have taken especially constructive alignment (Biggs 1996; Biggs and Tang 2007, 50-63), continuous assessment (e.g. Miller *et al.* 1998, 87-90) and problem-based learning (PBL) (e.g. Hmelo-Silver 2004) as suitable guidelines and frameworks, not as rigorous methods to be adhered to precisely; this approach is called by Felder and Brent (2005, 59) *engineering approach*. Our aim is to solve educational and assessment problems in practice and theoretical considerations run parallel, not before, after or instead of, the actual development and research work. Moreover, as Hmelo-Silver (2004) points out, it would be naïve to believe that, e.g. the medical school model of PBL could be imported into other settings without adapting it to the local contexts, goals, and development level of learners.

2 Environment for teaching, learning and assessment

If we take assessment into centre in our teaching, then what kind of teaching/ learning/assessment environment we must create and which aspects we must stress in order to create such an environment. Biggs and Tang (2007, 91-99) have listed some general characteristics of good teaching/learning contexts found in literature (see also Wankat and Oreovicz 1993, 4-5 and Trigwell 2003):

- *Appropriate motivational context*. There are two incentives that make students want to learn something: that something must be of value to the student and there must be a distinct possibility of success when learning that something. This means that if we are using a PBL-approach, the problems must be of value, i.e. their solution must enhance students' professional expertise, and the difficulty of the problems must be such that students can solve them.
- *Constructing a base of interconnected knowledge*. Students build on what they already know and sound knowledge base is based on interconnections, not on separate bullet points. Such a knowledge base must be, moreover, connected both horizontally and vertically.
- *Relevant learner activity*. Being active in, e.g. problem solving, while learning is better than being passive, e.g. listening to a lecture. In addition, our experience underlines that learner activity connected with peer teaching (see also Goldschmid and Goldschmid 1976) and group work is beneficial.
- *Formative feedback*. The most powerful enhancement to learning is feedback during learning, i.e. formative assessment. Formative feedback is the information communicated to the learner that is intended to modify his/her thinking or behaviour for the purpose of improving learning (Shute 2008).
- *Reflective practice and self-monitoring*. When self-monitoring, learners keep a watch over their learning by posing questions as: How am I doing? Why am I making mistakes here? What should I do in future? Where are the gaps/strengths in my knowledge?

The literature on teaching, learning and assessment is extensive. Here we cover some aspects of learning and assessment that are relevant in our context such as: what are students' approaches to learning, how they react when they are assessed, what are the current assessment practices and uses, what is the contextuality of assessment, how is the spectrum of skills to be assessed and what and how many assessment tools to use:

- *Student approaches to learning.* Research on student learning has demonstrated links between students' approaches to learning and their performance in assessment tasks; the converse also applies, i.e. the format of assessment can determine the way students set about their learning (Miller *et al.* 1998, 41). In the 1970's Marton and Säljö (1976a, b) identified two levels of approach to learning tasks namely deep approach and surface approach. A deep approach is characterised by a personal interest in learning and students using this approach set out with an intention of understanding the material; surface approach is characterised by a lack of personal engagement in the learning process and students focus on rote-learning and are constrained by the specific task (Byrne *et al.* 2010). Subsequent research drew attention to the influence of assessment on student learning and identified an additional approach: strategic (Ramsden 1979). Strategically oriented students are focused in achieving and they adopt those learning strategies, i.e. either deep or surface approach, they consider will earn them the best marks (Byrne *et al.* 2010).

