

## Promoting constructive alignment in engineering education at Chalmers

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# **The constructive alignment of aims, methods and assessment in engineering education. A Swedish case study.**

Michael Christie and Tom Adawi

## **Introduction**

Learning is common to all creatures but particularly developed in human beings. At least that is what we humans claim. We point to the incredible spurt of learning that takes place during human infancy. But of course chimps and other species also demonstrate an a rapid learning curve in their early years. A more convincing argument for our very special learning abilities is what takes place in schools and universities. Humans have created formalised learning systems where the object of learning is not just how to survive but also to how to accumulate and pass on knowledge. In postgraduate and research schools humans work hard at developing new knowledge. Because of this type of learning human knowledge has progressed at an exponential rate. We know, and do and believe things today that our ancestors could not even imagine. Part of this received wisdom includes how we can learn best in organised educational settings.

This chapter looks at one way of improving the quality of learning in tertiary institutions. John Biggs (1999), in a book on this subject, talks about ‘the constructive alignment’ of teaching and learning. He is credited with the label but both the concept and the process have been around for a long time. The label has two parts. The ‘constructive’ part refers to the type of teaching and learning that is favoured. John Dewey explains it most succinctly when he says ‘We learn best by doing’. Others, who call themselves ‘constructivists’, have built a theory based on this axiom. They argue that learning is most effective when we are lead to discover knowledge ourselves. Many of us have had the irritating experience of asking for help with a computer problem only to find that our mentor sits in our chair and proceeds to ‘show us’ how to do it. We feel instinctively that if we are to know, understand and repeat what we have sought help with, we need to do it ourselves not watch while someone else does it for us. In engineering education this style of learning is institutionalised in the ‘laboratory session’ where students experiment, see for themselves, discover things or confirm facts or theories that they have heard or read about. The constructive part of ‘constructive alignment’ is a marker of quality. We are interested in a

type of learning that is experiential and because of that more likely to be internalised and applied.

The second part of the label refers to linking or aligning the learning objectives, the teaching methods and the assessment of an educational course or programme. If this is well done the consistency that is achieved should percolate down to the lesson, project or laboratory level.

### **A project to promote constructive alignment of the curriculum**

The project that this paper refers to focused on an engineering education degree offered by the Chalmers University of Technology, situated in Gothenburg on the west coast of Sweden. The project was funded by phase 2 of C-SELT and was called 'The constructive alignment of teaching and learning at Chalmers'.

The aims of this project have been, in hindsight, over ambitious. They were:

- To consult and liaise with the leadership of the various sections at Chalmers in order to develop an action plan for the greater alignment of teaching and learning objectives, methods and assessment in key courses.
- To work actively with those responsible for courses in order to improve the degree to which the teaching and learning objectives, methods and assessment are constructively aligned.
- To build a number of model courses in each section and by advertising them disseminate the notion of aligning teaching and learning objectives, methods and assessment as a way of improving the quality of student learning at Chalmers.
- To investigate, via a survey of courses advertised on the Chalmers web the extent to which assessment requirements are spelt out and the degree of alignment between them and the stated aims and objectives.

The aims, nevertheless, highlighted the fact that any major reform of the curriculum required the will and support of people with the power to change things. These people included teachers but also those who made decisions about the number and nature of courses in the various degree programs. We had as a premise that a traditional and overcrowded curriculum was not conducive to the constructive alignment of teaching and learning. More importantly if those in charge were not clear about the generic capabilities that they hoped their program would develop then aligning specific and generic learning outcomes would itself be a problem. This in turn would effect the way in which individual teachers tried to align their particular course objectives with their teaching and assessment methods.

### **A survey of course descriptions**

A decision was made early on to tackle the last aim first. We believed we would have a more convincing case to take to section leaders if we could demonstrate conclusively that there were serious problems in the consistency between the stated learning objectives of

courses in their programs and the methods used to achieve them. This turned out to be a wise decision because an early survey of Chalmers courses revealed something more alarming. In many cases there were not even clearly written learning objectives. What we found was that in a majority of course descriptions there was a brief statement of general aims for the course, a list of course contents and a vague reference to the type of assessment that would be used. The aim was rarely broken down into specific learning outcomes and there was no indication of the criteria for learning, something one would expect in well formulated learning objectives. When we compared Chalmers course descriptions with those from universities in the English speaking world there was a disturbing difference. The Chalmers course descriptions had aims only and rather vague aims at that. The descriptions we found in UK, Australian and American universities tended to include criteria referenced objectives as well as broad aims.

