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If reform of science education is the answer -what were the questions?

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If Reform of University Science Education is the Answer – What were the Questions?

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Content

Contributors

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P**eter Ditlevsen** is a senior lecturer of physics at the University of Copenhagen. He has increasingly become involved in issues of quality teaching and is engaged in the teacher training programme at the science faculty of his university, as well as in innovative teaching of introductory physics.

Graham Gibbs is director and professor at the Centre for Higher Education Practice at the Open University, UK. For many years, one of his scholarly and political concerns has been how best to reward excellent teachers. His efforts have resulted in every English university implementing strategic plans to improve teaching, including rewards of excellence in teaching. His current research concerns the way assessment of science courses affects how students go about their learning, and also concerns how to change assessment so as to improve learning.

Niels Grønbæk is a senior lecturer of mathematics at the University of Copenhagen, and has worked for many years with curriculum development and competence concepts within university mathematics programmes as well as at the transitional level between high school and university.

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Bjarne Lundager Jensen is the director of The Confederation of Danish Industries. He is a significant participant in the national debate on science research and education.

Mogens Niss is a professor of mathematics and mathematics education at Roskilde University. He is the leading exponent in Denmark of the importance of definition and application of mathematics competencies at all levels of the educational system.

His work is internationally recognized and has been strongly influential in many parts of the world.

Agneta Olerup is a professor of informatics at Lund University School of Economics and Management. Her research has mainly been oriented towards the interactions between, on the one hand, organisations and, on the other, computer supported information systems and information technology. Since April 2003 she has been a member of the Office of Evaluation at Lund University.

Poul V. Thomsen is a senior lecturer and head of Centre for Studies in Science Education, University of Aarhus. His involvement in science education has included numerous investigations of the cognitive abilities and motivational forces in students in the Danish upper secondary school ('gymnasium').

Carl Winsløw is a professor at the Centre for Science Education, University of Copenhagen (until August 2003, he was at the Danish University of Education). His publications cover a broad range of subjects, from a structural linguist theory of mathematical discourse with applications in epistemology and didactics, over comparative studies of secondary school teaching, to studies of curriculum theory and computer based teaching in university level education. He has also published several papers on pure mathematics.

Foreword

These conference proceedings report on the third May Conference of the Centre for Educational Development in University Science (Dansk Center for Naturvidenskabsdidaktik, DCN). The main purpose of the DCN was to build a basis of pedagogical and educational competencies for educations in natural science at university levels. DCN was responsible for developing a network to pursue this purpose; for the development, coordination and implementation of activities directed towards improving the pedagogical and educational quality in university science education; and for a doctoral programme in mathematics and science education. The DCN-programme as such was terminated in 2002, and the DCN-torch handed over to the participating universities: University of Copenhagen, University of Southern Denmark, Roskilde University, the Royal Veterinary and Agricultural University, the Royal Danish University of Pharmacy, the Danish University of Education, and Aalborg University. In 2002, the task to prepare the May Conference 2003 was handed over to the newly established Centre for Science Education (Center for Naturfagenes Didaktik, CND), University of Copenhagen.

At most Danish universities dramatic changes of the natural science programmes are underway. These changes are carried out both in response to external forces (say, the demand for more university graduates or the need for more flexible educations), and to internal ones, such as the need to rethink curriculum and pedagogy. But while the answer – structural reforms – is clear, the major questions remain open: What is the aim of modern natural science education? Is it to provide students with ready-made competencies for a career in business or government? Is it research competence? Or…? And: how can the teaching methods and curriculum structure best support all this? How are changes of teaching practices best initiated? How does the university teacher improve his or her own teaching? These questions were addressed at the conference "*If reform of university science education is the answer – what were the questions?*", 22 – 23 May, 2003, in Korsør.

During the conference a number of keynote speakers presented their experiences and perspectives on the central themes: J. Bowden, G. Gibbs, M. Niss, N. Grønbæk, A. Olerup, B. Lundager Jensen, and A. Jakobsen. *Section 1* of this publication shares their presentations with the reader. Further, during the conference the participants were encouraged to discuss the conference themes and to pose central questions for discussion by a panel consisting of Professor J. Bowden, RMIT, Australia, Professor G. Gibbs, Open University, UK, Rector J. Oddershede, University of Southern

Denmark, and Director of Research B. Lundager Jensen from The Confederation of Danish Industries. The questions posed by the conference and the concluding panel debate may be found in *Section 2*. Finally, *Section 3* contains extensive reports from the four workshops arranged for the afternoon session, Thursday the 22nd of May. Instead of spending conference time on plenary reports from the workshop, the participants and other interested readers can now get an idea of what happened in the various workshops on *peer instruction* (by P. Ditlevsen and P. V. Thomsen), *competencies* (by M. Niss and N. Grønbæk), *capability-driven curriculum* (by J. Bowden), and *assessment supporting students' learning* (by G. Gibbs). We thank them all for their contributions. Text surrounded by [] is added by the editors.

The conference was organised by P. Geckler, N. Grønbæk, O. Hammerich, K. Bagger Laursen, University of Copenhagen, and C. Rump, The Technical University of Denmark. The conference proceedings have been compiled and edited by S. Horst, K. Eriksen, Centre for Science Education, R. Troelsen and J. Carter, University of Southern Denmark. For the May Conference 2004 the torch is hereby handed over to Aalborg University.

P. Geckler, O. Hammerich & K. B. Laursen, November 2003

Section 1 - Keynotes

This section contains the keynote presentations at the conference. Some of the speakers had prepared a paper in advance, but later changed it to bring it in to line with their actual presentation. Others have added a little to what they actually had time to present, and still others have subsequently prepared a paper based on the editors' transcripts and summaries and/or their own personal notes. One speech, prepared by Arne Jakobsen from the Technical University of Denmark, was not presented at the conference because Jakobsen was unable to attend. His contribution is also included in this section. Finally, this section includes a (second) paper by Professor Gibbs, Open University, UK, primarily prepared for Workshop 4 (Does Your Assessment Support Your Students' Learning?).

The editorial committee has decided to maintain the different styles and intended purposes of the various presentations, rather than requesting the contributors to steam-line their inputs. These contributions necessarily appear with varying styles and intended purposes, and editors have made no attempts to unify.

Why do we need reforms, which, and how do we implement them?

John Bowden, RMIT University, Australia

Introduction

It was an honour for me to have been asked to speak at the conference and I want to express my gratitude for the invitation. The context for the presentation and the workshop is that I am reporting on a research and development process that has resulted in RMIT University making it mandatory for every new and renewed programme (every five years) to have a capabilities-driven curriculum design.

I am well aware that European educational programmes are facing significant structural changes as attempts are made to develop uniform frameworks to facilitate, among other things, the mobility of students around the system – the so-called Bologna process. I have looked at the programme structure paper that the Faculty of Science at the University of Copenhagen has prepared, and note that it incorporates aspects such as

- freedom of choice for students,
- individualisation,
- options between the general and the specialised or professional tracks, as well as
- alternative ways of moving from a bachelor degree level to the master's programme.

Within those aspects alone there are elements that raise pedagogical questions, not least of which are

- the issue of coherence associated with freedom of choice,
- equivalence of entry when graduates from different bachelor programmes enter the same masters' programme, as well as
- the need to adapt existing teaching and learning environments to meet the different learning needs of students enrolling under the new structure.

My own experience in university science began when I completed a chemistry and mathematics combined major at the University of Melbourne in the mid 1960s. I then went on to a PhD, with about seven years spent doing teaching and research in chemistry at that University. I then moved into pedagogy. All of that was in a system that matches the Bologna process exactly. Three-year degrees have been the norm in Australia for at least five decades and two-year masters' degrees following the bachelor degree have also been the norm. I understand that the formal 3 plus 2 structure has also existed in Danish universities for several decades, although the formality of the three year exit point is now increasing. As well, I have been visiting Sweden for about one month each year on various projects for the past sixteen years and I am well aware of that country's four and a half year masters' degrees which are currently transforming in many places into five year masters' – somewhat in anticipation of the Bologna-inspired changes that are being addressed.

So what can I offer? Well, the work I have been doing these past ten years has been concerned with pedagogical reform that has quite a lofty aim. It is aimed at ensuring that students learn in the university in ways that make it possible for them to graduate with the capacity to do whatever they intend to do, with the greatest chance of success. Clearly, of importance for most students, and of highest priority for many, is success in their work and it is on this that I have concentrated my research and development effort most, but not to the exclusion of other aspects including preparation for becoming a responsible member of society in all its manifestations.

Why do we need reforms? I'll answer that question in some detail later but the answer for me at a general level is because research (including my own) shows us that as teaching organisations, universities can do a lot better. Examination performance often does not match capability to act. Some statistics were cited at a seminar I attended in Sweden early in May 2003 which showed a significant correlation between school examination performance and performance in university examinations. However, the correlation between university examination performance and workplace success appeared to be near zero. Anything we can do to improve that will be valuable. We certainly need to do something.

The kinds of changes that the research suggests should be made are equally applicable in a range of university systems, in the Australian and Swedish systems at least in my experience. It is possible to improve considerably what we do in university teaching and learning so as to make it possible for our graduates to emerge as more capable that they are doing currently. The reforms also have particular application to the issue of multiple pathways into masters' programmes.

Before going on and discussing those pedagogical reforms I want to make a brief comment. I am well aware wherever I go that there are excellent academics who are doing innovative teaching and for whom the suggestions I make are, at most, merely a confirmation of what they are already doing. There are likely to be universities, or parts of them, that are systematically achieving the kinds of goals I am arguing for. However, I also know that there are many universities or parts of them where it is not like that. My argument is about the potential for improvement in those latter situations.

Why reform?

Let me address this question in more detail now. My basic motivation for curriculum reform in Australia has been the observation that often there is an inconsistency between how we manage the learning environment and the kinds of outcomes we aspire to for our graduates. I have been engaged in a number of research projects about learning in science programmes that have shown time and again that, while academic staff do have realistic and appropriate aspirations for the learning they would like to see achieved in their programmes, the teaching and learning activities designed into them and the assessment undertaken within them combine to guarantee that graduates will have achieved less than was intended and less than they are capable of achieving.

One study in the late 1980s involved finding an explanation for the observation by physics academics in one of the most prestigious Schools of Physics in the country that the brilliant students who entered the programme some years before had, by third year, apparently forgotten all of the fundamental concepts they seemed to have displayed so well on entry into the university. Our major finding in this research was that the students never had actually understood the concepts in the first place, not in the way the teachers had imagined. This research was published in refereed journals like the American Journal of Physics in the early 1990s (for example see Bowden et al, 1992; Dall'Alba et al, 1993; Walsh et al, 1993).

The teaching and the assessment were such that students were motivated only to learn how to solve problems using the appropriate algorithm, normally without understanding the underlying concepts much at all. They had not forgotten the concepts at all; in fact they had never understood them in the first place, despite getting excellent grades at school and first year university.

That kind of finding is not isolated to physics, nor is it to be found only in one Australian university. Indeed Camilla Rump reported recently at a conference I attended that the same problem exists in Danish universities. I recall one of her studies with results that confirm my Australian research. She reported (Rump, 2002, Jakobsen et al, 1999) that in one engineering course at DTU, 60 per cent of those who passed the mostly quantitative examination failed a simple test of conceptual understanding on the same material. Twenty five per cent of the students failed both the examination and the test of understanding and 30 per cent of students passed both. However, while 45 per cent of the students who passed the examination failed the test of conceptual understanding, there was no student who passed the test of conceptual understanding and also failed the quantitative examination. This leads to an inevitable conclusion that is confirmed in other research studies and through pedagogical theory, namely that conceptual understanding facilitates quantitative problem solving but that the reverse is often not true. [See also Jakobsen in this publication p. 112].

For me those findings, in Australia and in Denmark as examples of a wide array of similar research studies around the world, provide a good basis for arguing for pedagogical reform. Another strong argument is that when appropriate changes are in fact made, students do learn in the way hoped for. A changed learning environment is effective. When the assessment is made authentic and an appropriate learning environment is established, students learn pretty much as intended.

And by authentic assessment I mean nothing more than assessing the objectives or goals directly. Often we state in course catalogues that we expect students to understand various concepts but we never actually assess their understanding. Instead, we assess whether they can solve equations with terms in them that represent those concepts or we assess whether they can reproduce material that can be rote-learned. That is not authentic assessment and generally does not lead to learning corresponding to the stated objectives, as shown for example both by my research in the 1980s and 1990s and Jakobsen's and Rump's more recent studies.

A third reason for reform comes from the experience of employers. I know that the extent to which universities should be accommodating industry is a contentious issue. Just such a question was put in the conference brochure. I have an argument I can put about that, but the point I am making here is a different one. What I am referring to is that industry tells us that our graduates are not even showing learning of the kind that we claim that they have achieved.

This is treated in some detail in my book "The University of Learning" (Bowden & Marton, 1998, pp 95-97) but essentially the data show that employers' observation of university graduates, certainly in science, engineering and business where I have looked most closely, leads them to conclude that graduates have a considerable array of knowledge but they don't know how to draw on it and relate it to the kinds of situations they have to deal with in the workplace. They have some skills but don't know how to apply them. That is an observation that does match the research and is further argument for pedagogical reform.

What reforms?

In many university programmes, observation of the kind of learning environment that students experience, including the examinations, would lead to a particular conclusion: that the theory of practice of the university is that if you know certain combinations of things from relevant disciplines, you will become equipped to carry out certain functions on graduation.

The employers say it isn't happening and pedagogical theory predicts it can't happen in this direct way. There must be other things to be learned along with the discipline content that assist graduates to deal with the new, unseen situations they confront on graduation, either in the workplace or more generally in the community. That combination I refer to as development of capabilities and I'll be talking about capabilities in some detail in the rest of this presentation.

Essentially I am arguing that accumulating knowledge is one thing but developing knowledge capability, the capacity to use the knowledge learned to deal successfully with previously unseen real-life situations, is quite another. I argue for capability outcomes as the goal of university programmes and not just knowledge accumulation.

You may have noticed that on a few occasions I have said something like "dealing with previously unseen situations". You may well be asking what I mean by that and why I am referring to it.

Just a week or two ago I met with about 10-12 students at a Swedish university. I asked them to jot down on a piece of paper where they thought they would be living in the year 2010 and what kind of job they expected to have. They had some idea of where they'd be, or like to be anyway, with proximity to the Alps being an important criterion for many of them, but they had very little confidence about predicting what kind of job they'd be doing. My next question became unanswerable – how do you expect the learning you did in your courses last semester to contribute to do your job in 2010. Few had any answer to that at all except laughter.

This exercise confirms a number of things that we concluded in The University of Learning (Bowden & Marton, 1998, pp 24-27). When students enrol in our programmes and attend our courses, they are learning what we are teaching without a clear idea of its direct relevance to their future beyond graduation. In fact, many graduates will never be employed directly in their field of study. Most graduates won't be working directly in their field of study within 5-10 years of graduation (I made my shift from chemistry research to pedagogical research within that period for example). Few current professional practices will last 10 years. Students need to learn how to deal with a professional future that can't be accurately predicted (certainly not for individuals). The curriculum should be designed around intended capabilities of graduates rather than the technical content, so that the learning of content is a means to developing the capabilities to handle situations in the future that are at present unknown.

Now it could be argued that the above is true only for general science degrees and that in professional degree programmes the comments above do not apply. However, this is not so. The research data on which these comments are based are about both professional degrees and general degrees. There is little differentiation in terms of the predictability of the labour market between the two in relation to the factors I've mentioned.

The task for students in general science degrees and in professional degrees is to learn the known so as to be able to handle the unknown in the future. The solution lies in what we describe throughout The University of Learning as variation theory and what I have been developing since then, which I have called capability theory (Bowden et al, 2000).

Across the decades

The capability theory that I have developed has not emerged in a vacuum. It is the product of a sequence of research and development activities over many decades (see figure 1) in which I have played at least some part among many, many others.

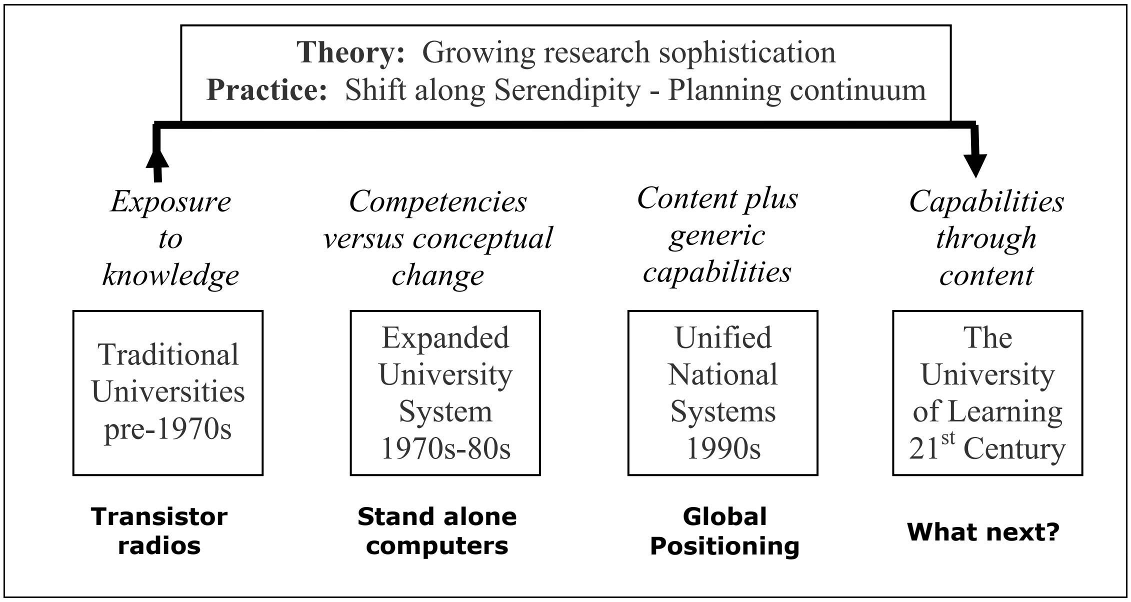

Figure 1. Education and research across the decades.

If you were to look at universities before the 1970s, when I was an undergraduate, you would conclude that the theory of practice about teaching and learning was exposure to knowledge. Teaching was about knowledge transmission and the research behind university education was by the educational psychologists like David Ausubel (1968). He was the advocate of advance organisers and retroactive facilitation. That was translated by the few educational development staff in those days into "Tell them what you are going to say, say it and then tell them what you said". Hardly sophisticated pedagogy but also very focused on the "telling" conception of teaching. Now there is nothing wrong with that advice *per se* and politicians probably do very well following it. However, it is a very limited pedagogical theory.

As the universities expanded with increasing participation rates (in the 1970's and 1980s in Australia and the UK), there was a dispute in those two countries between advocates of competencies and competency based training and advocates of conceptual change learning (see Jessup 1989; Bowden & Masters, 1993). Conceptual change learning is a self-evident advance beyond knowledge transmission but competency based training requires some explanation. I notice that the word competencies crops up in contemporary Danish literature but it seems not to mean the same thing as it did in the 1980s in Australia and the UK. Mogens Niss' concepts related to competencies have considerable overlap with my capabilities agenda despite their quite different origins (Niss et al, 2002). Niss' competencies are not the same as those argued for by the competency movement in the 1980s. [See also the papers by Niss, p. 29, Grønbæk & Winsløw, p. 37, and Workshop 2, p. 140 in this publication].

Back in the 1980s, while those who followed people like Ference Marton and his colleagues in Göteborg were advocating learning for understanding and conceptual change over knowledge transmission and rote-learning, the competency advocates claimed that the important issue was that people could do things well, whether or not they understood them. Knowledge wasn't to be tested – only people's capacity to perform what was required.

This was very much geared to the labour market and many jobs were analysed to yield the hundreds of competencies required to do the job properly (e.g. Debling 1989). Educational programmes were thought by the competency movement to be about developing each of those competencies. If someone could demonstrate they could do the required tasks (each tiny competency separately tested) then they didn't need to study the relevant subject. One of the difficulties with this thesis is the assumption that work roles can be described in terms of a large number of isolated and stable components. The complexity and dynamic nature of work roles make this an unlikely model in my view, quite apart from the other issue around knowledge and understanding.

Well, the conceptual change advocates were successful and they moved on as university systems became streamlined into national systems (in the 1990s in Australia, for instance). They embraced the additional need for what were variously called generic or transferable skills, among other names. However these tended to be taught separately from the knowledge content and often the science or engineering lecturer, upon being told by students that they couldn't complete their projects early because the following week they were to have a short course in communication skills, promptly told them not to pay too much attention to "that stuff" and to concentrate on the project. These additional aspects of the curriculum had little credibility among mainstream academics.

The capability theory that I have developed sees these so-called generic skills as needing to be integrated with the learning of knowledge and not treated separately from it. And I do mean integrated and not just mixed in. Capability theory is, for me at least, the last piece in the educational research and development progression over the decades. Clearly there is more change to come but we don't yet know what it will be.

At the same time as this development in pedagogy occurred, there have been parallel developments in technology. We have moved from the (at the time) revolutionary transistor radio through stand alone computers to global positioning equipment. Each new innovation built on earlier R&D as did the educational developments across the same period. Each was more sophisticated than what went before in both cases. In addition, the educational R&D moved from the serendipity end (lucky coincidence end) to the planning end of the continuum as we were going from the broadcast view of learning (like transistor radios?) to the "you can find a way no matter what context you are in" view (perhaps a bit like global positioning?).

Content focused versus capabilities-focused curriculum design

I want now to compare two different frameworks for curriculum design - the capability focus and the traditional content focus. There is no doubt that, as an undergraduate in the 1960s, I experienced a content-focused curriculum. Each topic was dealt with separately and independently, let alone each course. Typically in a content focused curriculum, information about content A is provided, along with examples of content A type problems. Students then go to a problem sheet or to the back of the textbook to practice solving type A problems. Later content B information is provided, content B examples and then practice with type B problems, and so on with content C, D and beyond. In the exam you could expect to find type A and type B problems, in much the same form as those at the back of the textbook. To be sure of this, you would always check the past few years' exam papers to check the pattern of questions.

One example of this type of curriculum that I experienced was in first year physics. Content A may have been linear motion. The course catalogue would have referred to, say, Newton's first law and perhaps to velocity, force and acceleration. Not much more than that and not much of an indication of what the course was about if you hadn't already studied it.

The problems that had to be solved always consisted of a description of some form of linear motion, usually involving cars on a straight flat road or trains on a straight flat track. Conveniently air resistance could almost always be ignored. I did very well in the examination and received a high grade. Perhaps I was an example of the kind of student that the lecturers in the School of Physics in the late 1980s thought had forgotten everything they'd learned in first year by the time they reached third year. In fact I never had understood anything that was intended, just like the students my research was about in the late 1980s.