- *Student reactions to assessment.* As teachers we tend to see the intended learning outcomes as central in our educational system. But as Ramsden (1992, 187) points out, our students see it differently, from their point of view assessment always defines the actual curriculum. Elton (1987, 92) coined this phenomenon backwash and it refers to the effects assessment has on student learning. Backwash can be negative, i.e. detrimental to intended learning outcomes, or positive but it is always present. Negative backwash guides students to surface learning so our aim is to create positive backwash, i.e. assessment should be aligned to what students should be learning (see also Scouller and Prosser 1994, 268).
- *Models of assessment.* In university environment two distinct ways of assessment form the basis of assessment practice and thinking: the measurement model and the standards model (Taylor 1994). In the measurement model results are reported in terms of comparisons between students. When using this model the negative effects of backwash are quite prominent (Biggs and Tang 2007, 170-6). The standards model, on the other hand, is designed to assess changes in performance as a result of learning, i.e. how well an individual meets the criteria of learning that have been set (Biggs and Tang 2007, 177).
- *Formative and summative assessment.* Two main types of student assessment are (Biggs and Tang 2007, 97) formative and summative assessment. To this list one can also add diagnostic assessment (Miller *et al.* 1998, 3), which provides teachers with information about students' knowledge before beginning a learning activity. Formative assessment is provided during learning, telling students and teachers how well students are doing and what might need improving. Summative assessment takes place after learning, informing how well students have learned what they were supposed to have learned. Usually these assessments are conducted separately, i.e. there are separate diagnostic, formative and summative tests, and usually diagnostic tests, if conducted at all, take place before a course and summative test takes place in the form of a terminal exam. However, based on our experience, there is no need to separate these tests, because diagnostic, formative and summative tasks can be done simultaneously, and if done simultaneously, the teacher is well-informed about students' progress in studies, before, during and after learning activity. Using continuous assessment this is easily accomplished as we will show later in this report.
- *Assessment context.* One question is whether the assessment tasks should be decontextualized, requiring students to perform out of context (in the abstract), or contextualized. According to Biggs and Tang (2007, 182) decontextualized assessments are suitable for assessing declarative or propositional knowledge (knowing *about* things) and contextualized or performance assessments suitable for assessing functioning knowledge (putting declarative knowledge *to work* by solving problems) in its appropriate context. In higher engineering education exams in mathematics, physics and chemistry are usually – regrettably – out of context and everything else, i.e. in the engineering education proper, is or

should be in context (see Heikkinen and Jaako 2010). Our two educational cases are concerned with teaching/learning activities that put knowledge into work in a professional, i.e. engineering, context.

- *Complexity and difficulty.* Besides aspects presented earlier we must also test in our exams skills that cover a broad spectrum of complexity and difficulty. This problem is usually approached with the help of the *Taxonomy of Educational Objectives* or *Bloom's taxonomy* for short (Bloom and Krathwohl 1984; Miller *et al.* 1998, 47-53). Bloom's taxonomy defines a hierarchy of six levels (Felder *et al.* 2000): (1) repeating memorized information; (2) paraphrasing text, explaining concepts in jargon-free terms; (3) applying course material to solve straight-forward problems; (4) solving complex problems, developing process models and simulations, troubleshooting equipment and system problems; (5) designing experiments, devices, processes, and products and (6) choosing from among alternatives and justifying the choice, optimizing processes, making judgments about the environmental impact of engineering decisions, resolving ethical dilemmas. Levels 1-3 are commonly known as lower-level skills and levels 4-6 are higher-level skills. Because according to Felder *et al.* (2000) most under-graduate engineering courses focus on level 3 skills, we must extend our tests, and assessment, to include also levels 4, 5 and 6.
- *Assessment tools.* Last but not least, we must consider which and how many assessment tools to use. There is a plethora of tools available (Felder and Brent 2003a, 13; Miller *et al.* 1998, 85-202) but during a single course we must restrict ourselves to the most useful ones from the point of view of learning outcomes. As Besterfield-Sacre *et al.* (2000) point out, using triangulation, i.e. using multiple methods (or tools) to obtain and verify a result, is an important feature of effective assessment. The more tools used to assess a specific course learning objective, the greater the likelihood that the assessment will be both valid and reliable (Felder and Brent 2003a, 13).