The consistent lack of detailed learning objectives throughout the university came as a shock. A comparison with other Swedish university course outlines provided some clues. Very rarely, at least in universities of technology in Sweden, were specific, criterion-referenced objectives or learning outcomes written into the course outlines. Only at the Linköping University's engineering faculty was the mould broken. This faculty uses problem based learning (hereafter PBL) which we take as a marker of pedagogical concern and innovation. There are good and bad examples of PBL but its introduction suggests a commitment to constructive learning processes and a greater awareness of pedagogical developments in tertiary education. At Linköping the writing of learning outcomes was much more refined. Our conclusion from this comparative survey is that universities of technology in Sweden have not kept abreast with current pedagogical theory and practice, including how one writes effective learning objectives or outcomes. It could also mean that since the Swedish language lacks specific words to discriminate between broader aims and more specific objectives the practice of differentiating between the two is not as embedded in planning or is expressed in other ways. This could apply to business as well as educational plans. A worthwhile research project would be to follow up this lead and check the way aims and objectives are expressed at different levels and in different disciplines of education.

### **A comparison across disciplines**

A random cross-discipline comparison of tertiary education showed that in some subjects there is a greater awareness of how to write good learning objectives. In the case of courses in pedagogy the difference is easier to explain since writing clear criterion-referenced objectives is one of the things such courses are meant exemplify. Differences in other disciplines might be due to conscientious or pedagogically trained individuals but to prove this would require a separate investigation and analysis. Our random survey generated a large number of questions. Is the use of short, vague general aims the result of a belief in the need for concise course descriptions? Or is simply a habit based on how such course descriptions have always been written at the particular university. In other words the unthinking replication of the way things have always been. Chalmers this year celebrates its 175<sup>th</sup> year as a tertiary institution. It is justifiably proud of its traditions and it might just be that writing course descriptions that are vaguely expressed is one of those traditions. A

more critical question might be: are these vague descriptions due to a lack of up-to-date pedagogical knowledge about the efficacy of well written learning objectives/outcomes? Other questions that interested us were: How do students react to this type of course description? Can they work out in advance what is required of them to pass the course? How do they determine the relative importance of various parts of the course? What type of knowledge is expected of them? Is there any obvious relationship between what is to be learnt and what is to be tested? How do they determine the level of performance that is required for different grades? Would a more pedagogically course description where a general aim was followed by a series of criterion-referenced objectives that were linked to content, teaching methods (including varied and continuous assessment) be appreciated by students?

In order to learn the answer to some of these questions we downloaded and analysed a large number of Chalmers course descriptions. We then interviewed twenty students from different faculties and asked them about their experience of course descriptions. We also showed them a description from a basic course in mathematics that is compulsory for all students starting at Chalmers as well as an example of a corresponding course description from a United States university (see the appended documents). They were asked to comment on the differences between the two and say which of them they preferred. What we learnt from these interviews was that students used the content section of the Chalmers course description as a sort of substitute for learning objectives.

Unfortunately for them the list of what was to be learned was simply that – a list. There was no indication of the sort of learning that was expected or the criteria by which their learning would be judged. They had to be content with the a general aim that was, in most cases, an admonition ‘to understand’ what was on the list. The students were surprised at the detail of the learning outcomes in the corresponding US course description. They were also impressed by the fact that the verbs that were used in the objectives indicated the type of learning activity that was required of them. The overarching ‘to understand’ that they often encountered in their own course descriptions was broken down into more specific requirements in the overseas document. Students were expected to be able to explain, describe, analyse, calculate, exemplify, apply and synthesise. The verbs suggested actions and those actions were explained in the assessment requirements that were aligned with both the learning objectives/outcomes and the content, as well as the methods of facilitating and/or delivering that content.

#### Feedback from focus groups

A separate group of twenty doctoral students were engaged in a workshop that looked at the ramifications of how course aims and objectives are written. These doctoral students are paid to teach part time at Chalmers as well as being required to take 40 points of course work. This gives them a unique perspective on this part of the curriculum development process. They were asked to bring to the workshop examples of aims and objectives from the courses they help teach. During the workshop one of the authors of this paper showed them different samples of course aims and objectives and asked them to critique them. One aim stated that the ‘this course will teach the basic principles of...’. It took a good deal of

discussion before the workshop participants came to the conclusion that this was a teaching rather than a learning objective. 'What's the difference?' asked one PhD student in the group, 'Everyone knows that it refers to what is to be learnt'. This workshop was designed to be part of our action research project and in the discussion that was generated the group finally agreed that there *was* a difference and that it is grounded in pedagogical theory. The Swedish language might lack the corresponding word for learning objectives/outcome but, in education at least, it has two very useful words. In Swedish you can 'learn out' (teach) something and 'learn in' (learn) something. It was precisely this difference that was emphasised in the workshop.

The way the above mentioned aim had been written underscored a particular attitude. It was an attitude that emphasised a transmission model of teaching and learning rather than a 'constructivist' one. The doctoral students divided into focus groups and were asked to interrogate the copies of course aims and objectives that they had brought with them. The conclusions that they drew in the light of pedagogical principles regarding learning outcomes were similar to those that the authors had arrived at after analysing a wide range of course descriptions. Many of the aims that were used were not only vague, and therefore of limited value to the students who read them, but they also encapsulated a transmission model of learning. Students were told what they would be taught or perhaps what they had to 'understand' but there were few clues as to what they would be required to do in order to demonstrate that they had acquired knowledge or skills in a particular subject. Nor was there any indication as to the quality of learning that was expected. For example a course aim in electromagnetic theory might state that by the end of the course students would understand Maxwell equations. The aims and objectives did not state how they would demonstrate this nor how they would show the quality or level of their understanding.