The reason I managed to get good grades was because my understanding of acceleration, for instance, was quite clear. It was that acceleration is the answer to the equation that has “a” in it and for which numbers are provided in the problem for all the other letters. We had three equations to choose from: $v = u + at$, $v^2 = u^2 + 2as$ and $s = ut + ½ at^2$. If the problem said a car starts from rest and uniformly accelerates to 100 kph in ten second, what is the acceleration, I would say “I want to find “a”. I know u = 0 (starts from rest), v = 100 (gets to 100 kph) and t = 10 (in ten second). What is the equation with a, u, v and t in it? Why it’s v = u + at.” I would then solve for “a”. And so on with the next problem.

Unfortunately, when we did the research study I described earlier, the same School of Physics was teaching and assessing in the same way a quarter of a century later. High marks in such examinations do not imply conceptual understanding. For that you need authentic examinations, i.e. examinations that actually test the goals. If you want students to learn for understanding, you need to test understanding and not only the ability to solve problems by rote-learning the algorithm. This is what Camilla Rump’s more recent research in Denmark also showed.

But the difficulties with the content focus of the traditional curriculum do not end there. I well remember content B, in my case rotational mechanics. In those days we focused on planets going around the sun or moons around planets. Perhaps these days it is communications satellites around the earth. I don’t remember the equations for this one but they contained “π” and “r”. But it was the same process of information, example and practice, with little incentive for conceptual understanding. At the time, I certainly had no concept of the continuity of the concepts across those two contexts (linear and rotational motion) or that characteristics of acceleration (changing speed and changing direction) were variably present in different situations. There was nothing in the curriculum structure, the learning environment or the assessment that encouraged such speculation.

The capability focus in curriculum design is intended as a remedy for this, among other things. Students are encouraged to speculate about real situations, perhaps to compare a car getting faster on a straight road and a car turning on a curved ramp at constant speed and to consider the similarities and differences (see Bowden and Marton, 1998, pp 114-122, for more detail). Students can see that two aspects of acceleration are present and absent in opposite ways. Yet they can also see the need for force to be applied in both cases for the motion to occur as described. They can ponder a third situation of a car both changing direction and changing speed. Here both aspects are present simultaneously. Each of the three scenarios needs to be handled differently. Students should be encouraged to discuss these aspects and situations, to argue about them, to reflect on them and to write about them. In the traditional curriculum that I experienced, along with students in the same university 25 years later, and Danish students in the 1990s, there is little scope for such qualitative discussion and writing about ideas and concepts and too much emphasis on quantitative problem-solving through rote-learned algorithms.

Through reflection and discussion, students might well conclude that the first case above can be handled by the "v = u + at" type equations. Of course they then need to be able to solve those equations. However, in this way, the equations acquire their rightful status – as tools for problem solving once you've worked out that they are relevant. They are not truth in themselves. And they are not useful as tools if they are learned in isolation so that graduates are unable to work out when and how to use them to deal with real-life problems.

This ability to handle previously unseen, real-life situations, to make sense of them, to figure out what the relevant aspects are, to relate them to what you know and find out what you don't know but need to use (e.g. the equations), then define the problem and only then solve it, is what I have termed knowledge capability. You still need to be able to do the quantitative solution but only after you've figured out what is needed. Mere knowledge acquisition is one thing; the capacity to use it in this way is both more complex and more powerful. I would argue that knowledge capability should be the goal of all university learning and that such a goal should be clearly expressed in programme and course handbooks or catalogues. On many occasions, the kind of content I've been talking about is listed merely by a few technical words like: Newton's first law, velocity, force, acceleration.

The following is an alternative curriculum statement that addresses some of the content in the example I just described (see Bowden and Marton, 1998, p 126). No doubt a physics teacher could do a better job but our effort illustrates the issues I am concerned with. I argue for a much fuller description that is focused on the student, and which describes what is expected of a student as a consequence of studying such content; in particular it emphasises that the intention is for the student to learn to make sense of previously unseen situations.

> *Students successfully completing this course will understand how the concepts of force and acceleration enable explanation of the motion of physical entities in a variety of contexts, will be able to discern which aspects of those concepts are relevant to a particular context and will be able to use these understandings to explain and solve problems within that context. The contexts that will be dealt with are the idealised case of vehicles moving on straight, flat pathways without*

air resistance, more realistic contexts involving motion along the earth's surface and motion under gravity, and some cases in which the concepts of force and acceleration are only part of the explanation, along with other scientific concepts and theories. However, students will be expected to develop the capability to deal with previously unseen contexts to which the concepts and processes dealt with in this course also apply.

Knowledge capability
I would define knowledge capability more fully as the ability

- to work out what are the key aspects to be dealt with in each new situation
- to relate those aspects to the knowledge already acquired and/or to knowledge the graduate knows how to access
- to determine what the underlying task or problem in that situation might be
- to design a process or solution to deal with the situation, and then
- to follow through and complete the task or solve the problem, either alone or with others.

So far, in contrasting a content focus and a capability focus, I have been talking only in terms of the scientific disciplines. But university education is about more than that. Over a period of twenty five years I have regularly asked academics in a wide variety of disciplines, in a range of types of university, in various countries including Australia, Sweden, Hong Kong and the UK, to describe the qualities they are seeking in graduates from their programmes. I have compiled a list summarizing their responses (see Bowden and Marton, 1998, p 96), which are perhaps surprisingly consistent across all of the variables mentioned:

- knowledge of core facts
- general knowledge
- understanding of knowledge structure in related fields
- understand theory-practice relation
- appreciate real-world variation
- ability to solve problems
- ability to define problems
- lateral thinking
- communication skill
- insight
- perspective
- self-motivation

- capacity for self-learning
- ethics

You will have noticed that these deal with discipline content in various ways and also deal with other qualities commonly referred to by universities as generic skills, transferable skills or some term like these as I've already mentioned. Later I am going to present an argument that these so-called generic skills can't be separated from the discipline content but for the moment I want to show you some data about how important these other aspects of learning are rated by employers and academics.

In a study by Harvey (1993), both academics and those who recruit their graduates rated communication, problem-solving and analytical skills as the top three criteria (see Table 1). Employers added teamwork and flexibility next, while, perhaps not surprisingly, academics added independent judgement and enquiry-based skills. Knowledge *per se* was rated much lower by both groups and, while core knowledge in particular was considered somewhat important, there was little interest among employers in differentiating between graduates according to their specific knowledge. Capability theory argues that learning knowledge is a means to developing capabilities and not an end in itself. That is consistent with the findings I've just reported. Recruiters of graduates are interested in recruiting the right person, the person with the appropriate capabilities.

Top 5 criteria	***Employers***	***Academics***
Communication	1	1
Problem-solving	2	2
Analytical skills	3	3
Teamwork	4	
Flexibility	5	
Independent judgement		4
Enquiry-research skills		5

Table 1. Recruitment criteria (Harvey, 1993)

Capability theory
Let's look at capabilities theoretically. You can imagine that for any theory to have pedagogical value, it has to explain varying levels of learning outcome, it has to apply to a range of types of outcome and it needs to discriminate between performances in one situation compared with another. It is on just these three dimensions that the capability theory is based: (1) types of capability (2) levels of outcome and (3) kinds of situation.

So far as type of capability dimension is concerned, I see it more as a series of overlapping continua than as discrete values associated with a particular discrete capability. However some people still think in terms of communication capability or capability to operate in a team situation as separate from each other and from knowledge content. I believe this is not a helpful framework but in some respects it is easier to illustrate the theory by using a commonly understood type like communication that everyone knows about. I will do that for convenience here but in explaining such an example you will see that it turns out to be inextricably integrated with the knowledge content.

Levels of capability outcome
So let's look at the levels of outcome dimension. I have defined four levels. It doesn't make sense to say simply that a graduate is capable of communication. The questions "in what way?" or "to what extent?" or "for what purpose? or "with whom?" are several among many that need to be answered. So the four levels.

Scoping: defining the capability range. When dealing with communication, are we talking about written, oral or electronic communication? Is the purpose of the communication

- to pass on information
- helping a group of people understand something in a new way,
- convincing someone that your argument is valid or
- trying to understand someone else's argument (the listening side of communication)?

It might be about any or all of these and it might be about other aspects of communication. From a learning perspective, the curriculum has to be designed with these questions in mind and the student needs to scope out for him or herself just what he/she is focusing on in developing his/her communication capability.

Enabling: developing specific skills related to the capability. With the capability scoped at level one, there is no necessary demonstrable ability developed. At level two, there may be some enabling skills related to the capability that can be developed but which are not the capability itself. Here presentation skills (oral, written or electronic), debating skills, logical argument and personal manner play a part, among others, but would need to be adapted at higher levels to the various purposes defined in the scoping level and to the characteristics of the person or persons to whom the communication is directed.

Training: elaborating meaning of the capability in a particular field. The training level has been identified because different disciplines and different fields focus on some specific aspects related to the field. For example, a characteristic of communication in the field of law may be the importance of precision in language and the absence of ambiguity. Why? For the very purpose of communicating something to someone in ways that can withstand critical analysis of a legal kind.

On the other hand, a characteristic of communication in the field of nursing may be the importance of using language that displays empathy with the patient's situation. Indeed, in contrast with legal communication, ambiguity may be more acceptable in many nursing contexts than lack of empathy. And the attitude of empathy and support may be the very 'something' being communicated rather than the actual things spoken about.

Relating: developing understanding of the relation between meaning and context. The relating level goes beyond the training level and is necessary because the narrower focus of the training level is inadequate both within the professional role and in other aspects of life. The relating level is about adapting behaviour to deal with the particular context.

Consider the lawyer who has just returned to her office after a successful case in court where she communicated legally in a precise, unambiguous and ultimately successful way. She has an appointment with an elderly couple in danger of losing their home who want legal help to avoid the disaster. Upon listening to them for a few minutes during which time they talk about what their daughter advised them and how hard they have worked all their lives, she imperiously tells them to get to the point. She lists the legal issues that have to be addressed and asks them not to introduce any more irrelevancies.

If the clients were the opposing barrister, that form of communication might be appropriate. But in the circumstances, a more complete professional in law would change the way of communicating according to the context and would use simpler, more supportive forms of communication in stressful situations for clients. The lawyer could do well to display some empathy with her clients' predicament and circumstances.

In a similar way, nursing professionals communicating with a patient being discharged from hospital about the medication to be taken at home need to be quite precise and clear about the detail, even perhaps using both written and oral communication to reinforce the message, irrespective of whether they communicate empathy. A more complete professional in nursing would also understand that modes of communication need to vary with context and would focus less on empathy and more on precision when necessary.

Finally, the folly of a lawyer communicating at a party in a legalistic style (or as we've all experienced at least once, an academic 'lecturing' friends on such an occasion) points to the importance of the relating level beyond the profession. Achieving a communication capability outcome at the relating level involves contextual sensitivity of behaviour in terms of the purpose, the people involved and the circumstances of the communication process.

Of course, different students may reach different levels of outcome from one situation to another. And the pathway may or may not be continual progression. All three dimensions are important from the perspective of curriculum design, learning experience and assessment. All must be provided for.

Water quality engineer – an example of integration

I want again to reinforce the argument that the so-called generic skills are inextricably integrated with the knowledge being learned. Consider a project aimed at cleaning up a river system that has salination problems due to a century of irrigation farming that has continuously diverted water through farmland and then returned it to the river. This is a real situation in my home state.

Imagine that two water quality engineers are engaged in the project and need to interact with a variety of people as a solution is sought. Those people would certainly include other scientists and engineers but also local farmers and perhaps elected officials in the district or local bureaucrats. Most water quality engineers would be readily able to communicate with other technologists in such circumstances. You would hope so anyway. But not all would necessarily be capable of communication with the farmers in a way that helped them understand what solutions were needed and that the short term negative impacts on them are necessary to enable a long term solution. One engineer may be able to communicate with farmers effectively but another may not. Yet both engineers might be very skilled at speaking at meetings.

The difference is not just a question of communication skill as a separate entity; it is related to understanding of the subject matter. If you can explain your field in a way that the farmer can understand, and another graduate is less effective in such circumstances, then you have a more comprehensive knowledge of your field. Your knowledge is more complex and linked to other knowledge structures. So-called generic skills and the learning of content are integrated in the notion of knowledge capability which I've defined earlier.

How do we implement the reforms?

The overall focus is on graduates' ability to use what they know to do professional things rather than merely accumulating knowledge. To design such a curriculum, you need to determine the programme goals first (the intended capability outcomes), then course goals, then necessary learning experiences, and only then the teaching plans. [See also Workshop 2 in this publication p. 140.]

Authentic assessment is essential but not just at the course level. Since the capability outcomes are at programme level, there needs to be assessment across courses, i.e. at the programme level too. Inevitably, for programme capability goals to be achieved, students need to have learning experiences in which they get a chance to integrate across various disciplines – hence integration and cooperation across courses is necessary.

There is a need for students to have not just a varied experience but also to experience the variation. The content focus I mentioned earlier provided a varied experience e.g. content A is different from content B, content C etc. But there is no encouragement for students to reflect on that variation. Hence they don't (certainly I didn't) actually experience the variation and they thus don't make the connections. The capability focus encourages reflection about variation with context so that principles and contextual elements are differentiated, thus enhancing the capacity to apply the principles to new contexts in the future.

Let me give a quick example. At RMIT, accountancy has been taught for decades and graduates have gone into the workplace and successfully used accounting processes quite routinely. During the past decade or two, there has been a large increase in the number of overseas students taking studies in Australia, many from Singapore and Malaysia. After such graduates returned to Singapore, for instance, they found that the accounting practices they had learned didn't seem to work. Similarly for students from other countries. Subsequent investigations also showed similar problems for Australian-born graduates going to work in other countries. Some of them adapted but many didn't.

It was soon apparent that the problem was that accountancy was being taught with the Australian legal system being taken as given. Now, instead students are given accounting problems and asked to address them in relation to the Australian legal system and as well in relation to the legal systems of other countries and to reflect on the differences. Now, students are not learning accounting practices per se, they are learning how accounting principles are applied differently in different legal systems. Such a graduate could go to any country, would look to see what the legal system was, and then adapt the accounting principles to build an appropriate practice. Such graduates would have accounting capability and be able to use that capability to deal with new, i.e. previously unseen situations. [See also Gibbs' contributions in this publication p. 53 and 68, Workshop 4 p. 157].

Respect for students' ways of seeing

I put this forward not as an issue of democracy or politeness but rather as a pedagogical issue. The student goal should be to learn to discern relevant aspects of the situation, figure out what the problem is and how it relates to things you know or need to find out and then find a solution - developing capabilities to the relating level; to do that they must learn to value their own ways of seeing but continue to question their efficacy. Teachers who scorn students' responses as "wrong" inhibit their pondering why they saw the phenomenon that way and what aspects might be relevant to a more powerful way of seeing.

Finally, I think it is a logical conclusion that with capability goals it is the students' responsibility to learn. We can't do that for them. What we can and must do is to design the learning environment so that they are developing their capabilities and to support them as they do that. Explicit programme and course descriptions, supportive teachers and authentic assessment are a few of the essential aspects.

References

Ausubel, D.P. (1968). Educational Psychology: A Cognitive View. Holt, Rinehart and Winston, New York

Bowden, J.A., Dall'Alba, G., Laurillard, D., Martin, E., Marton, F., Masters, G., Ramsden, P., Stephanou, A. and Walsh, E. (1992). Displacement, velocity and frames of reference: Phenomenographic studies of students' understanding and some implications for teaching. Amer.J.Physics, 60, 262-9

Bowden, J.A., Hart, G., King, B., Trigwell, K. and Watts, O. (2000). Generic Capabilities of ATN University Graduates Final report to DETYA. (Retrieved June 14, 2003, from www.clt.uts.edu.au/ATN.grad.cap.project.index.html)

Bowden, J and Marton, F. (1998) The University of Learning: Beyond Quality and Competence, Kogan Page, London (paperback edition due September 2003)

Bowden, J. and Masters, G. (1993) Implications for Higher Education of a Competency based Approach in Education and training, AGPS, Canberra

Dall'Alba, G., Walsh, E., Bowden, J.A., Martin, E., Masters, G., Ramsden, P and Stephanou, A., (1993) Textbook treatments and students' understanding of acceleration. J. Res. Science Teaching 30, 621-635

Debling, G. (1989) The Employment Department/Training agency standards programme and NVQs: implications for education, in J.W.Burke (ed.), Competency-based Education and training, Falmer Press, London

Harvey, L. (1993). Employer satisfaction: interim report, presented to the Quality in Higher Education 24-hour Seminar, University of Warwick, December

Jakobsen, A., Rump, C., Clemmensen, T. and May, M. (1999): Kvalitetsudviklingsprojektet “Faglig sammenhæng”. Hovedrapport. [The Quality Development Project: Coherence within Programmes”. Main Report.] Center for Didaktik og Metodeudvikling, DTU, Lyngby

Jessup (1989): The emerging model of vocational education and training, in J.W.Burke (ed.), Competency-based Education and training, Falmer Press, London

Niss, M. et al. (2002): Kompetencer og matematiklæring. Ideer og inspiration til udvikling af matematikundervisning i Danmark. [Competencies and the learning of mathematics. Ideas and inspiration related to the development of mathematics teaching in Denmark.] Ministry of Education (Undervisningsministeriet), Copenhagen

Rump, C. (2002). Assessment in Engineering Education. (Slide 6). Presentation at Chalmers Grundutbildningskonferens, Lingården, Sweden, August (Retrieved June 14, 2003, from http://www.ckk.chalmers.se/cselt/cselt2002/proceedings/rump/camillarump.ppt)

Walsh, E., Dall'Alba, G., Bowden, J.A., Martin, E., Marton, F., Masters, G., Ramsden, P and Stephanou, A., (1993) Physics students' understanding of relative speed: a phenomenographic study. J. Res. Science Teaching 30, 1133-1148

The need for reform: Perspectives on the result of education – students' competence in mathematics

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Problems concerning university education in science and mathematics

Before looking at the problems we are facing in university education in science and mathematics in Denmark, let us remind ourselves of the well-known quotation from Reinhold Niebuhr

"God, give us grace to accept with serenity the things that cannot be changed, courage to change the things which should be changed, and wisdom to distinguish the one from the other."

The predominant problems seem to be the following:

Problems of recruitment

The problems of recruitment manifest themselves through the following *syndrome:*

University programmes of science, mathematics and technology *recruit too few students* to cater for (a) the needs of society at large – except for a possibly temporary economic recession that currently is reducing the demand for university graduates in many disciplines; (b) the fostering of new researchers for the pipeline of research and development; and (c) the fostering of new teachers at secondary and tertiary levels. In Denmark, as in many other countries, the baby boom cohorts of the forties will leave the labour market of teaching, research and development around 2010 and will have to be replaced by new generations if the gaps thus created are to be filled. Moreover, because of today's funding schemes for Danish universities, based on the numbers of students passing examinations, science faculties are not financially viable with the current student enrolment.

What would be a reasonable *diagnosis* of the causes of this syndrome? First, possible post-university careers are neither well known nor attractive enough, if related to the efforts that have to be invested in successfully accomplishing tertiary studies in science or mathematics. Why do something difficult and demanding if you are likely to be better off in terms of social prestige, working conditions and salaries by doing something easier? Or "why be a scientist if you can be his boss?", as a young academic said when leaving academia for industry.

Secondly, science and mathematics studies often have a bad reputation of being "nerdy", unrelated to life in general, lonely, devoid of creativity, difficult with high flunk rates, demanding, suffering from bad teachers living in ivory towers without caring for students. In summary: "not cool".

This leaves those of us working in universities with the following *challenges*. We have to identify what can, and what cannot, be influenced by universities, and then concentrate on doing something about that on which we have an influence.

Problems of retention

Not only do we have problems at getting enough students to tertiary mathematics and science, we also have problems concerning the students we do get. The *syndrome* is three-partite. It is difficult to retain the students, because many of them either turn out not to "fancy the smell in the bakery" or do not pass the exams often, early or well enough for their studies to satisfy their ambitions. Next, in many places there are tendencies for the student population to be bi-polar. On the one hand, we have the "happy few" with immense success, those who do well with a minimum of teaching or guidance. On the other hand, we have the "many who are not so happy", because they experience difficulties of learning, motivation or finances. These factors give rise to the final component in the syndrome, the genuine dilemma between maintaining standards (assuming that we know what this means) or lowering them. Whatever we do, severe costs follow from our decision.

What are the underlying causes of these retention problems? Here is the *diagnosis* I offer. Students often choose studies on an ill-informed basis, a combination of the public image of the disciplines, communication by older peers or family members, extrapolation of school experiences, and career and life expectations and prospects. The resulting conceptions do not necessarily correspond too well to the actual state of affairs. Then by tradition (but there are exceptions to that tradition), universities still tend to focus on the "happy few", while paying lip service only to the needs of the majority. One might even coin an implicit motto of many universities: "Those who need our teaching don't belong here". Also by tradition (modulo exceptions), university teachers tend not to engage themselves in students' learning processes, only in the outcomes of these, and they often mistake brilliant lecturing for good teaching. Furthermore, university teachers are not, in general, inclined to discuss the nature and characteristics of their discipline with theirs students. They take these characteristics for granted and tacitly assume that so do the students, or they consider it futile to talk about the discipline instead of simply demonstrating how to profess it. Finally, when university programmes and curricula are changed, they are seldom revisited in a fundamental way - reforms tend to be defensive, in response to externally generated needs or pressure. Reforms, therefore, tend to focus on structure and organisation rather than on ends, purposes, goals and (fundamental) content.

All of these factors can actually be influenced by universities themselves, albeit to varying degrees. It is a major *challenge* to us to commit ourselves to do something about them.

Further problems

The problems of recruitment and of retention are not the only ones that are nagging Danish universities in general and their science faculties in particular. But they are probably the more significant ones. Without going into details, let us briefly list a few more.

Problems of transition
The transition from upper secondary school to university is, for most students, marked by a strong discontinuity, which causes several problems. The same is often true of the transition of graduates to extra-university professions where they are met with conditions and requirements quite different from those they encountered at university.

Problems of quality and progression
When dealing with the fundamental issue of quality and progression of students' learning, we tend to tacitly nurture the following line of reasoning. The point of departure is the "equations": "quality = progression", "progression = more subject matter is acquired", hence "quality = quantity". But that is at best misleading. Instead, we should base our considerations on this equation:

"quality = in-depth mastery, insight and reflection"

If this is our point of departure, I'm afraid we have to admit that too many students gain too little quality from the diets we offer.

Problems of assessment
There often is a mismatch between the explicit ends and goals of tertiary science and mathematics education, on the one hand, and many established assessment modes and instruments currently in use, on the other. Moreover, many of these modes end instruments do not allow us to gain real insight into students' actual learning and competencies.