To sum up, we aim at a teaching/learning/assessment environment which provides students with a motivational context, constructs a base of interconnected knowledge, has relevant learner activity, gives feedback in abundance, and gives students possibility for reflective practice. Moreover, our environment must 'force' students to use deep approach in their learning; we must limit the negative effects of back-wash; we must assess students on how well they attain intended learning outcomes; we must use a lot of formative assessment mixed with diagnostic and summative assessment; in our cases we will assess functioning knowledge; we must test skills that cover a broad spectrum of complexity and difficulty; and we must use different assessment tools.

3 Continuous assessment

In educational practice we need a tool, something tangible to work with. Early in our research work we noticed that in order to create the sought-after environment, the use of final or terminal assessment is not possible for several reasons: when using terminal assessment it is very difficult to accomplish a working feedback system from the student to the teacher and vice versa; following student's progress in his/her learning during the course is difficult; and motivating students is also difficult, because you, as a teacher, do not know what is motivating for the lack of information. As Byrne *et al.* (2010, 379) point out, there is a need to reconsider the over-reliance on terminal assessment within the assessment strategy. In continuous assessment (CA) there is no final examination as such, and the mark or grade is determined on the basis of scores in individual tests or assignments scattered throughout a course of study (Miller *et al.* 1998, 88). Succinctly CA could be phrased as *assess as you go* (Isaksson 2008). Also our experiences from other courses and from prior research (e.g. Tang 1992) indicated that continuous assessment is more likely to encourage deep approaches to learning than terminal assessment.

One drawback in CA is that it usually, according to Miller *et al.* (1998, 88), leads to confusion between the distinctive purposes of formative and summative assessment, but this should not be seen as a problem but as an asset. We noticed that students put serious effort only on that work of theirs that had effect on their grade; everything else was more or less ignored (see also Price *et al.* 2007). It is not very useful to make a formative test on students and expect reliable results by telling them, especially to strategically oriented students, that 'this test is a formative test and it has no effect on your grade'. Consequently we created an environment where every piece of work done by a student affects his/her final grade, and these tests are used, at the same time, in formative and summative way. These small tests can also be used in a diagnostic way, e.g. if a problem proves to be too difficult for students, you can make the next one less difficult and vice versa, and in this way you can also detect gaps in student knowledge base and act accordingly.

CA is not a panacea. According to Miller *et al.* (1998, 88-89) major difficulties when CA operates include:

(1) students have too little time for in-depth studying because of the many tests,
(2) teachers have intolerable marking load,
(3) tests used encourage students to use surface approach,
(4) measuring student's grasp of broader principles might be jeopardized,
(5) the general stress level of students increases,
(6) the variation of work load between students is excessive, and
(7) plagiarism in those tests that are not controlled by the teacher, e.g. homework assignments.

In our cases we have noticed all these difficulties and items (6) and (7) are the most problematic and items (1), (4) and (5) are the least problematic ones. It is perhaps surprising to note that students report (Jaako 2011) on *decrease* of general stress level; this can be attributed to the fact that student's grade is not based on a single test but on considerable amount of tests and failure in some tests has only minor consequences. Marking load (2) is not excessive if sensible scheduling of tasks is used, but it can be considerable when other duties are pressing. Plagiarism (7) is a problem but this can be remedied partly by introducing constantly new, previously unknown problems to students. We can say that the biggest difficulty, when using CA with PBL, is that most of the teacher's time is not used in marking, teaching or tutoring but in finding, designing and implementing new, pedagogically relevant problems for students to solve.

The good news is that CA provides us some impressive advantages (Miller *et al.* 1998, 89-90) which can be used effectively in feedback, from student to teacher and *vice versa*, and in following student progress:

(1) results of tests can be returned to students soon after each test is completed, which gives the teacher a powerful tool for two-way-feedback,
(2) both students and teacher are kept informed in real-time of student's progress in learning,
(3) each section of course can be tested in more detail than in terminal assessment, and remedial work can be done *during* the course,
(4) if a student is sick or absent and alternative test can be administered , and
(5) student guiding and tutoring is easier because of (2).