### **Examples of good assessment**

As part of this project the same group of students were asked to bring to a second workshop examples of assessment which they felt were constructively aligned to the aims and objectives of courses they taught in. Their examples touched on a number of common themes the most notable of which was that varied and continuous assessment procedures encourage learning throughout the course and avoid 'hysterical rote learning towards the end of week 7'. It should be noted that at Chalmers, especially in the earlier years, the school term is divided into six weeks of lectures, a seventh 'swot' week where students prepare for the closed-book exams that take place in the final or eighth week. This organisational structure endorses and in some senses enforces a traditional type of engineering education, divided into lectures, labs, practice sessions that culminate in a final written exam.

An example of continuous assessment that students found particularly tough but which really promoted a deep understanding of the subject was a course in quantum physics that allowed students to either take a traditional exam or be assessed in a more varied and continuous way. All the doctoral students who had taken the course opted for the latter and believed it was an effective form of constructive course alignment. They felt that because of this the quality of their learning had been particularly high. They also noted that there

were organisational repercussions when a course like this provided varied and continuous assessment. Courses that students were forced to take simultaneously were neglected or else real study on them left to the 'swot week'. Most passed the tough course but failed the traditional one and had to sit it again. In Sweden students can resit exams at almost any time without financial or other penalties. As a result of political pressure from both students and other teachers the quantum physics course was increased from a four to a seven credit point course where each point represents a week of study. In this way it became a stand alone course that did not affect other courses that happened to be running at the same time.

There were other examples of appropriate assessment. One teacher, who was chosen as exemplifying good assessment practices, turned every lecture into a mini formative assessment. Another used take-home exams and questions to stimulate the desire to learn. This form of assessment can encourage creative problem solving and raise practical problems that the teacher is then asked to solve or provide help with. This in turn creates a learning dialogue. Other teachers used online laboratories and quizzes with automated corrections which saved enormous time and acted as good formative assessment. Of course it takes technologically and pedagogically skilled people to set up such systems but perhaps FAQs on a teacher's homepage is a simple way of doing this.

One of the group had experienced problem based learning including some exams where this form of teaching and learning had been used. PBL has many advantages. One of them is that the student is learning while he/she is solving the problem. This is also true of labs and lab reports if they are constructed well. Only one of the group cited end-of-course, closed-book exams and did so because he had experienced a particularly good one. His example emphasised the fact that the form of closed-book exams is important. It takes, for example, a very skilled multiple-choice-question exam to test functioning knowledge.

One of doctoral students in the workshop could not think of a single example of good assessment so he did a statistical analysis of all the exams he had taken. In total 81% used traditional closed-book, end-of-course exams. Was this the reason, he wondered, why he couldn't think of a good example? The statistic that he gave was consistent with the investigation carried out in the project 'Appropriate ways of assessing learning at Chalmers' that is reported on in another chapter in this book. When the students were asked how many of their examples came from first year courses the answer was similar. Almost all of their examples of good assessment occurred in the latter years of their engineering education.

In the discussion that took place during the workshop it was clear that large numbers and limited resources appear to be a problem in providing more pedagogically sound forms of teaching, learning and assessment in first year courses. On the other hand we have demonstrated in one of the case studies in the project mentioned above that a more continuous and more varied form of assessment is possible in first year subjects (Christie and Nordlund, 2001). It may take some extra time initially but once established the demands on time and resources are no greater than more traditional forms of teaching and learning.

## Conclusions

We have concluded, from our comparative surveys, our interviews with students and the workshops that we have conducted, that writing clear, criterion-referenced objectives or learning outcomes is the first step in a process of constructive alignment of the engineering curriculum. This does not demand so much extra time or resources. What it does demand is an awareness of the difference between diffuse general aims and specific, criterion-referenced objectives. It also demands a change of attitude. Teachers who write clear learning outcomes and align them with constructive teaching/learning methods and meaningful assessment have a positive view of students. They do not have a 'mushroom model' of learning where students are kept in the dark, fed compost and left to grow on their own. The teacher is a partner in the learning process. Assessment is not kept a secret. Students are not cajoled into coming to lectures because there will be clues each week as to what will be on a final, closed-book exam. The course description is not a vague document where the aim is general, the content a long list and the assessment form and criteria vague. It is, rather, a precise road map where the aim of the journey, the prerequisites for travel, staging posts, the nature of the terrain and the way itself are clearly marked. There is even a detailed guide telling them how they will know they have reached their destination and how well they have travelled. Better still they will pick up skills and knowledge along the way that will serve them well in undertaking other learning journeys whether inside or outside the university.

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