Once again, most of these problems can be influenced by universities themselves – and, once again, we should commit ourselves to do something about them.

However, when so doing, it is crucial that we keep in mind that harmonisation across universities would be disastrous. Programmes and curricula cannot be canonical. Genuine dilemmas with no unique solution have to be dealt with, balances have to be struck, choices have to be made, and widely varying conditions have to be taken into account. This calls for continuing reflection on what we are doing and why we are doing it. But while recognising the need for variety, we should also at the same time recognise the need for a common ground for reflection and debate, across institutions, subjects, and levels, not with the purpose of creating unity but with the purpose of making us better informed and wiser.

We should begin by asking: What does it mean to master discipline X? To illustrate how this question may be approached, we shall consider the case of mathematics.

Case: Mathematics

The question with which we shall be preoccupied in this section then is: What does it mean to master mathematics? An attempt to answer it has been made in the Danish so-called KOM project (Competencies and the Learning of Mathematics) (Niss & Jensen, 2002). The idea is to devise and adopt a competency based description of mathematics education.

Definition
To possess *mathematical competence* means to have knowledge of, to understand, do and use mathematics and to have a well-founded opinion about it in a variety of situations and contexts where mathematics plays or may play a role. *A mathematical competency* is a distinct major constituent in mathematical competence. Or, cast in action terms:

A mathematical competency is *preparedness* for *acting* purposefully and adequately, in *insight-based* ways, in *situations* that involve a certain kind of mathematical *challenges*.

This is meant to lead to a pragmatic delineation involving neither too few nor too many specific competencies. The result arrived at in the KOM project consists of eight competencies, which can be grouped in two clusters.

Two clusters of competencies

The first cluster of (four) competencies focuses on

The ability to ask and answer question in and with mathematics:

Mathematical thinking competency – *mastering mathematical modes of thought*
To

- understand and deal with the roots, scopes, and limitations of given concepts
- abstract concepts, generalise results
- distinguish between different types of mathematical statements
- possess awareness of questions typical of mathematics, and insight into the types of answers to be expected
- be able to pose such questions

Problem handling competency – *formulating and solving mathematical problems*
To

- detect, formulate, delimitate, and specify mathematical problems, pure or applied, open or closed
- be able to solve problems, posed by oneself or by others, in different ways if relevant

Modelling competency – *being able to analyse and build mathematical models concerning other areas*
To

- analyse the foundations and properties of existing models, and assess their range and validity
- perform active modelling in given contexts
  i.e. structure and mathematise situations, handle the resulting model, drawing mathematical conclusions from it, validate the model, analyse it critically, communicate about it, monitor and control the entire process

Reasoning competency – *being able to reason mathematically*
To

- follow and assess others' mathematical reasoning
- understand what a proof is (not) and how it differs from other kinds of reasoning
- understand and utilise the logic behind a counter example
- uncover the main ideas in a proof
- devise and carry out informal and formal arguments, thus transforming heuristic reasoning into valid proofs

The second cluster of (four) competencies deals with

The ability to deal with mathematical language and tools:

Representation competency – *being able to handle different representations of mathematical entities*
To

- understand (decode, interpret, distinguish) and utilise different kinds of representations of mathematical entities
- understand the relations between different representations of the same entity
- choose and switch between different representations

Symbol and formalism competency – *being able to handle symbol language and formal mathematical systems*
To

- decode symbol and formal language
- translate back and forth between symbol language and natural language
- treat and utilise symbol laden statements and expressions, including formulae
- understand the nature of formal mathematical systems

Communication competency – *being able to communicate, in, with, and about mathematics*
To

- study, interpret, and make sense of written, oral or visual mathematical expressions or texts
- express oneself in different ways, and at different levels of precision, on mathematical matters to different kinds of audiences

Aids and tools competence – *being able to make use of and relate to the aids and tools of mathematics*

To

- have knowledge of the existence and properties of different relevant aids and tools for mathematical activity (rulers, compasses, abaci, tables, calculators, computers)
- have insight into the possibilities and limitations of such aids and tools
- reflectively use aids and tools

The eight competencies are closely *related*, yet *distinct*. They all have a *dual* nature, in that each of them contains both an aspect of critical understanding and examination of others' work, and an aspect of independent and active performance of own work. Even if the terms are not listed explicitly, the competencies also comprise *intuition* and *creativity*, both of which are distributed across several competencies. Finally, although the labels used are somewhat general, and may have counterparts in other disciplines, the competencies are *specific to mathematics*, yet *overarching* across educational levels and topic areas.

Overview and judgement regarding mathematics as a discipline

The eight competencies just listed are activated in situations containing some element of mathematical challenges. In addition to the competencies, the KOM project also identified three forms of overview and judgement regarding mathematics as a whole, i.e. as a discipline. These consists of knowledge of and insight into

- The *actual application* of mathematics in other subject and practice areas
- The *historical development* of mathematics, both internally and from a societal point of view
- The *nature* of mathematics as a discipline.

How can we use this framework in mathematics education?

First, the framework can be used *normatively*, as a basis for (a) discussion of what we should be doing in a given context (e.g. assigning weight profiles to the set of competencies); (b) defining curricula in overarching, non-circular terms; (c) controlling coherence and progression.

Secondly, it can be used *descriptively*, as a means of (a) characterising what happens in an existing piece of mathematics teaching; (b) comparison of teaching and curricula, in different classrooms, at different levels or at different institutions; (c) identification of the causes of transition problems, and of (d) monitoring teaching or learning outcomes.

Finally, it can be used as *metacognitive support* for teachers and students, in formulating and answering questions such as "where are we, and where should we be going?"

If we go beyond mathematics, such frameworks, if created for other disciplines as well, can be used as a means for comparison and discussion of *different educational subjects*.

Conclusion

The adoption of a scheme, such as the one described here, as a way to characterise the mastery of a discipline or a subject is certainly not a miraculous cure to solve the problems listed in the beginning – there is no such cure. But the scheme may serve as a means to come up with less haphazard or superficial answers than the ones sometimes encountered in reforms of university teaching. The following chapter, "Competencies at ground level", by Niels Grønbæk and Carl Winsløw, illustrates how thoughts along the lines presented here can be put to use in actual university teaching of mathematics.

Reference

Niss, Mogens, & Jensen, Tomas Højgaard (eds.), 2002: *Kompetencer og matematiklæring*. Ideer og inspiration til udvikling af matematikundervisning i Danmark. København: Uddannelsesstyrelsens temahæfteserie nr. 18., side 1-334.

Competencies, version ground floor

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Introduction

As the title of this conference indicates, there is strong pressure on universities to change. The agenda is well known from abroad, in particular from U.K. where it has been prevalent since the Thatcher era, and is often formulated in terms of implementing strategies from the private sector into the public. With a, perhaps typical, delay of a couple of years, it is dominating the political discourse on education in Denmark. Some of the buzzwords are *bench marking, capacity to adapt to new situations, and ability to plan changes,* expressing society's need for a flexible workforce and the consequent need for efficient manufacturers of such workers, i.e. the educational institutions, who are then expected to set up measurable goals for this 'production'.

Being the academic nerds that we are we, and probably most university teachers, find it difficult to familiarize ourselves with the management–line of thinking which lies behind. Even if it is accepted, which is often the case, it seems to us that there is a rather long way from the glossy headings to their implementation in university teaching and learning with its strict focus on subject matter. How does one meet these demands without sacrificing academic standards? Seeing them as an add-on, we might soon find ourselves in a schism between being teachers of mathematics and coaches for personal development. To the extent universities accept this challenge for change one must find solutions to the problem of transforming the management concepts into forms that are commensurable with academic tradition and standards. One such concept, at which it appears to be promising to have a go, is that of 'competency'.

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The penthouse view

At the Faculty of Science of the University of Copenhagen, the on-going reforms may be viewed as the institutional response to the demands for change. At the curriculum level of the reform one finds under the heading "The concept of competency made operational"[2] the following list of goals:

- "Disciplinary competencies within
    - The specific subject matter universe
    - Interdisciplinary skills
    - Knowledge
    - …

- Application competencies
    - Problem perceptive skills
    - Capability to analyse and give perspective
    - Critique
    - …

- Personal competencies (the longest list) expressing
    - Responsibility for own learning
    - Ability to work autonomously
    - Capacity to adapt to new situations
    - Intercultural understanding
    - Initiative and entrepreneurial spirit
    - …

- Community competencies
    - Understanding of society
    - Ethical commitment
    - Organizational understanding
    - Economy understanding
    - …" (Clausen et al. (2002), our translation)

Appropriately interpreted, this undoubtedly is a list of desirable abstract goals. Whether it is operational, and in particular so within a given disciplinary context, is a

[2] Kompetencearbejdsgruppen (nov. 2002): *Kompetencebeskrivelser af uddannelserne.* (Report from workgroup under The Faculty of Science, University of Copenhagen, giving suggestions to study boards of the faculty in terms of a framework of competency concepts).

different matter. It is perhaps only in trying to answer this question that one can see how difficult the transformation exercise is. In all fairness it should be said that the authors of the above list make no claims of having found the final solution, but view this as a first approximation.

Here we shall not try to tell you how to implement all these desirable features in a traditional mathematics-teaching context with its traditional concepts of discipline standards. This does not mean that we do not find a change in the indicated direction to be desirable. There are many good reasons for a change of this nature:

- External reasons in terms of political and financial pressure and of applicability of university education, various ‘internal reasons’ partly having to do with meeting the external pressure;
- Reasons arising from ‘intramural affairs’ such as revision of study plans, positioning of the department in relation to other departments, etc., and
- Reasons having to do with local didactic aspects, that is, running courses with good learning outcome.

These reasons are of course interwoven, but we will focus on the last one in the setting of a specific course. This is done by presenting a rather pragmatic outline of a project, which will be presented with much more details, results and analyses in (Grønbæk and Winsløw, 2003, forthcoming).

The ground level

Let us begin by recalling a quite familiar, albeit tacitly transmitted, tradition of mathematics teaching. It has been prevalent in much of our lives as learners and teachers of mathematics. In this tradition mathematics is autodidactive, meaning it teaches itself, when presented appropriately and orderly. Accordingly, key matters such as fundamental ways of reasoning, the nature of the discipline, its core issues as well as an appropriate arsenal of additional issues are learnt by the students by means of some sort of cognitive osmosis. Hence the good teacher is the committed communicator and interpreter and the good student is the equally committed subscriber. The rest is in the subject, the message is the medium, and carefully planned exposition is the ideal of teaching. Thus when a student says ‘I don’t understand…’ the teacher will respond ‘Let me explain it differently …’ or even ‘Let me explain it once more…’ An extreme, but nevertheless attempted policy, based on this osmotic pressure idea is summarized in the folklore principle: ‘Students always learn half of what you teach them. Therefore you should double the curriculum.’

When students are devoted and gifted this model probably works fine. But in today's educational system there are perfectly good reasons other than devotion and special talents to study mathematics. This ought to be an obvious statement. At the University of Copenhagen, much has been done in the past ten years or so in order to facilitate the transition from Gymnasium (upper secondary school) to University, and to accommodate the variety of reasons for being a student at a first year calculus and linear algebra course. The result is not perfect but it is fair to say that first year mathematics has become a more manageable task for the students, while still meeting reasonable criteria for discipline standards.

Quite the same cannot be said about the course that we will report on here. The course, a third semester course in real analysis, "Matematik 2AN", is considered as containing very (or, in fact, too) high thresholds, both by the students and by the various teachers involved over the past 5 years. Due to study plan requirements and other restrictions, the course has remained more or less unchanged in terms of content. The course enrols approximately 180 students from a variety of study lines of mathematics (as a single subject or in combinations with one of physics, economy, computer science, or statistics). Some of the characteristics of the difficulties the students meet are:

- A much raised level of abstraction.
    - In the first year distance is measured by means of the usual concept of distance, say on the real line - in this course by means of an abstract concept of distance in abstract spaces.
- High demands on the ability to make formal and informal logical statements operational and/or conceivable.
    - The statement 'continuous functions on compact spaces are uniformly continuous' must be unfolded in a rather long and complicated string of logical atoms in order to be accessible to a proof.
- High demands on the ability to upgrade concepts to higher levels of abstraction.
    - For instance sets of sets or sequences of sequences.
    - Interplay between, say, different notions of distance.

- High demands on the ability to shift between different representations of the same mathematical object, and to handle different interpretations of one particular representation (Duval, 2000).

    - A function can be represented by a graph, by a rule of assignment, by a subset of a Cartesian product, …
    - The set of coordinates (s,t) of real numbers can be viewed as a geometric object to describe real valued functions, as a site for analytic geometry, as the set of functions $\boldsymbol{f}: \{1,2\} \to \Re$, …

All these aspects are part of a progression, which is fundamental to the educational goals. However, it seems a worldwide phenomenon that first courses in real analysis provide a particularly tough battleground for students' encounters with these matters. We believe that it is inevitable that students have to take cognitive leaps during their study and that we cannot smoothen everything out to one gentle slope. But very few people learn from banging their head against a wall.

A project

In the second term of 2002 we undertook to develop a project in the framework of so-called didactical engineering. Our aim was to address some of the problems mentioned above. In order to do so we found it necessary to describe course goals in a multidimensional way rather than just in terms of course content. It seems natural to focus on three aspects:

- Action - what is the student expected to *do* e.g. in terms of manipulating and applying mathematical objects?
- Level - at which degree of sophistication, technical difficulty etc.?
- Content – in relation to which subject matter context of the course?

Having set the goals for teaching and learning we further needed to back it up with descriptions on how to monitor and measure learning progression and learning outcomes. Teachers and students have common as well as differing interests in this. As an illustration, teachers may focus on reflecting on outcomes with subsequent teaching or even future runs of the course in mind; students need possibilities to demonstrate ability in accordance with the actual course goals. Hence we needed to construct forms of evaluations to meet a variety of purposes: diagnostic, formative, and summative.

The ability to bring content knowledge into action, i.e. using and acting with what one knows, is at the heart of the competency concept in whatever form it is postulated. A general framework for describing competencies related to mathematical activity has been given in what we refer to as "The KOM-report" by Niss and Jensen (2002). Our project may be seen as an attempt to implement the ideas of the KOM-report in the setting of university teaching in order to construct both a theoretical framework and a set of practical tools that are fit for use in this context. In our view, the KOM-report is a rather thorough description of mathematical expertise and competency. However, as pointed out in several places by its authors, it is not a recipe for constructing course descriptions. Accordingly we have adopted it as a resource of inspiration and point of reference for extracting the essence of what is at stake in an actual mathematics course, within a specific educational context. [See also Niss' contributions, p. 29, and Workshop 2, p. 140, in this publication].

Our main tool is that of *specific competencies*. A specific competency consists of the ability to perform a general type of mathematical action (for instance in the sense of the KOM-report's classification of competencies) in the context of a specific area of mathematical contents. In real life, one cannot observe (and evaluate) 'competency' directly, but only 'performance'; and performance is always situated in specific contexts. Of course, we may *interpret* performance as based on specific competency, which, again, can be analysed in terms of more general competencies, such as those described in the KOM-report. Schematically the approach may be pictured as in figure 1.

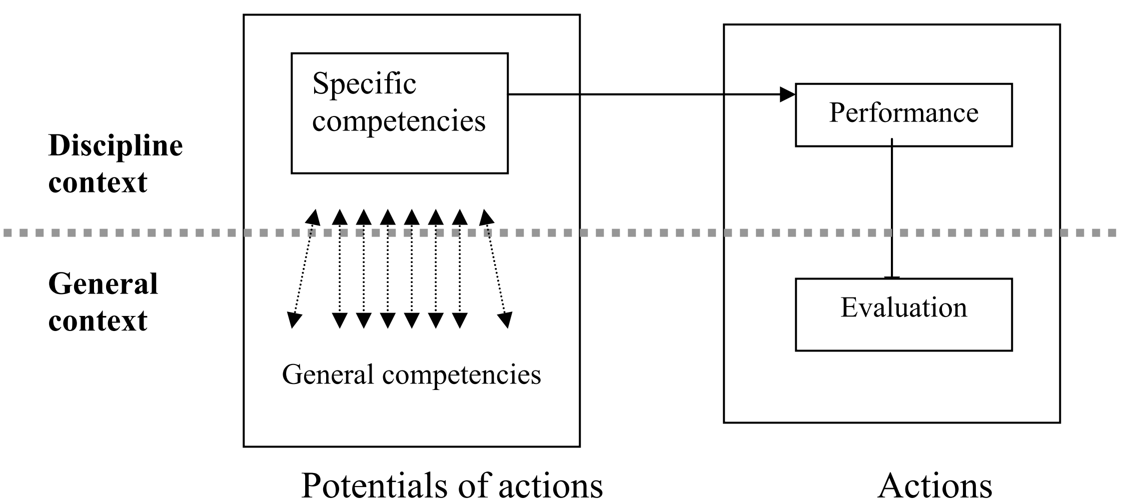

Figure 1. The competency approach of the project.

We communicated the *specific competency goals* (abbreviated here as SCG's) of this course to the students in the form of a table relating specific course content to descriptions of requirements in terms of performance. An example of an SCG entry in the table could look like:

- Content description: Equivalence and cardinality of sets, cf. textbook p…
- Action:
    - Explain the concept of 'countability' and the most important examples in …
    - Handling of simple unseen examples
- Level: Exercises … of Chapter …

Our ambition was that the totality of the table would provide the students with sufficient examples from the teaching environment in order for them to assess their success in daily learning tasks, and in order to give them a basis for evaluating important aspects of their competencies relative to pertinent course subject matter. The latter point requires that course assessments have counterparts to the table's SCG's.

Changes in the course organisation
Several changes to the course were implemented:

- Adoption of a textbook (instead of lecture notes). Of course the abovementioned descriptions of SCG's rely heavily on the teaching material. We found that a textbook with a more contextual approach and possibilities for exploration suited our purpose better than notes tailored to the lectures.

- Exercise sessions were organised around the development of separate SCG's, as they appeared in carefully chosen problems - for instance illustrating the meaning of an SCG at various levels.

- Six 'thematic projects' constituted a significant part of the course work. Each was formulated as a guided tour of a topic within the scope of the course content, in the form of a list of more or less open-ended tasks. Whereas the exercise sessions focused on SCG's one by one, the thematic projects dealt with several SCG's in combination. An important aspect was that it was possible for the students to upgrade answers to (parts of) the thematic projects during the course, thus demonstrating increase in competency with respect to volume and level.

- Traditionally it is recommended – rather informally - that students form study groups and ask questions to the lecturer. We addressed this issue much more directly by actively organising the formation of study groups for work on the thematic projects, and by converting some hours of lecturing into ‘consultation hours’ where students could get help and feedback on their project work.

- The lecturer (the first author of this paper) refrained from ‘wall-to-wall’ coverage of all the central proofs. Instead, lectures served to introduce and discuss the general ideas and results of the textbook, to point out difficult and important steps in arguments, and to make introductions and connections to related points of the thematic projects.

Except for the first point, on adoption of a new text, which required the acceptance of the study board, all of these changes took place within the ‘usual’ teaching formats and resources. At the level of course content headings our version of the course covered the usual topics.

One feature of “Matematik 2AN” which seems almost inevitable is that new material is presented in rapid succession. It is probably necessary that one exert single-focused narrow attention at one’s first encounters with new material in order to acquaint oneself with unfamiliar properties, so typically exercise sessions deal with simple closed tasks relating to the agenda of the lectures of the previous week. If this were the only activity of the course, the students might get a fragmented impression of SCG’s and consequently miss important properties dealing with combinations and connections. Likewise such an organisation seems somewhat inappropriate as a setting for development of more general aspects of competency, such as creativity, independence, and communication and reasoning skills. The main reason for the introduction of thematic projects is to compensate for these shortcomings.

New features of assessment

We did not change the general format of examination for “Matematik 2AN”. This has two parts: a written, 3 hours test (books, notes etc. allowed) and an oral exam (30 minutes examination on a randomly drawn topic, with 30 minutes preparation). The final grade is given as an average of the results from the two parts, balanced with an overall performance assessment, but there is no official grade given for each part.

The usual procedures are, roughly, as follows: the *written* exam consists of 3-4 longer problems, of varying difficulty; according to many students, this means ‘mostly difficult’. At the oral exam, the student draws a question from a list of (typically 10-

20) topics, and after preparation the student presents that topic (for instance a theorem and its proof). The list of topics is usually published a couple of weeks prior to the end of the semester. For some students this provides a good exercise in understanding and communicating intricate mathematical arguments; but especially weaker students tend to deliver memorised 'proof recitations' with little evidence of understanding.

After the presentation of the drawn topic, it is customary to ask a few supplementary questions (on another topic). An external examiner assists the teacher at the oral exam.

The changes in assessment we implemented were announced from the beginning of the course, and consisted of:

- The *written* exam was based solely on simpler problems, with each question pertaining to one or a few SCG's (as in the exercise sessions).

- At the *oral* exam, one of the six thematic projects is "drawn" and presented after the usual preparation time; the student gave two copies of his report for the drawn project to the examiners.

It is paramount to the credibility of (summative) course assessment that it reflects important points of the teaching agenda. Accordingly the written exam was adjusted to correspond to the practice of training separate SCG's in the exercise sessions. The change of the oral exam is of a more thorough nature and served a range of purposes. First of all it encouraged the students to work with course issues throughout the semester rather than in a hectic and relatively short exam preparation period. Secondly, it directed focus on students' own work rather than on reproduction or reformulation of ready-made expositions such as they appear in textbooks. We believe that this provides a wider territory for students within which to exercise their competencies. This of course is at the likely cost of ending up with less fancy mathematical results, but we find it a price worth paying. It is better to state and prove a version of a theorem one can comprehend than to attempt a version in which basic ideas are overshadowed by technicalities or complicated hypotheses.

In a situation like this, in which the final assessment is based on students' work through the semester, there are two immediate questions to address. First, it must be clear that students really do present their own work. We believe that the emphasis on the importance of students defending their own work had, in itself, the effect of diminishing cheating. This, in combination with requiring the students to sign the work they presented, makes us believe that the level of cheating has been at least no higher than with the standard exam, in which it also is possible to present 'borrowed material'. The second question deals with feedback during the semester. As we did not want complete answers to be circulated, the TA's were instructed to give only oral feedback to questions such as 'How do I get started on this?' or 'Am I on the right track?' In addition, we did not have means (in terms of allocated TA-time) to give the students confirmation of the satisfactory state of their work, say in the form of corrections of reports. Thus there was substantial emphasis on students having to maintain the overall responsibility for their work.

What were the effects of the change?