We have noticed same advantages in our own research. According to students' feed-back (Jaako 2011, see also Isaksson 2008) they are most pleased with items (1) and (2) and, additionally, in case B with item (4). From student feedback it can also be deduced that some students move from mere learning to reflecting their own learning; possibly there is a change in the level of thinking about learning (compare with *Bloom's taxonomy's* levels 4-6 in chapter 2). The biggest advantages of CA for the teacher are items (2), (3) and (5) which are connected with the effective two-way feedback possible in CA. Our two cases have demonstrated to us that in educational practice the advantages of CA are much bigger than the difficulties. Of course terminal assessment has also advantages as well as disadvantages; for details see Miller *et al.* (1998, 90-92).

When we connect CA with constructive alignment (Biggs 1996; Biggs and Tang 2007, 50-63), i.e. intended learning outcomes (ILOs), course content, learning environment (including teaching formats), assessment and grading are aligned, we gain further advantages which are not readily evident. Alignment can be made *dynamic* and ILOs, environment and sometimes even assessment can be changed during course, because of the real-time information about student learning. The effects of these changes, .e.g. does a new teaching format work in practice, can be seen almost immediately.

4 Two cases

Case studies are an important research method in areas where innovations are studied and they enable us to study contemporary and complex social phenomena in their natural context (Yin 1987). The problem with case studies, however, is whether observations and conclusions are relevant outside the contexts studied. To make results gathered from case studies applicable in other contexts, we can use approaches such as: we can compare several cases and draw our conclusions from that; we can compare our results with the experiences of other teachers; and we can compare our results, or parts of them, with research results of others.

This chapter presents two educational cases (case A, 4 ECTS, 'Process Optimization' and case B, 5 ECTS, 'Thermodynamics'), in which we have used continuous assessment (CA) as a central tool in creating a learning environment. Our cases are not experiments, and the history of both courses goes beyond single application: development in case A started in 1994 and in case B in 2006. In the 1990's case A consisted of strictly separated parts: lectures, exercises, and final exam. Student learning was weak and students passed the terminal exam with difficulty or not at all. The first phase in development was a portfolio-based approach until CA was adopted and parts were constructively aligned. Case B was born in the year 2006 when separate courses in chemistry were integrated into a single process engineering thermodynamics course. Case B started with CA and constructive alignment from the very beginning.

Starting points in cases A and B were different and the contents of the courses are also different but implementations by the year 2011 proved to be surprisingly similar (see Table 1). We started our work to remove the scattering of course content, to better student learning and to improve student retention and throughput in our course. We integrated different parts of a course in a new way and originally we called this approach 'internal integration of a course'. In the end, however, our courses presented many characteristics of constructive alignment (Biggs 1996; Biggs and Tang 2007, 50-63).

In Table 1 the application features of cases A and B are presented. N.B. In the tables the word 'exercises' denotes a working format in which problems are given to students to solve during the time frame of 'lecture'. 'Lecture' means contact teaching time (usually 2-4 hours) when teacher and student are present in the same room; the word 'lecture' used here has no reference to teaching method 'lecturing'. 'Homework' means problems given to students to solve at their own time, individually or in groups.

Table 1. Application features in cases A and B.