We are not done with the detailed analysis yet, so this will only be a qualitative response, mainly based on spontaneous reactions from involved parties. Nevertheless we believe that our immediate experiences encapsulate essential features of our project as well as more general aspects of reform as such. Let it be said from the outset that our project is not a clear success if this is to be understood as improvements on all of the troublesome characteristics mentioned above – much raised level of abstraction, high demands on ability to work with formal and informal logical statements, etc. First of all, the pass rate is at the same level as previous years. Secondly, despite the abundance of explanations of what the students were expected to do they did express anxiety and uncertainty about course and examination requirements, particularly in the beginning of the term. It is a big lie to say that "change cheers" as a transliteration of a Danish colloquial expression reads. Real change often hurts in the beginning, although the succeeding development might be delightful.

Table 1 summarizes the reports from the teacher to the study boards of his two most recent runs of "Matematik 2AN", namely in 2000 and 2002 (the course was taught by another teacher in 2001). The pass rate is computed as the percentage of students with at least a pass grade (i.e. 6) against students attempting the written exam.

Year	Enrolment	Written Exam	Oral Exam	Pass rate, %	GPA
2000	215	156	128	73	7.4
2002	173	114	94	72	8.5

Table 1. Enrolment figures, numbers sitting for written and oral exams, pass rates and average score (GPA) on the Danish ten step marking scale. The scale goes from zero to thirteen omitting the figures one, two, four and twelve.

The increase in average marks from 7.4 to 8.5 could, indeed, be seen as an indication of increased quality of learning. This is also substantiated by remarks from students and the external examiner and confirms our own believes that the basic idea is good (examples provided in figure 2). However, this needs further adjustment. [See discussion remarks p. 51].

External examiner

…Students are forced to study rather than to go to school.

Students

…I have learnt much from working with the thematic projects. About defining a problem, about solving it, and about precise formulations…. The hard work paid off at the end.

…It really provides opportunities to handle the subject matter in completely new ways. In addition, one is forced into substantial and called-for self-discipline.

Figure 2. Extracts of comments on the project, provided by the external examiner and two students (our translation).

In list form some of our immediate experience reads:

Bad aspects:

- Thematic projects were too encompassing and too difficult.
- SCG's never became really clear in the problem sessions, partly because the TA's were not instructed properly, partly because the exercises had too high initial threshold.
- We had underestimated expectations about traditional ways of teaching.
- Focus on competency should be addressed much more directly so that students do not see it as just an added complication to the curriculum.

All these aspect have to do with the actual implementation. We think they can be dealt with by modifying the implementation, without serious consequences for subject matter standards, but with the effect of enhancing competency achievement.

Good aspects:

- Students have acquired ownership to exam questions and to course outcomes as such. We believe that this makes their learning more lasting.
- Students have been forced to reflect positively on what they know and can do. In purely content-based teaching students are typically assessed by counting down from the ideal. In the competency-based teaching one assesses students by adding up their abilities.
- For the first author of this paper as a teacher the competency aspect worked in two ways: in the planning phase as a second dimension in the stipulation of course requirements for satisfactory participation and during the semester as a means to keep focus and goals in mind. In particular, having decided that the purpose of lecturing was to give perspective, to explore difficult or exemplary arguments and reasoning, to point to (mostly intrinsic) connections, etc. rather than going through (all) proofs in detail, it served as an anchor point, preventing one from the pitfall of adding on and rushing. If the teacher feels his responsibility is to have covered most content knowledge in great detail, as is usually the case when the curriculum is purely content based, it often leads to information overload during lectures. In the two dimensional content–competency approach, the teacher's responsibility is rather to set the scene. This gives a totally different pace and opportunity to address learning more directly.
- As a 'learner of students' learning', the teacher became aware of learning obstacles related to the competency dimension, that he has not paid sufficient attention to previously. As an example: focus on the representation competency made it clear to him that frequent changes in representation during a lecture is not just mere rephrasing, but may be precisely what makes an exposition incomprehensible.
- The competency dimension, as it was expressed in SCG's and in thematic projects, was the basis for a semester long dialog with students about course goals both as an issue and as a reason for many fruitful discussions.

But the most crucial outcome of competency basing is to us expressed in one word: **contact.** All learning is the result of qualified and purposeful contact – between teacher and student, between student and subject matter, among fellow students, etc. If focus is purely on content, there is simply less need for contact and if contact occurs it will most likely be of a static nature, amounting to respective reassurance that the content is "in place". The dynamics lie in exchange of content. Interaction requires doing and is therefore in compliance with a competency focus. Of course, in more or less tacit ways competency goals have always been on the teaching agenda. However, when it remains tacit, some opportunities for learning oriented contact will be lost. By explicitly telling the students what the teacher wants them to do with the subject matter s/he invites them to interact and perform with fellow students, the teacher, and the subject matter.

Some examples of enhanced contact:

- Many letters (e-mails) from students about their views on mathematics with constructive criticism of the course.
- More extensive use of office hours.
- More students contacting the teacher in the break between or after lectures.
- More students questions from the auditorium.
- More curiosity expressed by students about further topics.

We are aware that much of this is also the effect of the mere change in course formats. Any attempt to make people do unusual things and under changed conditions provokes resistance and anxiety in some and excitement in others. So one will automatically get reactions and thereby contact. However, in the case at hand, these reactions have been to the point and will serve as a basis for the adjustments for next run of the course.

If a primary function of competency based educational programmes is to facilitate contact, it is perhaps not paramount what underpinning it has in terms of abstract formulations of competency goals – as long as such an underpinning exists, is explicit and transparent to the parties involved, and describes aims at competencies that are assessable and operational in concrete subject matter contexts of the relevant education. And this is a tall order. We have found that the framework of specific competencies may well serve.

References

Artigue, M. (1994): Didactical engineering as a framework for the conception of teaching products. In Biehler, R. et al. (eds.), Didactics of Mathematics as a scientific discipline, pp. 27-39. Kluwer, Dordrecht

Biehler, R. et al. (eds., 1994): Didactics of Mathematics as a scientific discipline, pp. 27-39. Kluwer, Dordrecht

Clausen, H. et al. (2002): Kompetencebeskrivelser af uddannelserne. Oplæg til begrebsskabelon til studienævnene. [Description of competencies in study programmes. A template provided to the study boards for their consideration]. Det Naturvidenskabelige Fakultet. Københavns Universitet, København

Duval, R. (2000): Basic issues for research in mathematics education. In T. Nakahara et al. (eds.): *Proceedings of the 24th conference of the international group for the psychology of mathematics education*, vol. 1, 55-69. Hiroshima University, Hiroshima.

Grønbæk, N. and Winsløw, C. (2003, forthcoming): Developing and assessing specific competencies in a first course on real analysis.

Nakahara, T. et al. (eds., 2000): *Proceedings of the 24th conference of the international group for the psychology of mathematics education*, vol. 1, 55-69. Hiroshima University, Hiroshima.

Niss, M., Jensen, T.H. et al. (2002): Kompetencer og matematiklæring. Ideer og inspiration til udvikling af matematikundervisning i Danmark. [Competencies and the learning of mathematics. Ideas and inspiration related to the development of mathematics teaching in Denmark.] Ministry of Education (Undervisningsministeriet), Copenhagen

Discussion after the contributions of Niss and Grønbæk

Reporter: Jessica Carter, University of Southern Denmark

During Grønbæk's presentation Ditlevsen, University of Copenhagen, commented on the results in table 1 [p. 46] that it was the "good students" that had become better. To this Grønbæk replied that two of the students who took the course for the third time had taken up the challenge of the new course and had actually obtained 9 and 10. However, Geckler, University of Copenhagen, commented that it is impossible to draw any definitive conclusions from the numbers in table 1.
Gibbs, Open University, UK, stated that it is not possible to draw any conclusions about whether the students have become better when changing a course. Most often when a course is changed, the assessment is also changed. Only in the subsequent modules that have not been changed, will it be revealed if the students actually have improved.

Janfeld, University of Southern Denmark, asked for the conclusions from the research project concerning the use of competencies in high school and its relation to the students' choices of subjects that Niss had talked about. Niss commented that it was not a research project but a project of some of his students he had supervised. The objective of the project was to determine to which extent the teaching is a factor in students' future choices of a subject. Along the way the students' found out that they could use competencies both as a method to describe what was going on in the classroom and to interview the teachers. As it was not a research project there were no conclusive results, but the project indicated that the teachers who emphasised the problem handling competencies were best able to interest the students.

Niss also asked Grønbæk a question which led to the final discussion: In his presentation, Grønbæk indicated that adding competencies to the course implied that the course became more complicated. Niss asked Grønbæk to elaborate on this. Grønbæk answered that one of the mistakes they had made in the course was that they had not been thorough enough in explaining to the students what they were doing and why they were doing it. Niss remarked that from a students' perspective it could look as if something in addition to the traditional syllabus had been added, so that they would have to learn both the syllabus content and competencies. This led to a comment from Gibbs, who claimed that when one chooses to work on the basis of competencies one has to get rid of some content. The question is what is valued most. In the light of the evergrowing body of mathematical knowledge, Grønbæk answered that it would be more valuable to know how to read a mathematical textbook than to learn a small amount of the current knowledge. Bowden, RMIT, Australia, agreed that there is a trade-off with content and added that it is more valuable to know how to access knowledge, especially because you do not carry content with you forever.

Incentives for teachers –

How should we reward participation in reforms?

Graham Gibbs, Open University, England

Background

In 1991 I tried to find out what proportion of academic promotions in UK Universities and Colleges were made primarily on the basis of research achievements and what proportion were made primarily on the basis of teaching excellence. A survey of 140 institutions revealed that 90% included teaching excellence in both appointment and promotion criteria. But when they were asked what proportion of promotion decisions was made on the grounds of teaching excellence, the answer was below 10%. Responses included "not in living memory" and "not at this university!"

In 1963 there was a review of higher education in the UK – the Robbins report.[3] This report identified a new phenomenon: that academics whose research was strong were getting promoted much more often than those who concentrated on their teaching. This was identified as potentially a serious challenge to the main mission of universities: to teach undergraduates. Well, of course, nothing was done about this problem. There was another similar review of the entire system more than 30 years later in 1997 – the Dearing report.[4] And Dearing said that the phenomenon of unbalanced rewards for research and for teaching was by then very serious for the quality of teaching throughout higher education. In America a parallel review was undertaken by the Carnegie commission and that led to what in America is called the 'Roles and Rewards' initiative'.[5] This review was a re-analysis of what it meant to be an academic – what the role of an academic was, and what academics should be rewarded for. Huge national surveys showed that every category of staff, from junior teachers through professors to senior administrators, in every type of institution, from community colleges to elite research institutions, believed that more emphasis should be placed on teaching, and the reward of good teaching, than was currently the case. This is a phenomenon that has happened all over the world and it has happened over the last 30-40 years. There has been a reorientation of universities everywhere to

[3] Higher education: Report of the Committee appointed by the Prime Minister under the chairmanship of Lord Robbins. 1963. Her Majesty's Stationary Office.
[4] http://www.leeds.ac.uk/educol/ncihe/ [retrieved 2003, July 24]
[5] http://www.aahe.org/FFRR/ffrrnew2.htm [report: 2000, January 24. Retrieved 2003, July 24]

become research institutions and to stop being teaching institutions, even if they still have the students or even far more students.

When the Dearing report was being prepared in 1996 I was commissioned by the Higher Education Funding Council for England (HEFCE), which is a body placed between the government and the universities. The government allocates €5 billion to the HEFCE who distribute it to universities. In effect the HEFCE said: "We are going to be told by the Dearing commission that teaching has not changed fast enough. The context has changed dramatically quickly. Instead of having 6% of our 18-year olds in higher education, we now have 42%. Average class sizes are six times as big as they were when Robbins reported in 1963. And despite that, teaching looks pretty much the same as it did 30 years ago, and this despite lots of initiatives designed to support innovation." And that was the problem – they'd had initiative after initiative after initiative. The Teaching and Learning Technology Program cost € 100 million, and left hardly a ripple in its wake. About six months after the funding stopped the software was on people's shelves collecting dust. Innovation is not the issue – there is no shortage of heroes and heroines who are innovating despite the system. The problem is spreading beyond the heroes and heroines. It is embedding innovation so that it becomes mainstream activity which is the problem. I keep telling the HEFCE that we don't need more innovation. That's not the issue. The problem is getting beyond the innovators.

I was asked to review all the kinds of expensive national initiatives and institutional initiatives that had tried to bring about change, to say why it hasn't worked and to propose an alternative. It led to the 'Teaching Quality Enhancement Fund' (TQEF) which was underpinned by an explicit strategy for change. The first sentence of that strategy reads "This strategy is for encouragement and reward. We wish to increase the status of learning and teaching and to reward high quality." There are a number of elements to this strategy. One element is to support the development of disciplinary networks, like the DCN, for sharing teaching, learning and assessment practices within disciplinary areas, across institutional boundaries. The UK now has 24 'subject centres' – a subject centre for physical sciences, one for biological sciences and so on. Each centre has an office staff, organises workshops and conferences, has a website and does all the kind of networking the DCN does. But the most important element of the strategy, and the one with most financial support, is called the 'Institutional Learning and Teaching Strategy Initiative'. This initiative works by the HEFCE offering institutions substantial sums of cash in relation to their size provided that they develop and implement a strategy for improving teaching and learning at your university. This is not about using tactics (such as using C&IT) or projects (such as a particular use of C&IT in one course), but about being strategic. Provided institutions report each year on their activity and plans in relation to their strategy then they continue to receive funds. Despite it being an entirely voluntary system every university and higher education institution in Great Britain now has a learning and teaching strategy. One of the most important features of all these strategies is how the universities reward excellence in teaching and how they change the climate within which academics work so that teaching is more valued. So it is a huge national scale initiative that is changing cultures, career structures and academics' sense of what their work is about.

As well as involving changes to promotion this involves changes to initial academic appointments. The Ivy League in the USA – or at least most of them – Princeton is the best example – use a process that focuses on teaching when they appoint somebody to a tenured position. They call it a 'pedagogical colloquium'. An applicant, as well as talking to the selection panel about their research, is told: "If you come here, you'll probably be teaching this course. We want you to give us a seminar about how you are going to teach this course and how you are going to develop it over the next five years, and in particularly how you are going to assess this course." This is part of the selection process. Now, they are going to be selective primarily for their research potentials – it is, after all, Princeton – but they also make sure that they do not appoint people who are going to be an embarrassment to them as a teacher for the next 40 years. In England even the London School of Economics has an initial training programme which you have to successfully complete or you cannot get tenure. This is of course already the case for all Norwegian universities – you have to complete their pedagogical programme or you cannot become an assistant professor. So they are putting a filter in at the beginning to stop people coming in who do not value teaching. Academic values are a key issue.

If less than 10% of promotion decisions were being made on the basis of teaching excellence, in England, the question arises: "What proportion of academics do you have to reward to get the whole institution to change?" The pro-vice-chancellor for teaching at the University of Coventry has managed to bring about some fairly spectacular organisational changes across the whole university. His strategy is based on three categories of academics. He calls them tigers, elephants and hippos. The tigers go off through the jungle – you have no idea where they are going, and often they don't even leave a path behind them. You don't have to worry about them. Some of them leave a bit of a trail behind them – and if they do, some of the bold elephants will follow. And elephants leave a great big trail behind them, and then the other elephants follow until all the elephants have gone through the jungle as well. But the hippos stay in their mud hole and there is nothing you can do about it. He is interested in what it takes for the elephants to follow – that's the thing that makes the difference to the organisation. It doesn't help to keep rewarding the tigers – they will go of and do new things without any reward. It is no good having reward mechanisms that only reward 9% - you won't get anywhere like that.

Why is it that incentives are the issue here? If providing incentives to teachers is the answer, what is the question – why have we got to a position where this is an important issue? Later I will describe to you some of the incentives mechanisms that universities are actually using so you can see how it is done. But first I'd like you to think about what it is that you are trying to get out of having incentives? Incentives are a process, but what are they for, what are they trying to achieve? After that I will exemplify some of the different kinds of mechanisms (promotion, teaching awards, teaching development roles and other incentives) that institutions are using. These mechanisms achieve very different kinds of things. And finally I'll highlight some key issues about choices you may need to make.

If providing incentives to teachers is the answer, what is the question?

Why have teachers not reformed already? I think this is largely a cultural issue. I did a research study about whether the training of university teachers makes a difference. We got money to do a big international study of whether people who went through one-year programmes for new university academics in different countries teach any differently than people who did not go through them. We studied 22 universities in 8 countries that had year-long in-service programmes. We did before and after measurements of various kinds and we discovered that students perceived those who had been trained to be competent as classroom teachers in a whole variety of ways to a greater extent after a year. We also found out that teachers moved from being teacher-focused to being learner-focused – so they changed their conceptions of what their job was and what they should be doing as a consequence of these programmes. Finally we discovered that their students were less likely to take a surface approach (only trying to memorise) a year later. So we had a variety of evidence of impact. But we also had a control group of universities where there was no support of any kind for new academics. And the teachers there didn't just change over their first year of teaching, they actually got worse. They got statistically worse on most of the measures we were using. And we asked ourselves: "Why would unsupported teachers get worse over their first year?" Is it because they see their colleagues getting rewarded in the university system for their research and not their teaching, and the new academics tune in very quickly to what counts? This is a reward and value issue. Or is it perhaps a kind a self-protection – the new unsupported academics have perhaps had some bad experiences with having to teach less interested students and therefore to avoid any further defeats they change their priorities to research instead of teaching? This might be a question of fearing failure instead of hoping for success. We talked to some of these new academics, and what they said was: “Your main priority in your first year is to be accepted as a real academic. You have been a senior student, now you are a junior academic. You have to somehow make that transition to be one of a new community.” And this is a cultural phenomenon, and the way you do it, is to be as like them as possible. So you revert to the cultural norms of how things are undertaken. So the main thing for the new academics was learning how to be like the others. Universities have cultures and communities where these things take place, and tigers don’t care about that. Tigers ignore those things – they go off their own way anyway.

So why don’t teachers put more effort into improving teaching? There are different kinds of incentives – there is the formal one, promotion – but teaching seldom gets rewarded. Rewards are largely given for research excellence. And teaching is a solitary activity – it takes place behind closed doors and nobody else knows about it. Your research is a public activity – people send you e-mails saying: “I really liked your article on this”, they applaud you at conferences. There is a difference between the ways we behave towards research excellence and teaching excellence. It is not all about prizes; it is about peer esteem, and for that to happen it has to be more public.

And there are some curious disincentives for improving teaching. We have very odd ways in Britain of allocating teaching duties and it has to do with class contact hours. In all the new universities that used to be polytechnics there is a contract to fulfil a certain number of hours teaching in a year. If you manage to work out a very cost effective way of delivering a course with resource based learning or computer based learning that involve less class contact time, you would simply be allocated another course to teach to make your hours up to the contract maximum. So there is a very explicit disincentive to be cost effective. There are lots of mechanisms like this about the ways duties are allocated. People innovate on a course, and your head of department promptly moves you to another course so that somebody else takes over the work you have done for the last five years and you innovate on another course. Teachers learn to keep their heads down and not get noticed.

The next thing I want to pursue is the issue about beliefs about where teaching excellence comes from. Many of our universities say that the quality of their teaching is based on the quality of their research. “We are good at teaching because we are a research led institution”. It is a very pervasive belief. But what we know from our research evidence is that the level of the individual teacher, whatever kind of measure of research you use, and whatever kind of measure of teaching you use, there is no correlation at all between research and teaching. Good teachers can be good and bad researchers, good researchers can be good and bad teachers. You cannot predict one from the other. These are unrelated domains of endeavour as far as we can measure it. The kinds of studies that have been undertaken to explore the linkage between research and teaching collect data across many universities within the same discipline area, inside a single institution, inside a single department – it doesn't matter what unit you are studying, the same phenomena occur. In recent years the studies of these kinds have even shown negative correlations, and my interpretation of this finding is that people are so busy now that one hour extra on research means one hour less to spend on your students, on preparing your teaching or on giving feedback on students' work, and it is as simple as that. More of one means less of the other.

As a result of the lack of correlation between good research and good teaching, people have made very specific hypotheses that "if I'm a researcher then my students will develop greater independence of mind", so they would describe generic academic outcomes that obviously could only possibly be nurtured by an active researcher. None of these hypotheses has been supported by empirical studies. Nobody has yet come up with a hypothesis, about what it is that students get out of a person being an active researcher that would benefit the students, and been able to identify an impact. You have to distinguish between undergraduate teaching and supervising somebody doing research. But there is a clue there, because if undergraduate learning resembled postgraduate learning, involving teachers' supervision of research-like learning processes, then maybe there would be correlations at undergraduate level between teaching excellence and research excellence. But there is a curious phenomenon in Britain that teaching in our research led universities tends to involve traditional lecture and exam-led learning processes, whereas teaching in our teaching led institutions tends to involve more active learning processes and assessment by coursework. In fact undergraduate learning often looks more research-like in teaching universities than it does in research universities – you get more project work, more open ended tasks, more collaborative learning, in those institutions that specialise in teaching. Paul Ramsden, who developed the Course Experience Questionnaire now used throughout Australia, undertook a large study in Britain that used the Approaches to Studying Inventory (ASI) that measures whether the students take the deep or surface approach to learning. The study compared the polytechnics (teaching institutions) with the universities, and found that students took a deep approach to a greater extent in polytechnics than they did in universities. This lack of linkage between research and teaching is not a law of the universe and it is not inevitable that there is no link. What happens is simply the result of the way we at present organise ourselves, our teaching and our staff.

More recently researchers have been doing interview-based qualitative studies asking students: “what effect does it have on your experience as a student that your lecturer is currently an active researcher?” Students are ambivalent. They say things like “Some of the lectures – not all – are really interesting, because she/he is talking about what they are researching and that’s really interesting. Unfortunately, that is the only time I see them. They are never in their office. They go away for four months at a time.” There are practical downsides of your lecturer being an active researcher, and the benefits are experienced here and there in little peaks.

When the Americans started looking at this phenomenon of relationships between research and teaching, the framework that helped most was that of Charles Boyer, describing scholarship as the key issue. He distinguished between: scholarship of discovery, which is what scientists mainly do when they’re researching; scholarship of integration which is what a review article would be in a journal, or what the Open University does when it writes course materials; scholarship of application which would include consultancy, and scholarship of teaching which includes understanding your subject from a students’ perspective and understanding the pedagogy of your discipline, so that you can teach well. To give an illustration of what Boyer means by scholarship of teaching, I was doing some workshops at Stanford University, and I attended a lunch time event where the Professor who was being given the Stanford Teaching Prize gave a presentation about what he did. And it turns out that this was an internationally famous chemist who taught Chemistry 100 (an introductory course to chemistry) and he chose to teach introductory chemistry. He thought this was the most important course he could teach. And the thing that was applauded was that every week he met with all his graduate teaching assistant who taught the ‘sections’ (the American model involves big lectures, and smaller discussions convened by post graduates) and would say: “This week the things that students will have trouble understanding are these. And this is why they will have trouble understanding them. And these are good ways of explaining them.” He really understood not only what the key concepts were to a very deep level, but he understood how students understood and misunderstood them. That’s one aspect of scholarship of teaching.

If you want your teaching to become better, what helps you most is the scholarship of integration, the scholarship of application and the scholarship of teaching. It is being able to pull material together and to communicate it in a coherent way and it is being able to give examples and relate the abstract to the concrete. Scholarship of discovery is much less useful to you in your teaching and yet, in Britain at least, the scholarship of discovery is the only thing that is valued. Our ‘research assessment exercise’ does not care about consultancy. If you have written a textbook this is considered of no value whatsoever when research is reviewed. So we only value one particular kind of scholarship and that is the part that relates least to teaching.

But why is teaching not valued? It is obviously perceived as a by-product of research as I have talked about before. I hope I have undermined the perception of being a good researcher means being a good teacher. But it has also to do with the perception of teaching as a craft rather than a scholarly or intellectual activity. It has a much lower cultural status as only a craft. Then there is the perception of teaching as immeasurable – that it is easy to measure research but you can't measure teaching, so you might as well stop trying. But teaching can be measured. There have been developed extremely reliable questionnaires like SEEQ[6] and other methods developed from pedagogical research. But most questionnaires that most universities use are appallingly unreliable, they're not built on pedagogical research about what makes a difference to students' learning and so they are indeed very poor measures of teaching. Students are perfectly capable of distinguishing between teachers they like and teachers that are good. When they can't distinguish it is because the questionnaire is badly developed. And students can rate teachers reliably and validly immediately – they don't have to wait until years later when they might finally appreciate how they were taught. It is also possible to do observations reliably with observation schedules, but nobody does it. The interesting thing is that many of these judgements are more reliable than peer review of research.

Lee Shulman has said that teaching is not valued because it is not judged. The value comes as a consequence of rigorous regular judgement amongst peers. It is not seen as hard to teach. While research grant applications have a very low acceptance rate, plans for teaching courses are almost always accepted: the judgement standards are much lower. Imagine what would happen if only one in five course proposals were accepted and you did not get any funding (or pay) unless your course proposal was accepted. Those who managed to get their proposals accepted would immediately become high status individuals and the quality of course proposals would soar. It is through the rigorous judgement of teaching that value and quality can be generated, just as it is rigorous peer review of research that creates quality and status and value in research. That is why the quality of research is often high and the quality of teaching is often low – because there is a lack of rigorous and regular peer review. At Gloucestershire University they use teams of five teachers, from across different courses, that regularly meet and review each other's courses and teaching informally.

[6] Student Evaluation of Educational Quality. See for example http://lsn.curtin.edu.au/seeq/about.html or http://www.umanitoba.ca/UTS/publications/teachingevaluations.php

At Gloucestershire this is a quality enhancement procedure and has nothing to do with promotion, but it has a good deal to do with values.

Incentives through promotion

The next section will illustrate some of the practices that universities and departments in the UK are actually using to reward teaching and to reward engagement in reform.

Universities started adding teaching criteria into criteria for promotion a long time ago and frankly it doesn't make much difference, it is just ignored. Sometimes people have specified the criteria much more explicitly and elaborated what they mean by it. Sometimes even in relation to pedagogic literature, so they've got a particular model of what they think excellence is and they describe it quite carefully. I think that doesn't make much difference either, actually. Some people define excellence not just in terms of good and bad, but in terms of the goals of the institution. The institutional teaching and learning strategy of the Napier University in Scotland is about lifelong learning. They've set themselves institutional targets like "We want a greater proportion of our graduates to return to us mid-career for professional updating than happens for any other university in Scotland." Now, what would it take to do that? So their definition of teaching excellence involves things that achieve that. So they haven't just said it is good teaching or bad teaching, what they are rewarding is people who successfully do those kinds of teaching that support lifelong learning. So they have strategically oriented their definitions so they line up with institutional goals or missions. That is quite interesting because it is often much more forward-looking than backward-looking in what happens: about what teachers are trying to achieve rather than about past 'performance'.

But what is promotion? Not many people in Britain or Denmark experience promotion and that is part of the problem. Some institutions in Britain and perhaps also in Denmark have had to re-organise their career structures and put multiple levels in with definitions of standards for these levels. In Holland there is an example, I think it is Utrecht, where they had a research-only route, a teaching-only route and a teaching and research route with four levels defined within each route. When you've demonstrated you've achieved that level you were automatically – it wasn't in competition with others – promoted to the next level, because they'd defined the standards you'd have to achieve so clearly. You could probably move from the research route to the 'mixed' route one or from the 'mixed' route to either the research or teaching route, but the research and teaching routes were so different that you never were going to span them. So you made a career decision about which route you were going to go down. But there was exactly the same structure for each route.

Now that is a complete re-engineering of career structures, and having four levels was an important part of it.

But even where there are promotions it is usually such a small number of people and for such special purposes that it actually has relatively little impact on most people's orientation to their work.

In the UK we have professionalized teaching in universities – we have a professional body, the Institute for Learning and Teaching in Higher Education. It now has 17,000 members and academics come in through completing certified initial training programmes. So the Institute accredits the programme the university runs. If you successfully complete the programme then you can become a member of the Institute. There is also a direct entry by a portfolio of evidence of competence in a number of ways: it is a competence based system. Some institutions now say: "We will not give you a tenured position unless you are a member of the Institute." It is just like the way other professional bodies operate. Universities are using it as a minimum level of standards to defend professional standards. They are simply making the baseline a bit higher.

Alternatively you can develop mechanisms that combine teaching, research and anything else you want, in a fair way, without research always winning out. The mechanism used at the University of Nebraska is illustrated in table 1.

	Research	**Teaching**	**Administration**
Percentage	30%	50%	20%
Rate (1-5)	3	4	2
Score	90	200	40

Table 1. Rating system for an academic at the University of Nebraska. Based on an agreed time distribution (1st row) and a rating scale from 1-5 this person has been assessed by some of his/her colleagues (2nd row) a final score calculated (here 330 out of a maximum score of 500).

Each year an academic will sit down with the Head of Department and they will make a deal about the proportion of time the person will spend on research, teaching and administration over the next year. So if you're developing a new course and a lot more time needs to be spent on it, then you'll say that you'll spend more time on teaching this year. At the end of the year each of these aspects of your work is reviewed and it is by somebody different for each aspect of your work: somebody who is a researcher for your research, and so on. You are rated from 1 to 5 on each aspect of your work. It produces a score, which then affects your pay annually and goes forward to decisions about promotion. What is happening here is that you are rated at whatever it is you do, and there is no value difference between different aspects of your work – the weighting is purely in terms of the proportion of time you spend on it. This ensures that research can't weigh more than teaching simply because it is valued more.

Many institutions also have 'teaching fellow' posts. Some of these posts are prizes so, whatever your position, you can be awarded a teaching fellowship because of your outstanding teaching. Unfortunately we have some other universities where teaching fellows only do teaching, they have worse pay, worse conditions, more work, lower status, no security in their employment and no career structure, and this does not help the perceived status of the title 'teaching fellow'.

Incentives through teaching awards

Many institutions now have teaching awards and prizes. This is a very American phenomenon but it now works in UK too. Some of the reasons it works is simply because excellent teaching is made public and because it has to be judged, and this tunes up people's thinking about what excellent teaching consists of.

I once attended a 'teaching awards' event at the University of Dalhousie in Canada and there were lots of prizes. There was the best laboratory demonstrator awarded by the students in chemistry and they put money up each year for this. There was an accountancy prize funded by a local accountancy firm. There were all kinds of prizes nominated by different people that worked in different ways – there were about 50 of them. And the event was held in the Town Hall and the public and students came in and cheered the teachers. This is an interesting phenomenon – they brought the community in to applaud excellence in teaching and this is some of where the value comes from.

Sometimes the award is money. Sometimes it is temporary titles. You may have the title of 'reader in teaching' (the readership post in UK lies between a lectureship and a professorship). These readerships in teaching would be for people who specialise in the pedagogy of their discipline – so this is emphasising the scholarship of teaching. Some of these posts are temporary – so you have the title for two or three years and then you drop back down again to whatever your title and role was before, and somebody else gets the 'readership in teaching'. In that way the reward gets spread amongst more people.

There are an increasing number of departments or faculties developing their own prizes independently of the university. There is lots of public celebration going on around recognising and rewarding excellence in teaching and you shouldn't underestimate the impact of such celebration.

The UK also has a national system of teaching awards – they are called National Teaching Fellowships. Every university is allowed to nominate one person and 50 National Teaching fellowships a year are given € 80,000 as a cash prize. And they can do what they like with the cash, more or less, but it is assumed that they use it in some way to develop their teaching. Some of them go off and visit other universities around the world to find out how they teach their subject elsewhere. The award ceremony is a big event with national television present and newspaper journalists present and the Minister for Higher Education. If an institution is going to nominate such a person they have to have a mechanism for nominating them, so they usually have to have an internal teaching award system, so that they can choose the best teacher to put forward nationally. One of the most interesting consequences of the national scheme is that virtually every university in Britain now has its own teaching award scheme. Within universities, departments put forward people for the university awards, so they, too, have to think about what makes a good teacher. My own university, like some others, rewards groups as well as individuals because often a course works because a team works well together. The teams can include a librarian, a technician and whoever contributes to the course. Many of these awards don't just look backwards, they also expect the award winner to do something. If there is cash associated with the award they may expect the winner to undertake a project or at least to give seminars around the university, or presentations at the university's teaching conference, so that people would know about it or so that others would benefit from the expertise in some way.

Incentives through teaching development roles

The other thing that is happening about recognising and rewarding engagement with reform is an emphasis on teaching development roles rather than just teaching excellence. Some institutions are realising that if they want reforms to happen there has to be some time to do it. This is not such a profound notion but it is usually not designed into people's programme of work. There is a department at Imperial College, one of the engineering departments, where they have a point system for allocating duties. So if you take on this responsibility you are allocated so many points, if you teach that course you get so many points. And they multiply the number of points by six if it's the first time the course is run. This is deliberately to encourage people to redesign their courses. So they've got an accountancy system for duties that takes into account the additional effort involved in change and in doing that, recognises and rewards that effort. This is a very important part of the way universities are run: how are duties allocated? If there is no time for revision and reform it is unlikely to take place.

Many institutions take the people who've had the funded teaching projects, or the teaching awards, or the teaching prizes, and they give them a title and they put them in a group, a so-called change group. In the USA they might be called a 'Teaching Academy'. They are given special status and they are expected to comment on any policy issue that the university is developing about teaching. So if such a group were to write a paper for the top university committee to propose changes to assessment then they would be taken very seriously. These groups are being used to bring about change and to transfer effective teaching practices from one department to another. At the University of Bournemouth this group of people who have won prizes and have had teaching projects, work to spot where a practice in one department might work well in another and to move it. So it is a "spreading practice" job that is done as a team. They see themselves as a team, they meet as a team across departmental boundaries, they are given time to meet, they are given resources to support their activity as a change team. And the University recognises their role. This isn't backward-looking "I used to be a good teacher" – it is forward-looking "I am a change agent and I am getting support and recognition in my role to bring about change". And that role is sometimes the main thing that institutions are interested in investing in, rather than the reward itself. So increasingly some universities are not interested in rewarding excellent teaching, but instead interested only in rewarding engagement with reform. So all the 'teaching fellowships' will be for people who are reforming or who are part of a group of people who are reforming.

Such change agents or change teams are often given secretarial and technical support and a budget. At Sheffield-Hallam University there is a group of research assistants that this team can 'borrow' to study the effectiveness of their innovations. The research assistants are connected to an institute for research into teaching and learning but can be "lent out" in pairs to support people in this team to study their own practice.

Other incentives

At the University of Sydney they now use a series of performance indicators (PIs) of teaching quality that determines faculty funding for teaching. They use the Course Experience Questionnaire (CEQ) which measures those aspects of course design that are known to influence whether students take a deep or surface approach to learning. They have PIs to do with scholarship of teaching, so if you present a paper at a conference, like this one, so many points are added on. When Faculties add their points up, it affects their funding for teaching. So for the first time core funding for teaching is related to PIs about quality of teaching and to efforts to reform.

Key issues in using incentives

To summarize my talk I will briefly mention these key issues in using incentives:

- If you are interested in incentives, is this to do with “Well I used to be a good teacher” or is it “We want to bring some change about next”. Are you going to reward past effort or future effort?
- There is the issue of whether you want to use generic notions of quality or whether you have particularly strategic definitions of what you’re after, like lifelong learning or competency based teaching, or whatever.
- Is this a permanent decision, that from now until you retire you are a Professor, or are you going to use your money in a different way and give people a special role and status for several of years and then revert to their old role. The consensus of opinion in the UK at the moment is that temporary benefits have much more impact because you can offer more of them, more often, to more people, and also change your criteria from time to time to align with changed institutional priorities. You have a lot more incentive and reward and support to share around if it is a temporary phenomenon rather than a permanent one.
- Is it a small number of people with big rewards or are you going to reward a large number of staff with small rewards?
- Part of what you’d want to achieve is to re-orient people’s career goals: to convince them that it is worth their while devoting a good proportion of time end energy for the rest of their careers as academics to develop teaching, and that this is a sensible decision to make. It is unclear how much of this can be achieved centrally or whether – if it is really a cultural phenomenon – it has to take place in your departments with peer review and discussion amongst colleagues if it is going to have the cultural and social effects you really want it to have.
- Standards are now very low for teaching (compared to the standards for research) – but in 10 years the standards might look more alike. For 15 years the University of Central England had an initial training programme that you had to pass in order to stay as a teacher in the institution. More than 50% of all the academics in the institution have been through that programme. Once that

had happened, it changed the entire culture of the institution. When they introduced some reward mechanisms, they operated very easily. A couple of miles away in the University of Birmingham they have had no such long standing process of reform and their new reward mechanisms are going to take a long time to have an impact.

- As an **input** you can say that you have changed your promotions mechanisms. But that is not enough – the **output** has to be more innovation amongst teachers and rewards of innovative teachers. Then the **outcome** should be that the culture is changed, so that everybody changes their behaviour and that most people participate in reform, not just the ones who are rewarded (except the hippos…).

Many of these initiatives, reward mechanisms and incentives are further described in the publication:

Gibbs, G. and Habeshaw, T. (2002): Recognising and rewarding excellent teaching – a guide to good practice. Milton Keynes: TQEF National Co-ordination Team, Open University.
Downloadable from http://www.ncteam.ac.uk/ilts/publications/excellence.pdf

How assessment influences student learning

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This overview summarises the way assessment influences student learning behaviour and learning outcomes. It structures this overview under a set of 'conditions under which assessment supports learning' and justifies these with reference to theory, empirical evidence and accounts of practice. These following eleven conditions are offered as a framework for teachers to review the effectiveness of their own assessment practice and to plan changes to assessment. The influences of assessment on the volume, focus and quality of studying depend on these conditions. [See also Workshop 4, p.157, in this publication].

Condition 1

Sufficient assessed tasks are provided for students to capture sufficient study time.

This issue concerns how much time and effort students allocate: the 'time on task' principle (Chickering and Gamson, 1987) that if students don't spend enough time on something they won't learn it. Berliner (1984), summarising research in the 'time on task' principle, concluded that there was strong empirical evidence of a direct relationship between time allocation by courses, student time management and actual student time on task, on the one hand, and student achievement on the other.

The relationship between effort and marks is not always straightforward. Kember et al. (1996) found that students' perceptions of their effort depended on their motivation more than on the number of hours they actually allocated, and that it was possible for students to put in many hours unproductively, especially if they adopted a surface approach to their studies. Some kinds of assessment can generate long hours of ineffective memorisation.

Courses in UK higher education are designed to involve a specified number of learning hours relating to the number of credits for the course. Students are normally expected to spend between about one and four hours out of class for each hour in class (depending largely on the discipline involved). Innis (1996) found students at Leeds Metropolitan University to spend between 1.4 and 3.0 hours out of class for each hour in class. How much of this 'out of class' time is actually allocated to studying may be determined largely by assessment demands. In the USA higher education students on average spend less than half as many hours out of class for each hour in class as teachers expect: between 0.3 and 1.0 hours out of class when teachers, on average, expect 2.1 hours out of class for each hour in class (Gardiner, 1997; Brittingham, 1998; Hutchings et al, 1991; Moffat, 1989). The emphasis in the USA in attempts to improve student performance through assessment is on 'classroom assessment' – activities undertaken in class to test students and use this assessment information to guide both students and teaching (Angelo and Cross, 1993). This focus on the classroom could be interpreted as recognition of the failure to generate much out of class learning through the type of assessment they use. Diary studies (e.g. Innis, ibid) show how students in the UK allocate their time largely to assessed tasks and that this becomes a more narrow focus over time as they become more experienced students, allocating as little as 5% of their time to un-assessed study tasks by year three.

Subject areas with less frequent assessed tasks (e.g. text-based subjects) have students who study fewer hours (Vos, 1991). Science and technology subjects that generate greater total study effort tend to have more frequent (though smaller) assessed tasks, such as problem sheets and lab reports.

Studies of students undertaking paid employment in parallel to full time study show that such students study fewer hours (Curtis and Shami, 2002) and perform significantly less well (Lindsay and Paton-Salzberg, 1993). Studies show that up to three quarters of full time students work during term time and they are likely to allocate their reduced study hours especially strategically in relation to assessment requirements. They report reduced reading and other out-of class study activity.

Assignments are not the only way to capture student time and effort through assessment. The conventional way to do this is by having unpredictable sampling of course content in unseen examinations so that for a student to ignore anything is a high risk activity. The quality, quantity and distribution of the study effort captured in this way are somewhat unpredictable and probably vary with student perceptions of the likely exam demands and the risks involved.

Time and effort can also be captured through social pressure, for example:

- the potential embarrassment of the poor quality of your work being seen by colleagues, as when a seminar presentation is assessed, or when a lab report is written and displayed publicly in the form of a poster

- the potential censure from colleagues if a student were to fail to complete his/her component of an assessed group assignment.

Condition 2

These tasks are engaged with by students, orienting them to allocate appropriate amounts of time and effort to the most important aspects of the course.

This condition concerns what the effort is oriented towards and what quality of effort is involved. Students usually distribute their time unevenly across courses, often focussing on topics associated with assessment and nothing else. If they drew a graph of weekly study effort for all the weeks of an individual course involving a sequence of assignments it might look more like the Alps than like Holland. McKenzie (2001) reported students engaging in on-line conferencing only in the week an assignment was due and at almost no other time. Two of the three case studies of student responses to assessment patterns reported in Gibbs (2002) involved students spending only half as much time studying in those weeks when there was not an assignment.

Exams can have the effect of concentrating study into a short intense period at the end of the course with little study of, for example, lecture notes, until many weeks after the lectures, because the content of the lectures may not be required for assessment until much later. Frequent assignments (such as short problem sheets) or tests (such as computer based assessment) can distribute student effort across the course, often on a weekly basis, while infrequent assignments (such as extended essays) may result in intensive studying for a week or two immediately prior to the assignment deadline, while topics not covered by the assignment can be largely ignored.

Condition 3

Tackling the assessed task engages students in productive learning activity of an appropriate kind.

This issue concerns the kinds of study and learning activity involved in tackling the assignment or in preparing for tests. Some assessment generates unhelpful and inappropriate learning activity even if it produces reliable marks. Studying for multiple choice test questions tests can orient students to a surface approach, as can short answer tests and examinations, while essay assignments can orient the same students towards a deep approach in the context of the same course (Scouller, 1994, 1996, 1998; Scouller and Prosser, 1994; Tang, 1994; Thomas and Baines, 1984).

Analyses of the demands of examination questions have also found that only low-level learning is required by them. For example Olssen (1999) analysed a wide range of examination papers in all courses and all years of a chemical engineering degree in terms of the level of the SOLO taxonomy required in answers (Biggs, ibid). He found that many questions in the early years only required students to produce 'multi-structural' (or list-like) answers that required little understanding and no integration. If students are aware that this is all that is required, this is all that they will learn.

Much assessment simply fails to engage students with appropriate types of learning. Submitting a lab report of a teacher-designed lab is unlikely to help students to learn how to design experiments. Probably the only way to learn how to solve problems is to solve lots of problems. Probably the only way to gain facility with the discourse of a discipline is to undertake plenty of practice in using that discourse, for example through writing. Assignments are the main way in which such practice is generated. Students are unlikely to engage seriously with such demanding practice unless it is assessed or at least required by the assessment regulations. It seems unlikely that the student quoted below would write essays, and gain the learning that resulted, without being required to:

"It's just work, in a way. Just all these essays, and reading's the worst part, it's just labouring really" (History student) (Hounsell, 1987)

Some assessment can mis-orient student effort. Snyder (ibid) described how students encouraged to be creative at MIT abandoned any such aspiration on discovering that most of the marks were derived from rote memorisation of material for multiple choice tests. Some assignments create appropriate learning activity as a by-product. For example setting essays can generate 'reading around' and can support the working up of coherent arguments in a way that simply asking students to read what is on the reading list does not. If you were to take the essay away the appropriate form of studying would not occur even in the unlikely event of a similar volume of reading of similar material taking place. The product, the essay, and the marks associated with it, may be less important to the learning than the framework the assignment provides for the learning activities of 'reading around' and of 'constructing arguments'. Similarly with lab reports or design briefs, the product may be less important than details of the studying required to fulfil the assignment requirements. Group projects can engage students in much discussion and confront individuals with alternative views and different standards of work. The quality of the group product (such as a report) that is marked may be less important than the qualities of the learning process that created it.

Students can tackle assignments that are intended as learning activities so as to maximise the marks they obtain rather than maximising the learning achieved from engaging with the assignment. This may involve "faking good" and pretending to be competent or knowledgeable, deliberately covering up misunderstanding and ignorance, telling teachers what they want to hear rather than what they as students believe, and so on. Norton et al. (1995) report a wide range of such cunning tactics adopted by students with the sole aim of gaining higher marks rather than learning more. Nearly three quarters of students admitted to choosing the easiest of the optional essay questions and a third to putting greater effort into the first essay so as to make a good impression on the tutor. Students were found to adopt similar tactics across a range of courses and across different institutions.

To some extent this is a consequence of the student's orientation, but assessment tasks, marking regimes and the way feedback functions can override such individual orientations and even encourage student behaviour that reduces learning. In the example below an intrinsically oriented student describes, in a learning log, the way he used to tackle assignments in Engineering in a way designed to obtain marks at the expense of learning:

"The average lecturer likes to see the right result squared in red at the bottom of the test sheet, if possible with as few lines of calculation as possible – above all else don't put any comments. He hates that. He thinks that you are trying to fill the page with words to make the work look bigger. Don't leave your mistakes, either, even corrected. If you've done it wrong, bin the lot. He likes to believe that you've found the right solution at the first time. If you're still making mistakes, that means you didn't study enough. There's no way you can re-do an exercise a few months after because you've only got the plain results without comments. If you have a go, you may well make the same mistakes you've done before because you've got no record of your previous errors." (Gibbs, 1992)

Condition 4

Assessment communicates clear and high expectations.