Course aim	To give students tools [A] to use in process optimization, [B] to examine industrial processes by using thermodynamical equilibrium data.
Starting point of learning: learning by doing (Bereiter 1994, Felder and Brent 2003)	A PBL-approach, problems are solved in groups and individually. [A] Student learns to solve process optimization problems by solving such problems. [B] Student learns to solve thermodynamical equilibrium problems present in industrial processes by solving such problems.
Intended learning outcome (ILO) vs. teaching/learning activity (T/LA) vs. assessment task (AT)	[A] ILO: ability to solve process optimization problems. T/LA: solving process optimization problems. AT: how well problems are solved. [B] ILO: ability to solve problems in chemical engineering by using computational thermodynamics (CTD) as a tool. T/LA: solving CTD problems. AT: how well problems are solved.
Lecture time	[A] 40 h, 15 times, á 2-3 h; [B] 22 h,10 times + simulation exercise 2 h
Use of lecture time	Most of the time is used in problem solving and group work, lecturing is limited to short 10-15 minute introductions (problem definition, describing concepts used, giving holistic view to substance under study)
Student learning hierarcy levels	Courses have tasks (exercises, home work, lecture diaries) at different cognitive levels, not just at level 3 in Bloom's taxonomy (see chapter 2).
How is the hierarchy of tasks accomplished	[A] *15 exercises*: students solve one problem during lecture in a group and the teacher acts as a tutor. *5 weekly homeworks*: students solve a problem within a given time limit (usually 7-9 days) *5 weekly lecture diaries*: students analyze their learning process (helps teacher in analyzing and correcting learning problems) [B] *Exercises*: students solve in groups 1-3 problems connected to the theme of the lecture. *5 weekly homeworks*: students solve a problem in groups within a given time limit. *Lecture diary*: answers to questions posed by the teacher, analysis of student's learning outcomes. *Simulation exercise*: students create report
Point of view in assessment	Different tasks aim at different assessment types: exercises during lectures are (but not exclusively) formative, lecture diaries diagnostic (ditto), and homework summative (ditto). Everything is given a grade, because, as experience has shown us, students take seriously only those tasks that have effect on their grade; everything else is ignored.
Timing	Task given must ALWAYS be returned on time (students learn to use time resources efficiently, and learn manage project work)
Coercive and feedback effect	Graded exercises are returned to students in the beginning of next lecture; feedback to students about exercises and homework is given repeatedly. N.B. In systems engineering terms (Sterman 2000) we have built a feedback loop and in control engineering terms that we build a real-time measurement system to monitor the progress of students' learning process.
Grade formation	From student's point of view grade formation is transparent. Grade is based on three different parts: [A] Exercises during lectures, homework & lecture diaries (weight 1/3 each). [B] Homework (weight 4/10) and lecture diaries (4/10), and simulation exercise (2/10). Exercises (1-3 per lecture) have no effect on the completion of the course. When grading SOLO-taxonomy (Biggs and Collis 1982) is used.

In both cases the environment described in table 1 possesses, according to student feedback (Jaako 2011, Heikkinen 2010), those characteristics described in the beginning of chapter 2 with special emphasis on relevant learner activity. The environment also addresses, or at least tries to address, those aspects presented in remaining part of chapter 2 with special emphasis on promoting students to use deep approach to learning; on giving students a lot of feedback; on working in engineering context; on providing students with problems of different levels of complexity and difficulty; and on using different assessment tools.

The next task in our report is to analyze results from our cases in educational terms. We can analyze these by using the following sources of information:

- Research done by the scientific community which provides us with supporting evidence (presented in chapters 2 and 3).
- Researchers/teachers personal view of the development results. This view is usually of highly subjective nature, but it can be amplified by quantitative data. Our views are presented throughout this report.
- Supporting quantitative data in the form of throughput (pass rate) (Figures 1, 2 and 3) and grades (Figure 4).
- Students' views of the course given as a written feedback. This comes in the form of qualitative data.

First we present data in the form of throughput in figures 1 and 2 for case A and figure 3 for case B.