'Conveying high expectations' is one of the 'Seven principles of good practice in higher education' (Chickering and Gamson, 1987). Challenging students and setting high standards elicits greater effort of a higher quality from students. Similarly setting clear goals has a considerable influence on student learning, provided that students understand these goals and orient their behaviour towards them. Studies of what features of course design affect the extent to which students take a deep approach to studying, attempting to understand material (or a surface approach, only attempting to memorise material) have identified 'clear goals and standards' as a crucial variable (Ramsden and Entwistle, 1981). 'Clear goals and standards' is one of the scales on the 'Course Experience Questionnaire' (Ramsden, 1991) used in all universities in Australia to provide performance indicators of teaching quality and used at the University of Sydney as a performance indicator determining funding for teaching.

Students obtain much of their information about goals and standards from the assessment system: from exam papers, from criteria, from assignments and from marks and feedback on their performance. Even quite modest interventions aimed at increasing students' understanding of standards can have a dramatic impact on student performance. For example Price et al. (2002) report the outcomes of a series of studies of the impact of an intervention involving a one-hour student marking exercise designed to encourage students to internalise the criteria used in assessment in a Business Studies module. In a controlled study, those undertaking the marking exercise scored 6% higher marks on the module. This benefit continued into a subsequent module, demonstrating that students had carried over their understanding of criteria, and of their importance, into other settings. Similarly Allan (1995, 1996) has reported that the introduction of explicit learning outcomes in courses at the University of Wolverhampton has resulted in a rapid development of students' conceptions of learning (Säljö, 1982), increasing the proportion of students who see learning as involving understanding from 4% to 55%. This alignment of students' perceptions with teachers' intentions, primarily through the assessment system, is termed 'constructive alignment' in the literature (Biggs, 1996).

The influence of feedback on learning

Knowing what you know and don't know focuses learning. Students need appropriate feedback on performance to benefit from courses. In getting started, students need help in assessing existing knowledge and competence. In classes, students need frequent opportunities to perform and receive suggestions for improvement. At various points during college, and at the end, students need chances to reflect on what they have learnt, what they still have to learn, and how to assess themselves. (Chickering and Gamson, 1987)

Conventionally, feedback is conceptualised as an issue of "correction of errors" (Bruner, 1974) or "knowledge of results" in relation to learning itself: if a student is informed that she is accurate then she will learn. This article is concerned more with how the provision of feedback affects student learning behaviour - with how feedback results in students taking action that involves, or does not involve, further learning.

In the Course Experience Questionnaire (Ramsden, 1991), used extensively in Australia and elsewhere to evaluate the quality of courses, the questionnaire item that most clearly distinguishes the best and worst courses is *"Teaching staff here normally give helpful feedback on how you are doing"* (Ramsden, 1992, p107).

Condition 5

Sufficient feedback is provided, both often enough and in enough detail.

This issue concerns what is conventionally defined as formative assessment: the impact on learning of feedback on progress, usually provided after a 'performance' on an assignment. The volume and thoroughness of feedback varies enormously between courses – I suspect far more than the variation in quantity or quality of teaching.

This feedback may need to be quite regular, and on relatively small chunks of course content, to be useful. One piece of detailed feedback on an extended essay or design task after ten weeks of study is unlikely to support learning across a whole course very well. There has been very widespread adoption of computer-based testing to provide at least some feedback on progress and, in some assessment software it is possible to provide 'remedial feedback' when incorrect answers are selected. Cook (2001) has reported that student final exam marks were closely related to the number (and therefore frequency) of computer marked assignments students had tackled. The frequency, and speed of response of such feedback that it is possible to provide reasonably economically may compensate for its relatively poor quality and lack of individualisation.

Feedback has to be quite specific to be useful. The Open University train their 7,500 part time tutors to give quite detailed and extensive feedback. They are expected to explain their comments in detail, to refer to specific course material that would provide further explanation, and to make specific suggestions for further study. Some of the feedback provided in the rest of higher education would be picked up by the Open University's Staff Tutors, who monitor tutors' marking, as totally inadequate and would lead to quality assurance and staff development interventions.

Condition 6

The feedback focuses on learning and on actions under the students' control, rather than on the students themselves and on their characteristics.

Literature on formative assessment distinguishes between feedback which tells students they are hopeless, or amongst the bottom 20% of students (a grade C, for example) and feedback which tells students exactly where they have gone wrong and what they can do about it (Black and William, 1998). The former can be de-motivating and can negatively affect students' 'self-efficacy', or sense of competence. The latter provides the student with options for action and is less closely associated with their ego – it is about their action rather than about themselves. It is this distinction which helps to explain why feedback without grades has a more positive impact on subsequent performance than grades, or even than feedback and grades combined.

Condition 7

The feedback is timely in that it is received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance.

This issue was highlighted in the 'Seven Principles of Good Practice in Undergraduate Education' (Chickering and Gamson, 1987, 1991). It is based on a range of studies of the timing of feedback (for summaries, see Dunkin, 1986; McKeachie et al. 1986). A teaching method which places great emphasis on immediate feedback at each stage of a students' progress through course units, the Personalised System of Instruction (PSI) has been demonstrated in many studies to improve student performance (Kulik, et al. 1980).

If students do not receive feedback fast enough then they will have moved on to new content and the feedback is irrelevant to their ongoing studies and is extremely unlikely to result in additional appropriate learning activity, directed by the feedback. Indeed may be unlikely to be read at all. Due to resource pressures feedback is being provided slower and as courses in the UK are now shorter, this may mean that feedback on coursework is not provided until after the course has finished. Much such expensively provided feedback is likely to be wasted. There may be a trade off between the rapidity and quality of feedback so that, for example, imperfect feedback from a fellow student provided almost immediately may have much more impact than more perfect feedback from a tutor four weeks later. Carroll (1995) describes 'formative assessment workshops' for classes of 300 medical students which consisted of multiple choice question test items followed immediately by a short remedial tutorial on the question. There is no individualised feedback in this system but the feedback is very immediate and the workshop sessions are scheduled to allow students time to study more material before moving on to the next section of the course. 85% of students reported wanting more such sessions.

Condition 8

Feedback is appropriate to the purpose of the assignment and to its criteria for success.

This issue concerns the relationship of feedback to what an assignment has been set for and what counts as a successful attempt at the assignment. Feedback can perform several functions. For example it can be used primarily to:

- correct errors
- develop understanding through explanations
- generate more learning by suggesting further specific study tasks
- promote the development of generic skills by focussing on evidence of the use of skills rather than on the content
- promote meta-cognition by encouraging students' reflection and awareness of learning processes involved in the assignment
- encourage students to continue studying

Which of these is appropriate depends on why the particular assignment was set in the first place. For example, was the intention to provide a single opportunity to practice the use of a procedure or algorithm in an accurate way, to provide one of many opportunities to practice in the use of a transferable skill, to offer a rich opportunity to reflect on learning or to provide an easy first hurdle in a course that it would be motivating for a student to complete?

A recent study at the Open University suggested that maintaining motivation was the most important and influential issue for students for the first assignment in a course (Gibbs and Simpson, 2002). If a student was looking for encouragement and only received corrections of errors this may not have supported their learning well.

Students need to understand why they have got the grade or mark they have and why they have not got a higher (or lower) grade. Criteria need to be explicit and understood by students, and demonstrably used in forming grades. Often criteria are not accompanied by standards and it is difficult for a student to tell what standard is expected or would be considered inadequate. Much of the literature on the use of self and peer assessment is about the reliability of such marking, and assumes that self and peer assessment is primarily a labour saving device. But the real value may lie in students internalising the standards expected so that they can supervise themselves and improve the quality of their own assignments prior to submitting them.

There are a number of studies that have identified discrepancies between students' perceptions of criteria or of what a 'good' assignment consists of, and tutors' perceptions. For example Merry et al. (1997) found that Biology students ranked the criterion 'factually complete' as the most important of six criteria for a good Biology essay while their tutors ranked this the least important of the six. By their third year these students' rankings of criteria had changed and were more in agreement with those of their tutors, but in the meantime there was plenty of scope for misunderstanding and mis-directed effort. Similarly Norton et al. (1998) interviewed students about what they thought were the 'rules of the game' (similar to what Snyder identified as the 'hidden curriculum') and then used a questionnaire to identify the extent to which these 'rules' were emphasised by students and by their tutors. They found that tutors had very different views than students about what these rules were and that the rules students reported themselves to be following did not relate at all closely to how grades were actually allocated. In such a context it seems likely that feedback is failing to orient students to criteria.

In contrast, Price et al. (2000) have reported using exercises with students, to raise their understanding of the criteria used in marking assignments, that result in an increase in students assignment marks of over 5% and also show continued positive impact on student marks in subsequent modules (Price et al, in press).

Condition 9

Feedback is appropriate, in relation to students' understanding of what they are supposed to be doing.

Students' conceptions of the task

Students have to make sense of what kind of a task they have been set when they tackle an assignment and what would count as a 'good' attempt at it. They can misunderstand and be confused by whatever briefing and feedback they have been given in the past, as in this example:

"What do you think the tutor was looking for in this essay?
Ah … well, this is confusing me. I know the tutor likes concise work, but doesn't like generalisations, and doesn't like too much detail, although on the whole I think he'd like more detail than generalisations. And because it was such a general question, I thought 'oh help!' I don't know what he's looking for." (Hounsell, 1987)

Whatever feedback these students' tutor gives will be interpreted in the light of the students' conceptions of what the tutor really wants or what the task really consists of. Students can have a great deal of difficulty understanding what form of communication an essay is (when the only audience knows more than they do about the topic) or what a lab report is for (when it has been already been written hundreds of times before in exactly the same format) or what a design task has been set for (when only the product is assessed and not the learning that was involved in creating it). Many academic tasks make little sense to students. This inevitably causes problems when they come to read feedback about whether they have tackled this incomprehensible task appropriately.

Students' conceptions of learning

Underlying the above students' confusion about what the tutor really wants could be an unsophisticated conception of learning. Säljö (1982) describes students as having one of five conceptions of learning:

- Learning as passive receipt of information
- Learning as active memorisation of information
- Learning as active memorisation of information or procedures, to be used at some time in the future
- Learning as understanding
- Learning as a change in personal reality: seeing the world differently.

A student with conceptions of learning 1, 2 or 3 might have trouble interpreting feedback that stated: *"Not enough discussion"* if they had accurately provided the tutor with information they had diligently collected. Feedback needs to be sensitive to the unsophisticated conceptions of learning that may be revealed in students' work.

Students' conception of knowledge

Perry's 'scheme of intellectual and ethical development' describes how students develop over time, and through academic experience, their understanding of what knowledge itself is (Perry, 1970). He describes students as starting off thinking that there are an enormous number of right answers and that their job is to learn these and give them back to the teacher correctly. Perry describes this learning process with the memorable phrase '*quantitative accretion of discrete rightness*'. He describes students as moving through a number of stages of increased understanding of the nature of knowledge involving, for example, extreme relativism, in which all answers are seen as equally right. A student who does not draw a conclusion to an essay may be leaving it up to the reader to decide, given that all conclusions are seen as equally valid.

Feedback that simply read *"No conclusion"* might not help such a student to progress! Teachers' feedback is often (though not always) generated from a more sophisticated epistemological stance than that of the student and this offers plenty of scope for misunderstanding of feedback or blank incomprehension.

Students' conception of the discourse of the discipline

Lea and Street (1998) describe a student who, after submitting an essay on a History course, received the feedback *"I like your conclusions to what is a carefully argued and relevant essay."* At the same time the student received feedback on an essay submitted on a parallel Anthropology course which was so critical of the students' ability to write a clear argument or produce a justified conclusion that they were advised to seek counselling help. Lea and Street interpret this as a consequence of Anthropology involving a very different form of discourse involving different forms of argumentation and use of evidence, as it was clearly not a case of generalised essay writing inadequacies. If the student did not understand the discourse of Anthropology and was un-practiced in using it, then generalised essay writing advice was unlikely to be helpful, whether from the lecturer or from a study skills counsellor.

Feedback needs to be sensitive to what kind of writing is expected and what students are likely to understand about this. In modular course structures it is common for students to cross disciplinary boundaries and have to cope with such differences in discourse. Science and Technology students often have particular difficulties with social science-type essays even if they can write in an articulate way in their own discipline, but there are also profound differences in discourse within the social sciences, for example between Sociology and Psychology, and within the Humanities, for example between History and Literature.

Similarly Higgins et al. (2001) discuss the failures of communication that take place in feedback. They describe a case in which the tutor's entire feedback consisted of *"A satisfactory effort. More critical analysis of key issues would have helped"*. The student, who wanted to be better than 'satisfactory' was left frustrated by the poor quality of critical analysis by the tutor.

Condition 10

Feedback is received and attended to.

A number of studies have described students receiving their assignment back, glancing at the mark at the bottom, and then simply throwing it in the bin, including all the feedback.

"Sometimes I do read the comments but I find that I'll never write the same essay again anyway … I tend to ignore them in some ways, unless there is something very startling." (Hounsell, 1987)

Jackson (1995) found that third year students were particularly likely only to look at the grade rather than at feedback on essays. He reported that students like to see the feedback, but more to assure them that their essay had been read carefully and marked fairly.

It is not inevitable that students will read and pay attention to feedback even when that feedback is lovingly crafted and provided promptly. Special steps may need to be taken to engage students with feedback, such as:

- asking students to specify, on their assignment, what they would like feedback on, and giving feedback on nothing else
- providing feedback but no marks, so that students have to read the feedback to get any idea how they are progressing
- requiring assignments to be self-assessed (without any marks being involved) so that students pay attention to whether teachers' views correspond to their own. In a review of literature on self and peer assessment Dochy et al. have reported that overt self assessment has been shown to increase student performance (compared with a control group, in controlled studies) and increase students' control over their learning strategies (Dochy et al. 1999).
- using two-stage assignments with feedback on the first stage, intended to enable the student to improve the quality of work for a second stage submission, which is only graded. Cooper (2000) has reported how such a system can improve almost all students' performance, particularly the performance of some of the weaker students.
- providing a grade only after self assessment and tutor feedback has been completed. Taras (2001) reports the successful use of such a sequence as a component of summative assessments.

Condition 11

Feedback is acted upon by the student.

This issue concerns the impact of feedback on future learning. Feedback may accurately correct errors but still lead to no change in the way a student goes about the next assignment or tackles any future learning task. This may occur for a variety of reasons:

- feedback may come too late to be acted on by students
- feedback may be backward looking – addressing issues associated with material that will not be studied again, rather than forward-looking and addressing the next study activities or assignments the student will engage with
- feedback may be unrealistic or unspecific in its aspirations for student effort (e.g. *"read the literature"* rather than *"for the opposite view, see Smith Chap 2 pages 24-29")*
- feedback may ask the student to do something they do not know how to do (e.g. *"be more Sociological"* or *"express yourself more clearly")*
- feedback may be context specific and only apply to the particular assignment rather than concerning generic issues such as study skills or approaches that generalise across assignments
- feedback may be discouraging and lead to less study effort rather than more
- there may be no follow-up to check if students have taken any action, so students can ignore feedback with impunity.

We currently know very little about what actions students take as a consequence of the feedback teachers provide, though Ding (1998) suggests that even if students read feedback comments, they do little with them.

However there are in the literature case studies of tactics which engage students in acting on feedback. For example Merry et al. (1999) reported that when assignments were two-stage, with students able to use feedback on stage one to modify their stage two submission, 40% reported changing not just their assignment but the way they, in future, went about tackling assignments. In a second study they reported the use of a feedback log in which students kept notes on their reaction to feedback on their first essay. Their second essay gained higher marks from their tutor while their self-assessment marks for the second essay were lower, demonstrating that they had internalised tougher standards.

References

Allan, J. (1995): Learning outcomes in higher education: the impact of outcome-led design on students' conceptions of learning. In Gibbs, G. (ed.): Using research to improve student learning, Oxford Centre for Staff Development, Oxford

Allan, J. (1996): Learning outcome-led modular design: an analysis of the design features which influence students' perceptions of learning. In Rust, C. and Gibbs, G. (eds.): Improving student learning through course design, Oxford Centre for Staff Development, Oxford

Angelo, T.A., and Cross, K.P. (1993): Classroom Assessment Techniques: A Handbook for College Teachers, Ca: Jossey-Bass, San Francisco

Baird, L.L. (1985): Do grades and tests predict adult accomplishment? *Research in Higher Education* 23, 1, pp. 3-85

Berliner, D.C. (1984): The half-full glass: A review of research on teaching. In Hosford, P.L. (ed.): Using what we know about teaching, Va.: Association for Supervision and Curriculum Development, Alexandria

Biggs, J.B and Collis K.F. (1982): Evaluating the quality of learning: the SOLO taxonomy, Academic Press, New York

Biggs, J. (1996): Enhancing teaching through constructive alignment. *Higher Education*, 32, pp 347-364

Black, P. and Wiliam, D. (1998): Assessment and classroom learning. *Assessment in Education*, 5(1), pp. 7-74

Bridges, P., Cooper, A., Evanson, P., Haines, C., Jenkins, D.,Scurry, D., Woolf, H. and Yorke, M. (2002): Coursework marks high, examination marks low: discuss. Assessment and Evaluation in Higher Education, 27 (1), pp. 36-48

Brittingham, B.E. (1988): Undergraduate students' use of time: a classroom investigation. *To Improve the Academy*, 7, pp. 45-52

Brown, S. and Knight, P. T. (1994): Assessing Learners in Higher Education, Kogan Page, London

Carroll, M. (1995): Formative assessment workshops: feedback sessions for large classes. *Biomedical Education* 23 (2), pp. 65-67

Chickering, A.W. and Gamson, Z.F. (1987): Seven Principles to Good Practice in Undergraduate Education. The Johnson Foundation Inc., Racine, Wi

Chickering, A.W. and Gamson, Z. F. (1991): Applying the Seven Principles to Good Practice in Undergraduate Education, Jossey-Bass, San Francisco

Cook, A. (2001): Assessing the use of flexible assessment. *Assessment and Evaluation in Higher Education*, 26 (6), pp. 539 – 549

Cooper, N.J. (2000): Facilitating learning from formative feedback in level 3 assessment. *Assessment and Evaluation in Higher Education*, 25 (3), pp. 279-291

Ding, L. (1998): Revisiting assessment and learning: Implications of students' perspectives on assessment feedback. Paper presented to Scottish Educational Research Association Annual Conference, University of Dundee, September the 25th – 26th

Dochy, F., Segers, M. and Sluijsmans, D. (1999): The use of self-, peer- and co-assessment: A review. *Studies in Higher Education*, 24 (3), pp. 331-350

Dunkin, M.J. (1986): Research on Teaching in Higher Education. In Wittrock, M.C. (ed.): Handbook of Research on Teaching (3rd Edn.) Macmillan, New York

Forbes, D. and Spence, J. (1991): An experiment in assessment for a large class. In Smith, R. (ed.): Innovations in engineering education, Ellis Horwood, London

Gardiner, L. F. (1997): Redesigning higher education: producing dramatic gains in student learning. *ASHE-ERIC Higher Education reports,* 23 (7). Association for the Study of Higher Education, Washington DC

Gibbs, G. (1992): Assessing More Students. Oxford: Oxford Centre for Staff Development, Oxford Centre for Staff Development, Oxford

Gibbs, G. (1999): Using assessment strategically to change the way students learn. In Brown, S. and Glasner, A. (eds.): Assessment Matters in Higher Education, SRHE: Open University Press, Buckingham

Gibbs, G. & Simpson, C. (2002): Vulnerable Students Project. Student Support Research Group, Open University

Gibbs, G. (2002): Evaluating the impact of formative assessment on student learning behaviour. Paper presented at European Association for Learning and Instruction Assessment Conference, August 2002, Newcastle

Higgins, R., Hartley, P. and Skelton, A. (2001): Getting the message across: the problem of communicating assessment feedback. *Teaching in Higher Education*, 6 (2), pp. 269-274

Hounsell, D. (1987): Essay writing and the quality of feedback. In Richardson, J.T.E., Eysenck, M.W. and Warren-Piper, D. (eds.): Student Learning: Research in Education and Cognitive Psychology. Milton Keynes: SRHE/Open University

Hutchings, P., Marchese, T., and Wright, B. (1991): Using assessment to strengthen general education. Newcastle, American Association for Higher Education, Newcastle

Innis, K. (1996) Diary Survey: How undergraduate full-time students spend their time, Leeds Metropolitan University, Leeds

Jackson, M. (1995): Making the grade: The formative evaluation of essays. UtiliBASE. http://ultibase.rmit.edu.au/Articles/jacks1.html, retrieved 10th of august 2003

Kember, D., Ng, S.; Tse, H.; Wong, E.T.T. and Pomfret, M. (1996): An examination of the interrelationships between workload, study time, learning approaches and academic outcomes. *Studies in Higher Education*, 21 (3), pp. 347-358

Kulik, C.C., Kulik, J.A. and Cohen, P.A. (1980): Instructional Technology and College Teaching. *Teaching Psychology*, 7, pp. 199-205

Lea, M. and Street, B. (1998): Student Writing in Higher Education: An academic literacy approach. *Studies in Higher Education*, 23 (2), pp. 157-172

MacFarlane, B. (1992): The 'Thatcherite' generation of university degree results. *Journal of Further and Higher Education*, 16, pp. 60-70

MacKenzie, N. (2001): Problems at Crumpton: Case study. In Rust, C. (ed.): Improving Student Learning through using Learning Technology, Oxford Centre for Staff and Learning Development, Oxford

Marton, F. and Wenestam, C.G. (1978): Qualitative differences in the understanding and retention of the main points in some texts based on the principle-example structure. In Gruneberg, M.M., Moris, P.E. and Sykes, N.K. (eds.): Practical Aspects of Memory, Academic Press, London

McKeachie, W.J., Pintrich, P.R., Lin, Y. and Smith, D. (1986): Teaching and Learning in the college classroom: A review of the research literature. Ann Arbor, National Centre for Research to Improve Postsecondary Teaching and Learning, University of Michigan

Melton R. (2000): Assessment and assignments – A review of related issues based on data collected from the 1998 courses survey. Report SRC 200, Open University

Mentkowski, M., Astin, A., Ewell, P. and Moran, E. T. (1991): Catching Theory up with Practice: Conceptual frameworks for assessment, AAHE Assessment Forum, Washington DC

Merry, S., Orsmond, P. and Reiling, K. (1997): Biology students' and tutors' understanding of 'a good essay'. In Rust, C. (Ed.): Improving students as learners, Oxford Centre for Staff and Leaning Development, Oxford

Merry, S., Orsmond, P. and Reiling, K. (1999): Biological essays: How do students use feedback? In Rust, C. (Ed.): Improving Student Learning through the Disciplines, Oxford Centre for Staff and Learning Development, Oxford

Miller, C.M.I. and Parlett, M. (1974): Up to the mark: A study of the examination game, Society for Research into Higher Education, Guildford

Moffat, M. (1989): Coming of age in New Jersey: College and American culture, Rutgers University Press, New Brunswick NJ

Norton, L., Dickens, T. and Cook, N. Mc L. (1985): Coursework assessment: What are tutors really looking for? In Gibbs, G. (ed.): Using Research to Improve Student Learning, Oxford Centre for Staff Development, Oxford

Norton, L., Brunas-Wagstaff, J. and Lockley, S. (1998): Learning outcomes in the traditional coursework essay: do students and tutors agree? In Rust, C. (ed.): Improving Student Learning Outcomes, Oxford Centre for Staff and Learning Development, Oxford

Olssen, T. (1999): Qualitative aspects of teaching and assessing in the Chemical Engineering curriculum: applications of the SOLO taxonomy. In Rust, C. (ed.) Improving Student Learning through the Disciplines, Oxford Centre for Staff and Learning Development, Oxford

Paton-Saltzberg, R. and Lindsay, R. (1993): The effects of paid employment on the academic performance of full-time students in higher education, Oxford Polytechnic, Oxford

Perry, W.G. (1970): Forms of intellectual and ethical development in the college years, Holy, Rinehart and Winston, New York

Price, M., O'Donovan, B. and Rust, C. (2000): Strategies to develop students' understanding of assessment criteria and process. In Rust, C. (ed.): Improving Student Learning Outcomes, Oxford Centre for Staff and Learning Development, Oxford

Price, M., Rust, C. and O'Donnovan, B. (2003, forthcoming): Improving students' learning by developing their understanding of assessment criteria and process. *Assessment and Evaluation in Higher Education*

Price, M., O'Donovan, B. and Rust, C. (2002): 10th International Improving Student Learning Symposium, Brussles

Ramsden, P. (1991): A performance indicator of teaching quality in higher education: the Course Experience Questionnaire. *Studies in Higher Education*, 16, pp. 129-150

Ramsden, P. (1992): Learning to teach in higher education, Routledge, London

Ramsden, P. and Entwistle, N.J. (1981): Effects of academic departments on students' approaches to study. *British Journal of Educational Psychology*, 51, pp. 368-383

Säljö, R. (1982): Learning and Understanding, Acta Universitatis Göthoburgensis, Göteborg

Scouller, K. (1994): Different learning approaches of undergraduate students in two assessment contexts. *Research and Development in Higher Education*, 17

Scouller, K. (1996): Influence of assessment methods on students' learning approaches, perceptions and preferences: assignment essays vs short answer examinations. *Research and Development in Higher Education*, 19, pp. 776-781

Scouller, K. (1998): How assessment-driven are students really? In Rust, C. (ed.): Improving Student Learning Outcomes, Oxford Centre for Staff and Learning Development, Oxford

Scouller, K. and Prosser, M. (1994): Students' experiences of studying for multiple choice question examinations. *Studies in Higher Education*, 19 (3), pp. 267-279

Snyder, B.R. (1971): The Hidden Curriculum, MA: MIT Press, Cambridge

Steadman, M. (1998): Using classroom assessment to change both teaching and learning. *New Directions for Teaching and Learning*, 75, pp. 23-35

Tang, C. (1994): Effects of modes of assessment on students' preparation strategies. In G. Gibbs (ed.): Improving Student Learning : Theory and Practice. pp 151-170, Oxford Centre for Staff Development, Oxford

Taras, M. (2001): The use of tutor feedback and student self-assessment in summative assessment: Towards transparency for students and for tutors. *Assessment and Evaluation in Higher Education*, 26 (6), pp. 605-614

Thomas, P.R. and Baines, J.D. (1984): Contextual dependence of learning approaches: the effects of assessments. *Human Learning*, 3, pp. 227-240

Torrance, H. and Pryor, J. (1998): Investigative formative assessment: Teaching, learning and assessment in the classroom, Open University Press, Buckingham

Tynjala, P. (1998): Traditional studying for examination vs constructivist learning tasks: Do learning outcomes differ? *Studies in Higher Education*, 23 (2), pp. 173-191

Warren, J.R. (1971): College Grading Practices: An overview. Report No. 9. Washington D.C., ERIC Clearinghouse on Higher Education

Wotjas, O. (1998): Feedback? No, just give us the answers. *Times Higher Education Supplement*, September the 25th

Yorke, M. (2001): Formative assessment and its relevance to retention. *Higher Education Research and Development*, 20 (2), pp. 115-126

Universities - in need of continual change and reform?

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Introduction

During the last few decades interdependencies between universities and the surrounding society have multiplied, making universities increasingly dependent on their environments. The number of demands on and requirements of universities from various sectors in society have not only grown in number but are also changing more quickly. This development affects universities which need increased flexibility and adaptability both in their overall government and control, and in their organizational structure (i.e. schools and departments). Furthermore it has important implications for study programmes and curricula, which need to provide not only knowledge in relevant scientific disciplines but also training in abilities or skills required in working-life.

This paper will start by reviewing the various environmental or societal sectors which have important implications for how universities need to operate. Subsequently there is a discussion of a number of current ideas about management and organization, which are crucially related to the need to manage change at an organizational level. Next, some implications for universities are put forward. Finally, some findings are presented concerning abilities or skills with regard to some engineering and natural science degree programmes at Lund University.

Universities are operating in changing environments

The greater dependence of universities on society makes universities more exposed to changes in environmental sectors, both directly and indirectly. Among relevant environmental sectors are the manufacturing and service industries, public administration and the civil service (including the educational sector), and the political sector.

Industry is constantly changing and restructuring. Basic industries, such as textiles, have largely moved to other areas of the globe, while other industries and industrial sectors have emerged and grown considerably and sometimes disappeared again. In particular, growth can be found in service industries and in high technology industries, i.e. industries using modern scientifically based technologies, such as information technology or medical and pharmaceutical technology. New means and methods for production based on high technology are available, increasing the efficiency and performance of production. New products and services based on high technology have been introduced, replacing existing ones or offering previously unknown facilities or services. Products and services are offered as packages, emphasizing the need for improved customer relationships. In addition industries have become much more dependent on their environments (i.e. suppliers, customers, competitors, among others), which are no longer local or national but in many cases international or global. Globalization and the growing number of interdependencies, due to increased collaboration between companies and more intense competition among companies, have the impact that environments, and hence industries, are less stable and more turbulent than they used to be. Nevertheless, there are large variations in the rates of change in and between industries, some (particularly high technology industries) are very turbulent, while others (some basic industries) are hardly changing at all. Changes may range from comprehensive structural changes to minor adjustments. The need for productivity in order to perform and generate profit has lead to recurring rationalizations of jobs. High technology and rationalization both mean that the new jobs created are much more abstract than previous ones, thus requiring a higher level of education, often a university degree.

The ongoing changes and restructuring in industry have important implications for the public sectors and their objectives and goals. The objectives and goals of public administration, the civil service and the educational sector used to be well-established and fairly permanent, in addition they used to provide secure markets of employment for graduates from the arts and science faculties. This is no longer the case, instead objectives and tasks are changing, thus employment is no longer secure, nor do the tasks involved seem to be sufficiently attractive. Employment is no longer for life, instead turnover has increased, and graduates are increasingly alternating between the private sector, the public sector and unemployment (Kotter, 1997). Public administration needs to provide support and training for the unemployed, the educational sector must offer education and training which cater to the changing nature of industry and society, but also provide students with the abilities to handle continual change.

The political system – at national as well as local levels – has become increasingly interested in influencing and controlling universities, with regard to education as well as research. Resources allocated are not always sufficient to cover needs, and allocation is often oriented towards politically interesting areas of research and education, thus requiring universities to find additional sources of income.

Universities are no longer elite-universities, catering for an elite which is conversant with the requirements of academic life and studies; instead they have become universities offering mass-education for a large number of students lacking an academic background, who thus have different needs and attitudes than previous elite-students, but who still need a university education in order to satisfy the requirements for the new, more abstract, jobs which have been created.

To summarize: there are changes at two levels in the environments a university is operating in, both of which are important from the perspective of this paper. First, the structures of environments are changing and they vary in their degree of turbulence. In order to adapt to these changes universities need to establish internal structures which can scan environments and identify the demands for changing internal structures or establishing additional structures. Secondly, the growing degree of abstractness in jobs, the need for employees to handle change as well as to be able to acquire new skills and knowledge means that the education and training offered by universities must prepare students for a changing working-life. Programmes of study and curricula must be constantly revised and redesigned, those that are out-of-date need to be discontinued and new ones introduced.

Current ideas about flexible organizations

The changes reviewed in manufacturing and service industries, in public administration and in the political system have changed the conditions under which companies and organizations operate. In particular, the increased degree of turbulence, instability and complexity, and thus increasing uncertainty, in organizational environments make it essential that organizations are able to adapt to changes by adjusting their processes and structure. This has given rise to a number of organizational and managerial ideas about how organizations should be structured, as well as a number of managerial techniques aiming to improve efficiency and performances. Among the fashionable ideas about organizational structures are: flattening the structure, network organizations, virtual organizations, and learning organizations. The common goal of all these measures is an intention to improve the ability of organizations to cope with changing conditions.

By reducing the number of hierarchical levels the structure may be flattened, with the aim of improving the capability of the organization to cope with increasing turbulence and instability. This strategy has been severely criticized, since flattening the structure by one or two layers does not make the organization more adaptable, nor is a flattened structure in any way equivalent to a flat organization (Kanter et al, 1992, Ohlsson & Rombach, 1998). The idea of flattening organizational structures has been put forward as a panacea for every organization which needs to become more flexible and adaptable. The basis for the idea is a simplistic analogy with the finding that organizations that have long operated in turbulent and unstable environments are often flatter than organizations operating in static and stable environments.

It has long been known that successful organizations operating in turbulent environments have an organic structure (Burns & Stalker, 1961), one feature of which is a smaller number of layers. More important, however, is the ability to restructure, to establish new structural features and to utilize additional structural mechanisms, thereby obtaining flexibility. Merely flattening the structure does not necessarily improve flexibility; in addition, in order for such a structure to work, other organizational features, such as management processes and reward systems, need to be aligned with the organizational structure. This is demonstrated by the case of the spaghetti organization of Oticon, which seems to have been undermined because of a deficiency in the aligning of reward-systems, etc., with the structure (Foss, 2003, forthcoming).

An organic structure requires more planning and coordination and thus processing of more information which to a large extent is not well-known and therefore cannot be defined in advance. On the other hand when environments are relatively stable and static, a mechanistic structure (Burns & Stalker, 1961) can be used, which requires planning and coordination, and thus processing of largely well-known information. Thus the requirements with regard to computerized information systems are different for organic and mechanistic structures. An organic structure is more expensive to operate than a mechanistic one, which makes it unnecessary to use organic or flat structures in contexts where environments are relatively static and stable. In such environments the need for additional organizational mechanisms is limited, thus mechanistic or bureaucratic structures will do the job at lower costs.

Another recent organizational idea is that of network organizations or lateral structures (Galbraith, 1994), which may be considered as a type of organic organizations. Inter-organizationally this refers to creating networks of distinct and independent organizations. Intra-organizationally it refers to creating internal networks, replacing or modifying the hierarchical organization. Network organizations are considered to be superior in adapting and adjusting to turbulent and unstable environments.

Inter-organizational networks are a type of meta-organizations (Agersnap, 1976). Another type of meta-organization is virtual corporations (Davidow & Malone, 1993) or imaginary systems (Hedberg et al, 2002). A virtual corporation is made up of organizational components belonging to different and distinct corporations, but one component plays the leading part. By collaborating they can offer a joint product or service. The concept is a new one, but the idea is actually old; most engineering companies, for example, rely on subcontractors.

The growing need for organizations to adapt and adjust to environmental turbulence and instability requires that they improve their ability to scan the environment and learn how to adapt, i.e. organizations need to be able to learn. Organizations – as well as organizational members – need to be able to identify new situations and to resolve them, to learn to solve new tasks. Thus environmental turbulence and organizational changes have put an emphasis on both organizational learning and learning organizations (Cohen & Sproull, 1996).

The factors mentioned above – environmental turbulence, instability and complexity (i.e. uncertainty), organizational changes, new organizational forms – mean separately and together that organizations need to process and communicate large amounts of information in order to coordinate, integrate and plan organizational processes and tasks (Galbraith, 1973). In order to process information, organizations employ a variety of mechanisms ranging from the human and organizational to computers, depending on the degree of instability and turbulence, and hence the type of information processing involved. Computers are used extensively in organizations; they are used as support for organizational tasks (e.g. enterprise resource planning), they are used to support communication and cooperation (e.g. computer mediated communication, computer-supported cooperative work), and they are used for administrative and personal support (e.g. word-processing, spreadsheets). Furthermore, organic organizations, network organizations and virtual organizations, as well as other novel organizational structures and forms have other requirements of the portfolio of computer systems than mechanistic organizations, since they require processing of large amounts of information in often varying ways. Thus computers and information technology play crucial roles in enabling novel organizational structures and forms.

Yet one further factor affecting corporate, public and organizational contexts is the numerous management techniques that have been introduced with the aim of improving organizational effectiveness and efficiency, as well as organizational performance. These management techniques include business process re-engineering (BPR), total quality management (TQM), balanced score-card, benchmarking and outsourcing. They all promise considerable improvements, but they are based on classical management thinking, which largely disregards organizational members and the changing nature of modern corporations and public administration. (Røvik, 2000)

Thus they need to be applied with careful consideration of the actual context instead of mechanically.

Summarizing: organizations need to handle growing environmental and internal uncertainty. However, a number of organizations are still operating in fairly well-known environments, which are stable and static. So, uncertainty has increased not only in intensity but also in range. Simultaneously, a large range of organizational structures and forms as well as management techniques have been introduced, enabling organizations to cope with a variety of environmental uncertainties.

Implications with regard to universities and the education offered

Taken together, the continual changes in various sectors of society and with regard to ideas and fashions about organizational forms and management techniques imply that universities are exposed to changes to a much higher extent than previously. They are subject to changes at all levels of their organization and tasks, as well as more frequently (cf. figure 1). Therefore, universities need to handle a variety of changes at several levels, which are increasingly interrelated and have different time perspectives. First, they must cope with changes with regard to their organization: at an overall level, at the level of schools or faculties, at the departmental level, and with regard to university administration. Secondly, universities need to handle changes with regard to programmes of study and course-curricula.

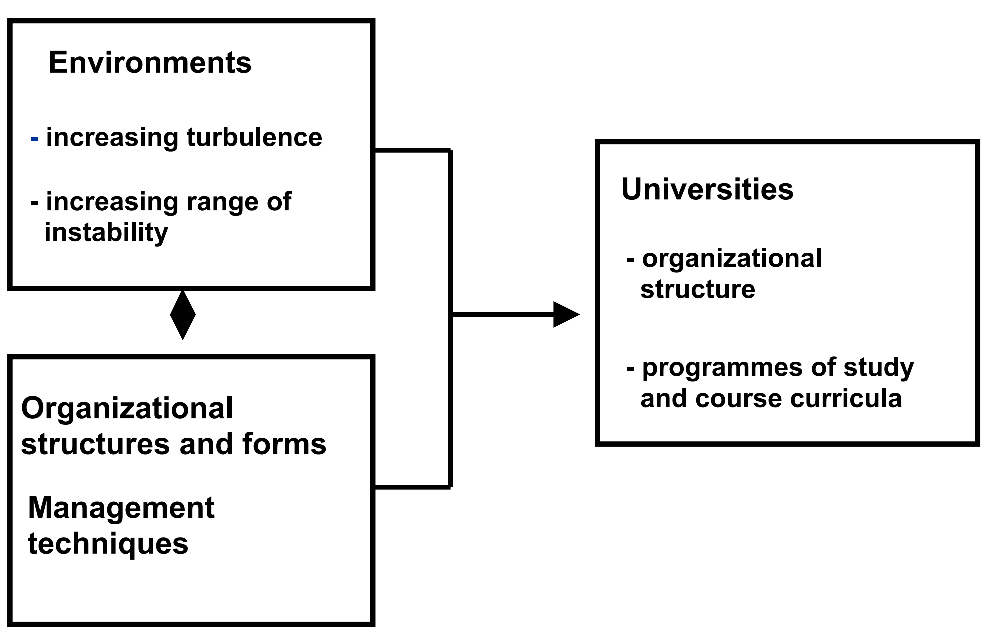

Figure 1. The changing situation for universities

The growing demand in society for collaboration between different fields of knowledge when solving problems requires collaboration between university departments in order to design and redesign programmes of study which are flexible in terms of the types of courses offered and their curricula. The departmental structure will always be fundamental in terms of development and progress in the knowledge of disciplines. But in addition there is a need for various matrix-oriented, project-oriented, lateral, collaborative and cooperative structures, making cross-departmental tasks a more accepted feature of university life.

The changing nature of society and working-life means jobs will change more than they used to, so graduate students will probably change jobs more often than previously. This means that university degree programmes need to prepare students for a changing working-life and changing labour-markets. First, students need to have such a foundation in their chosen disciplines that they are both sufficiently confident with regard to fundamental aspects and also capable of developing their knowledge and acquiring new knowledge within the disciplines. Secondly, students need to acquire skills which go above and beyond established disciplinary knowledge. By ensuring that students have such skills the intention is to make them capable of handling various professional, interpersonal and organizational aspects and able to use abstract and concrete tools in their jobs.

Concerning the first issue, knowledge in chosen disciplines, there is an external and an internal aspect. What knowledge is relevant is not only or even primarily an internal aspect (i.e. something decided by academia), instead it is an external one, as this is dependent on the changing nature of the jobs or professions students will enter. What knowledge does an accountant, a personnel officer, a mechanical engineer, or an environmental conservationist require? It is an internal aspect in so far that the theoretical structure and the relationships between various parts of the discipline are determined by the discipline as an academic field.

Which abilities and skills do students require?

Environmental uncertainty influences organizational structure and tasks in various ways. Internal changes – anticipated and not anticipated, planned and unplanned – occur more often. Interdependencies are growing in number and in intensity, hence changes affect larger parts of the organization. Tasks are growing in scope and complexity, making it impossible for a single individual to handle a task, but requiring instead the cooperative efforts of a number of individuals or the pooling of different abilities and types of knowledge. Information and communication technologies, including computers, play a crucial role in production and administration. This has several implications. Employees need to be flexible and able to adjust to changing and variable conditions, and to cope with new or novel situations. They need to be able to manage and participate in changes, to cooperate with others in developing ideas, as well as to utilize and develop individual competencies and knowledge with the aim of developing organizational knowledge. Personal communication between various parts of the organization and between different professional groups has grown in importance; likewise, communication with external parties plays a crucial role. Work is increasingly organized in terms of teams and projects. Employees need to be adept at using computers and computerized tools when performing tasks, in communication and presentation.

There is considerable agreement that university education needs to provide students with at least a basic foundation in the abilities or skills mentioned above - skills they can then develop further in the context of real-life situations. The Office of Evaluation at Lund University has conducted a number of alumni studies, which also have involved finding out to what extent university degree programmes provide students with the abilities and skills required by working-life. [See also the contribution of Bowden, p. 9, in this publication].

This paper will present findings from studies within the natural and engineering sciences, namely

- A study of graduates from the fire-protection engineering study programme at Lund University (Fasth & Nilsson Lindström, 2002). This study includes those who graduated between 1986 and 2001, 186 graduates (i.e. 62%) returned the questionnaire.
- A study of graduates from the biology sub-programme of the natural sciences study programme at Lund University (Nilsson Lindström & Persmark, 2002). This study includes those who graduated between 1990 and 1999, 371 graduates (i.e. 60%) returned the questionnaire.
- Data on graduates from the natural science study programme at Lund University (extracts of data on graduates from all Swedish Universities collected by Statistics Sweden). Data was collected on those who graduated in 1996/97 in 2000 (responses from 219 graduates) and on those who graduated in 1998/99 in 2002 (responses from 235 graduates). In both data collections the questionnaire included questions formulated by the Office of Evaluation at Lund University.

All these studies were particularly interested in evaluating the abilities and skills graduates had acquired, and assessing how well the training received in their undergraduate studies matched the requirements of their jobs.

Studies in natural sciences, including biology, have a long history at universities. They used to be particularly directed towards the public and educational sectors. In particular the goals of the sub-programme in biology are very much oriented towards preparing for the Ph.D.-programme, emphasizing the academic orientation. The fire-protection engineering programme, on the other hand, provides professional education. It was designed in order to cater to specific working life requirements, but it has unfortunately become narrowly technical. So, the two study-programmes constitute opposing cases with regard to university education, from the traditional research orientation of the biology programme to the professional orientation of the-protection engineering programme.

Grouping skills

The skills the graduates and their employers have been asked to assess may be divided into three groups. *Generic skills* are those skills common to any tertiary education and can be found in public documents (the Higher Education Act). *Academic skills* include subject-oriented skills specific to particular disciplines or programmes of study. Finally, *working-life skills* refer to skills required in working-life. The labels of the skills in each group are not identical, which is due to the fact that the studies of biology-graduates and fire-protection engineers have been performed in close cooperation with those responsible for the programmes of study, who have suggested skills or labels on skills of particular interest from their perspectives, cf. tables 1-3. It needs to be noted that this division of skills into groups was not used in the questionnaires.

Natural science graduates	Biology graduates	Fire-protection engineers
-	Think critically.	Think critically.
Use logical arguments to convince.	Use logical arguments to convince.	Use logical arguments to convince.
Solve problems independently.	-	Solve problems independently.
Oral communication.	Oral communication.	Oral communication.
Use written communication.	Use written communication.	Use written communication.
Make a presentation in English	Communicate in English.	Communicate in English.

Table 1. Generic skills.

It is noteworthy that the generic skills for biology graduates (table 1) do not include solving problems independently; instead solving scientific problems is included among the academic skills. It is also stated in the presentation of the sub-programme in biology that a purpose is to train the students in solving scientific problems. Independently solving problems in a practical setting is very different from solving scientific problems; in the first case it often involves identifying and implementing appropriate measures, while scientific problem-solving is oriented towards making a contribution to knowledge.

Natural science graduates	**Biology graduates**	**Fire-protection engineers**
-	Solve scientific problems.	-
-	Master discipline.	Develop disciplinary knowledge.
-	Essay and report writing.	Essay and report writing.
-	Perform field studies.	Use a wide range of skills in research-methods and statistics.
-	Do laboratory work.	
-	Analyze statistical data.	
-	Apply international perspectives.	Apply international perspectives.
-	-	Understand motives behind group or individual actions.
-	-	Understand cultural manifestations.
-	-	Identify and analyze ethical issues.