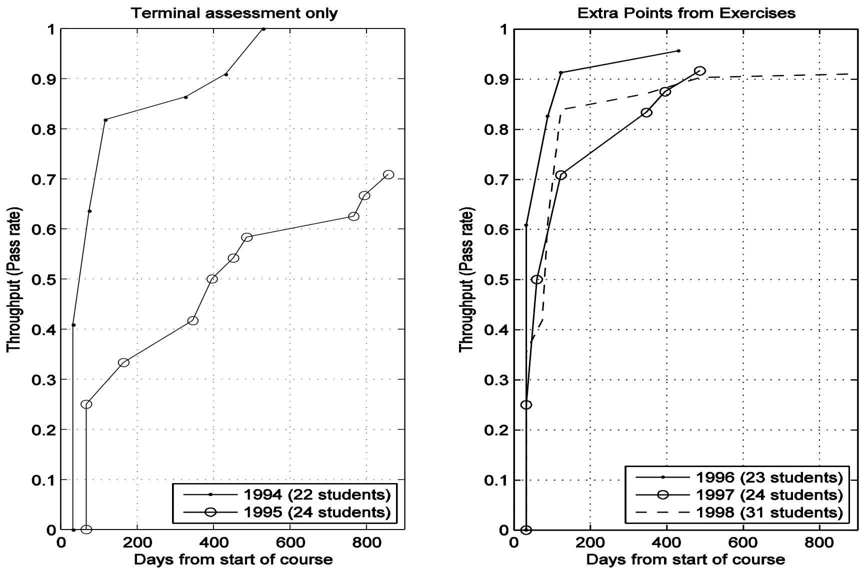

Figure 1. Course throughput, case A, years 1994-95 & 1996-98 (abscissa 0-900 days)

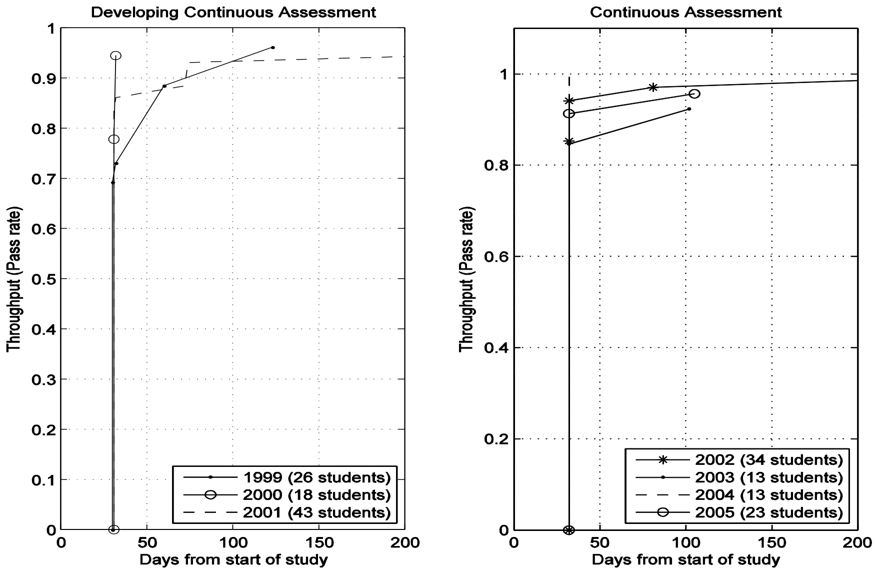

Figure 2. Course throughput, case A, years 1999-2001 & 2002-05 (abscissa 0-200 days)

In figures 1 & 2 the student pass rate (throughput) in case A is presented graphically. During years 1994-95 only terminal assessment was used and throughput was rather bad and it took a long time for students to pass. Considerable improvement in terms of throughput was accomplished during years 1996-98 when extra points were given to students from problems solved during lectures; this approach also gave students pedagogically relevant activity during course. However, from student feedback it was deduced that by removing terminal exam totally and replacing it with CA further improvement would be possible, this is what happened during years 1999-2001. The assessment practice reached maturity by year 2002 and results have been similar since: it takes students five weeks to pass the course and over 90% of the students pass.

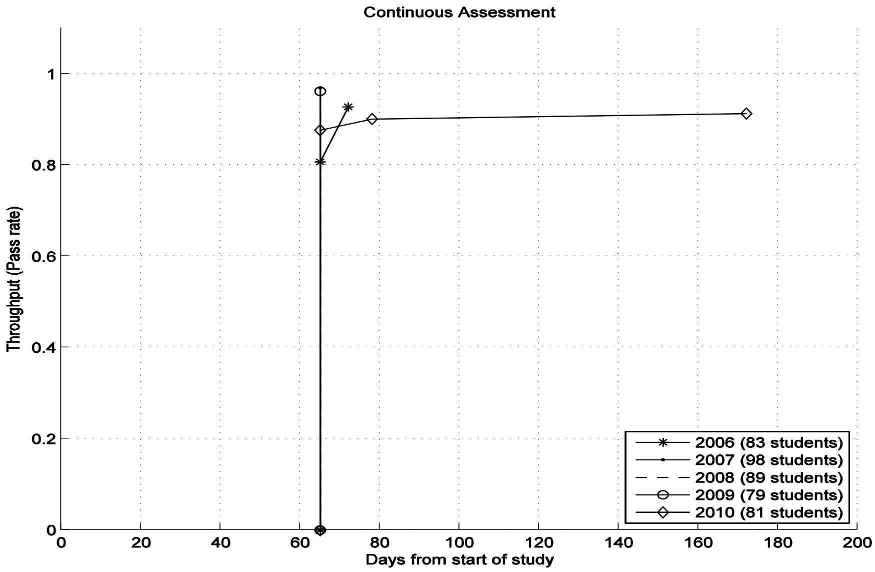

Figure 3. Student throughput, case B, years 2006-2010 (abscissa 0-200 days)

Student throughput in case B (figure 3) is very much the same as in case A from year 2002 on. The number of students in case A ranged from 13 to 43 (mean 24.5) and in case B from 79 to 98 (mean 86.0) so we can say that CA functions well in middle sized class (case A) and in a large class (case B). It is plausible to assume that CA, and our teaching/learning environment, also functions well in smaller sized classes but in huge classes (over 100 students) the marking load, and other limiting factors, will most probably be intolerable (see chapter 3).

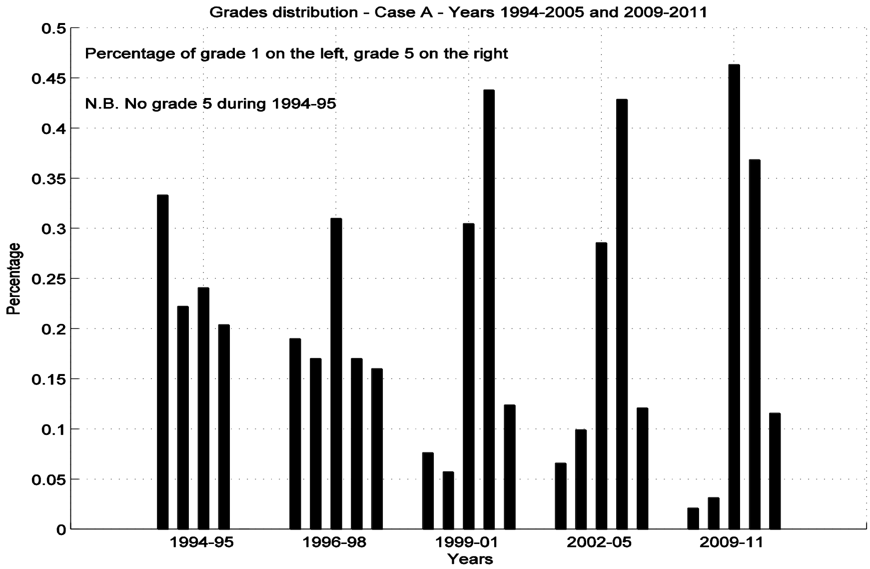

Figure 4. Distribution of grades, case A, years 1994-2005 and 2009-2011.

In Figure 4 the distribution of grades given to students is presented. Grades are 1 (worst), 2, 3, 4 and 5 (best). Changes in the distribution of grades can readily be seen: from mere terminal assessment (years 1994-95, N=54, mean=2.31), with extra points and terminal assessment (1996-98, N=100, mean=2.94), during development stage (1999-2001, N=105, mean=3.47) and in mature stage (2002-05, N=91, mean=3.44; 2009-11, N=95, mean=3.53; data for years 2005-08 is not available). Extra points given (1996-98) had twofold effect: points raised the grades as such and problem solving practice during lectures raised problem solving skills in the final exam. The real change happened when the move from terminal assessment to CA was completed and the most notable phenomenon is that the lowest grades (1 and 2) are rarely given today. In case B the mean of grades is at the same level as in case A, but of course, since there was no development stage, the use of CA in case B shows no increase in the mean of the grades. The distribution of grades (N=420) in case B during years 2006-2010 resembles the distributions of grades in case A from years 2002-05 on.

There is a lot of student feedback available on case A (Jaako 2011) and case B (e.g Heikkinen 2010). In our teaching/learning/assessment environment students experienced as *positive factors*: group work and peer teaching; learning by solving problems - student comment: ‘exercises forced me to study’; challenging homework; short lectures and group work; continuous assessment and constant learning activity; lecture diaries; coercion; work load not excessive; use of computer programs (Matlab®, HSC®) in problem solving; students were satisfied because their competency was addresses with different assessment tools; the use of these tools forced students to think more deeply on the course content; and course was designed from the point of view of learning outcomes.

As *negative factors* students experienced the following: some students did not like the lecture diaries; course materials were not always clear and comprehensive; in case A students with problems in mathematics and Matlab® experienced problems; in case B the simulation exercise with HSC® was deemed either as too difficult or too easy; and problems given to students to solve were not closely tied to engineering practice, i.e they were out of context. Perhaps surprisingly, no-one had negative experiences on CA and many students commented, especially in case A, that the course was their best learning experience so far. Also, perhaps more surprisingly, the use of coercion (or teacher control with time limits) was deemed a positive factor in learning. Negative comments are mostly due to the fact that students, especially in case A, form a heterogeneous group. Creating pedagogically meaningful problems for students to solve is somewhat difficult as mentioned previously and students recognize it.

If we compare students' comments on the list of Biggs and Tang (2007, 91-99) on general characteristics of good teaching/learning contexts or environments, we can say that, based on student feedback, we have succeeded in creating an appropriate motivational context, relevant learner activities with problems to be solved, a teaching/learning environment that gives students a lot of feedback, and a possibility for reflective practice and self-monitoring in group work and by writing lecture diaries. Whether we have succeeded in constructing a base of interconnected knowledge cannot be deduced from our data, but from students feedback it is evident that they think we have.

5 Summary

Research literature shows us that in learning there are certain characteristics that are desirable in student behaviour and some that are not. We as teachers must find a way to control, or coerce, all our students to use those approaches that show them the way to intended learning outcomes. In order to accomplish this, the teacher must master the substance of course, know the students and their learning approaches, know how to teach, know how to use assessment tools, and finally, know how to guide students' learning processes.

In the beginning of our report we presented two research questions. First one was *'Is it possible, by using educational research results, to create an assessment-centred teaching/learning environment in higher engineering education?'*. Based on the analysis of our two cases, our answer is YES. Whether our findings are useful in other disciplines requires further research. Our second question was *'Is it possible to show, qualitatively and quantitatively, that the assessment-centred learning environment thus created is advantageous in educational terms?'*. The problem with learning is that it can be measured only indirectly during studies, e.g. from grades, from course throughput, and from student feedback. Analysis of the data from these sources gives us a possibility to answer YES to our second question. Whether some other teaching/learning/assessment environment would be better in our two cases, cannot be answered based on our current knowledge.

We have strived to use different tools, especially continuous assessment and problem based learning, to create a learning environment, which possesses many of the characteristics of constructive alignment (Biggs and Tang 2007). Continuous assessment also provides us with real-time information about student learning and this enables us to make well founded changes even during a course. The experience gathered has enabled us – besides creating teaching that is more aligned than previously – also to move from integrating teaching activities to integrating learning activities and at the same time offering students real responsibility for their learning.

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