Table 2. Academic skills.

With regard to natural science graduates there are no academic skills (table 2) included among the questions in the questionnaires, since these skills are specific to particular programmes of study and the questionnaires were mailed to graduates of all Swedish higher education programmes. However, the skill “keep informed about progress in the discipline”, which has been labelled a working-life skill, could just as well have been classified as an academic skill. Further, the three skills “perform field studies”, “do laboratory work” and “analyze statistical data” for biology graduates have evidently been summarized for fire-protection engineers as “use a wide range of skills in research-methods and statistics”.

Natural science graduates	Biology graduates	Fire-protection engineers
Keep informed about progress in the discipline. Explain to non-specialists.	- Explain to non-specialists.	Apply knowledge from fire-protection engineering. Explain to non-specialists.
Work in projects or teams. - - Participate in change. - - - - -	Work in teams. Organize work. - Participate in change. Manage change. Direct and instruct. Organize training. Service-minded. -	Work with persons from different backgrounds. Manage work. Manage time-schedules. Participate in change. Manage change. Direct, instruct and train. - - Cope with a variety of social situations.
IT for information-access. IT for contact and communication Computer as tool. -	IT for information-access. IT for contact and communication. - Use IT to present ideas.	Computer skills. (Use IT for collecting, processing and analyzing information.)

Table 3. Working-life skills

Among working-life skills (table 3) three subgroups may be distinguished. One deals with management of knowledge in the discipline or knowledge-area, another encompasses the interpersonal issues involved in managing and organizing work (allocating tasks, monitoring, planning, scheduling, instructing etc.) as well as changes. A third subgroup includes the various abstract (e.g. IT or computer tools) and concrete tools (e.g. machinery). Working in teams or projects has become increasingly crucial in current work-organizations, which may involve working with individuals having different training and backgrounds. [See also Workshop 3, p. 147, in this publication].

In all three studies graduates were asked to rate their skills with regard to work requirements (from not at all to very much). Graduates from the fire-protection engineering study programme and natural science graduates were asked to rate their skills with regard to satisfaction with skill training (from very dissatisfied to very satisfied), while biology graduates were asked to rate in terms of amount of skill training (from not at all to very much). Though there is an important conceptual difference between amount of skill training and satisfaction with skill training, it does not seem to have affected the responses in terms of the patterns they provide, so the difference will be ignored in this paper.

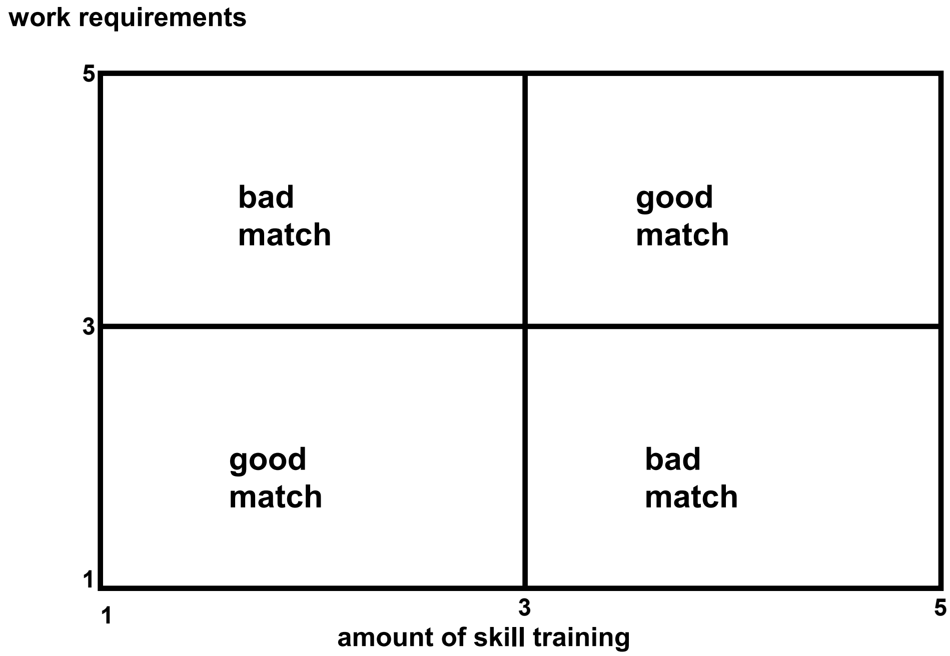

Figure 2. Satisfaction with skill training.

Data from the studies have been presented using diagrams, with work requirements on the vertical axis and skill training on the horizontal axis (cf. figure 2). This results in four quadrants showing the match between the two variables. There is good match in quadrants 1 (upper right) and 3 (lower left), while there is bad match in quadrants 2 (upper left) and 4 (lower right). In quadrants 2 and 4 there are needs of improvements, of aligning skill training and work requirements, particularly in quadrant 2 it is necessary to both increase and improve skill training.

Findings

There is quite good agreement among the three groups of graduates concerning *generic skills*. In all three cases the skills fall mainly in the first quadrant, with high work requirements and high satisfaction with training, suggesting that there is equally keen interest in industry and public administration as well as in universities. Generic skills are just as essential in industry and public administration as they are in university and education.

In the natural sciences (figure 3) all generic skills fall in the first quadrant, which means a good match between work requirements and skill training. There is however a need for improvements with regard to some skills.

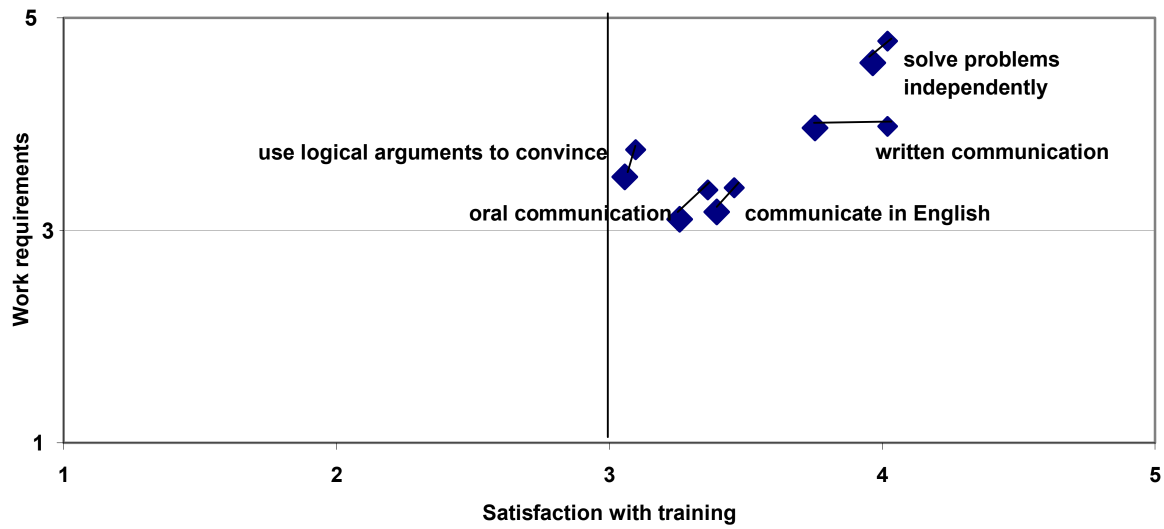

Figure 3. Natural science graduates: Generic skills (large squares 1998/99, small squares 1996/97).

With regard to biology graduates (figure 4) three skills fall in the first quadrant, while two skills – “use logical arguments to convince” and “communicate in English” – fall in the second quadrant. Thus the match taken all together is not a good one and needs to be improved. In particular the bad matches in the biology programme are worth noting, since “arguing and convincing” as well as “communicating in English” are essential abilities in a scientific career, and the purpose of the biology programme is to train students in solving scientific problems.

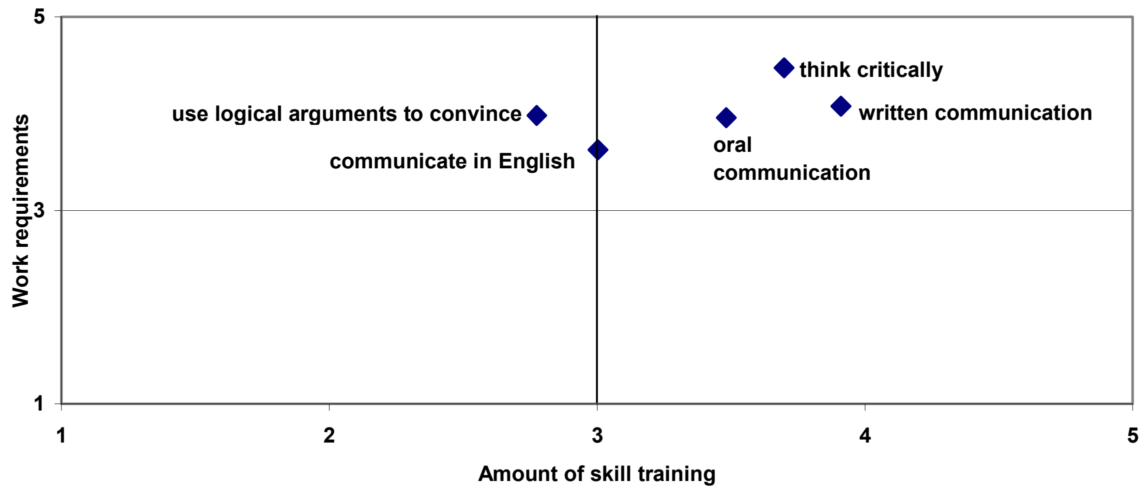

Figure 4. Biology graduates: Generic skills (Nilsson Lindström & Persmark, 2002).

Among the generic skills concerning graduates in fire-protection engineering (figure 5) four skills fall in the first quadrant, while "use logical arguments to convince" falls on the border between quadrants one and two, and "communicate in English" in the third quadrant. So, in this case the match can be considered a good one, but there is need for improvements particularly with regard to arguing and convincing.

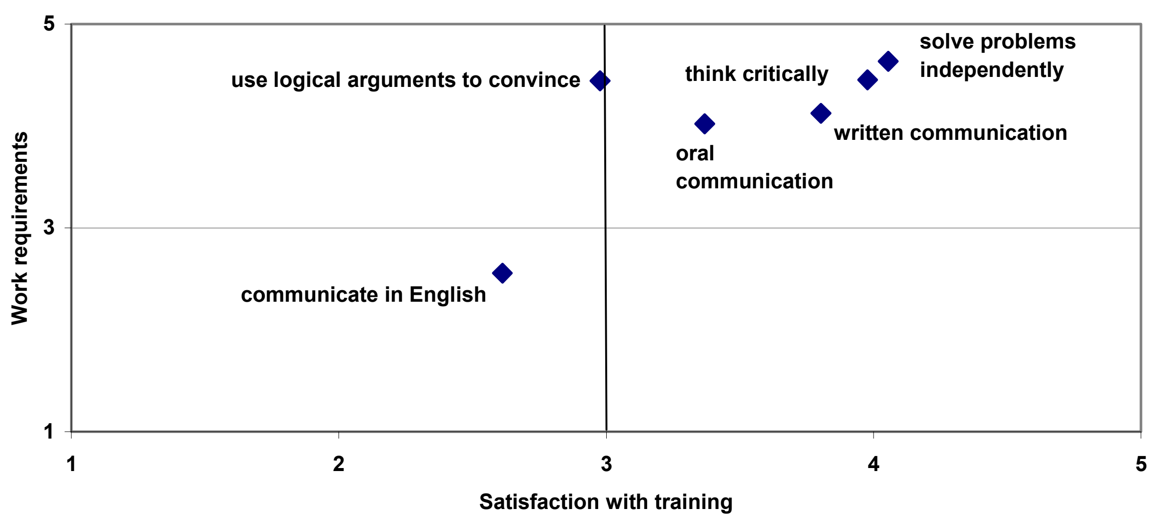

Figure 5. Fire-Protection Engineers: Generic skills (Fasth & Nilsson Lindström, 2002).

The *academic skills* show a much more distributed pattern. Skills can be found in all four quadrants, also there are no agreements between the outcomes for biology graduates (figure 6) and those of fire-protection engineering graduates (figure 7). Biology graduates show a good match for the skills "solving scientific problems" and "mastering disciplinary knowledge", while there is bad match with regard to the skill "developing disciplinary knowledge" for fire-protection engineering graduates. Similarly with regard to scientific methods, the skill "use a wide range of skills in research-methods and statistics" for fire-protection engineers falls in the fourth quadrant, while the corresponding skills for biology graduates can be found in different quadrants: "do laboratory work" falls in the first quadrant, "analyze statistical data" in the third and "field studies" in the fourth quadrant. It has been mentioned previously that the aims of the two study programmes are different. The biology programme prepares for doctoral studies, while the fire-protection programme provides a professional education.

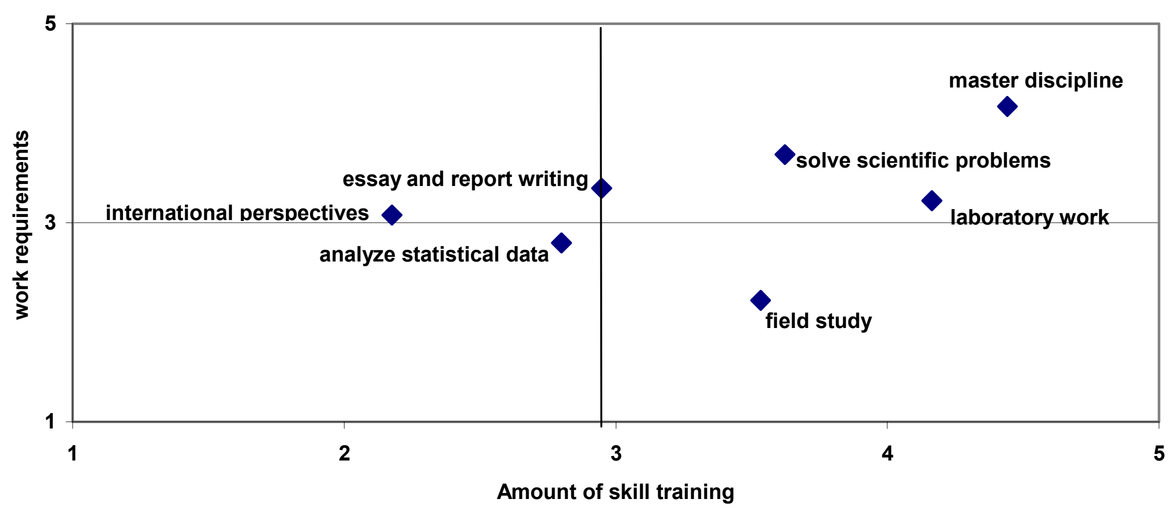

Figure 6. Biology graduates: Academic skills (Nilsson Lindström & Persmark 2002).

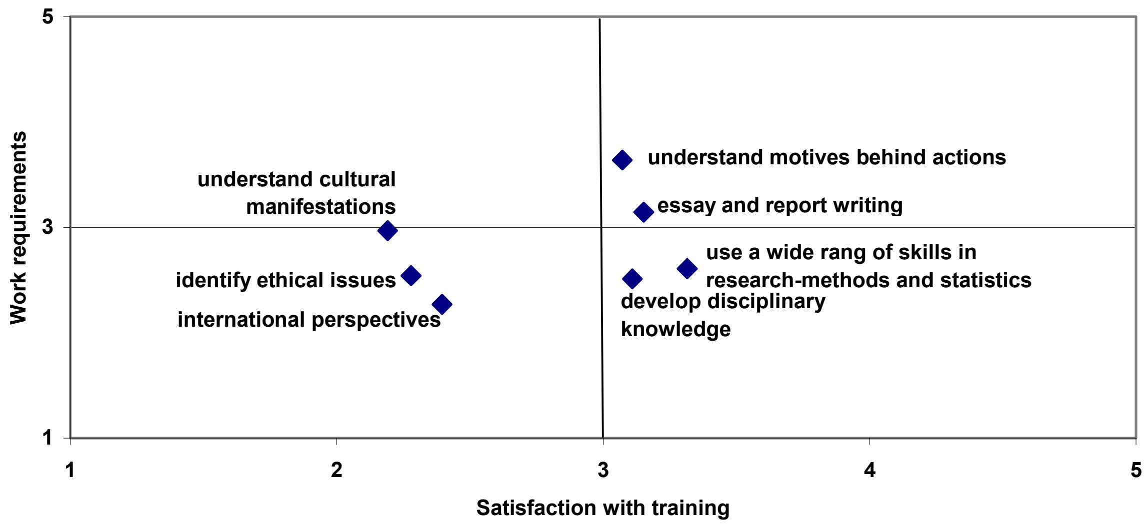

Figure 7. Fire-Protection Engineers: Academic skills (Fasth & Nilsson Lindström, 2002).

The fact that academic skills with regard to biology graduates are distributed across all four quadrants (figure 6) suggests that there may be some subgroups among the graduates. In fact among those returning the questionnaire three major subgroups can be distinguished:

- Employed with undergraduate studies (n = 116)
- Employed with finished/unfinished Ph.D.-studies (n = 62)
- Ph.D.-candidates (n = 121).

There are considerable differences regarding how the three groups assess work requirements of academic skills (figure 8), however the groups are in considerable agreement with regard to the amount of skill training in academic skills (figure 9). Apart from "perform field studies", where the assessment is fairly equal, the Ph.D.-candidates have the highest assessment of the work requirements of academic skills, while those employed who have only undergraduate studies, have the lowest assessment. Only with regard to mastering the discipline do all three subgroups have high assessments of the work requirements, furthermore there is a good match with the amount of skill training.

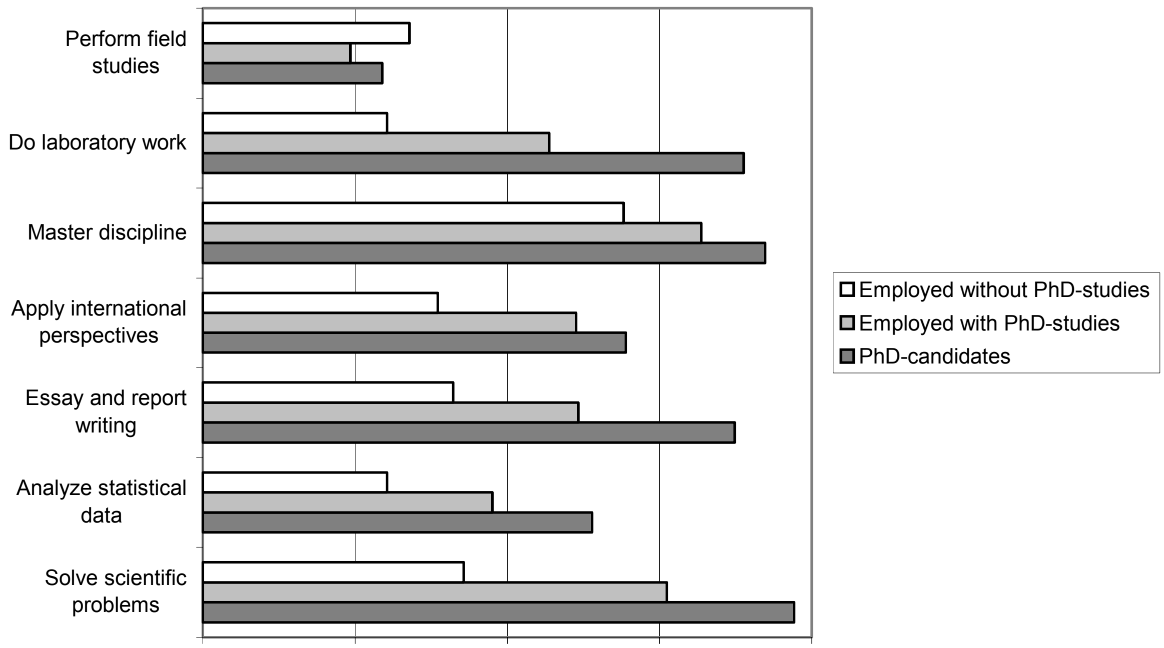

Figure 8. Biology graduates: assessments of the work requirements of academic skills (Nilsson Lindström & Persmark, 2002).

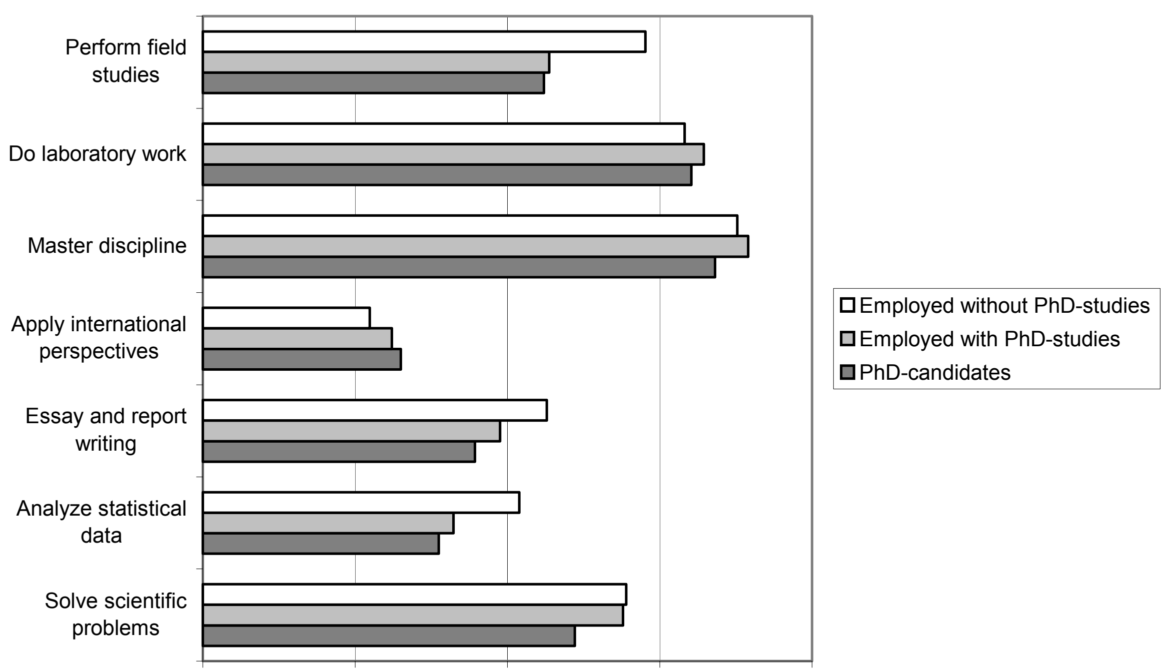

Figure 9. Biology graduates: assessments of the amount of skill training in academic skills (Nilsson Lindström & Persmark, 2002).

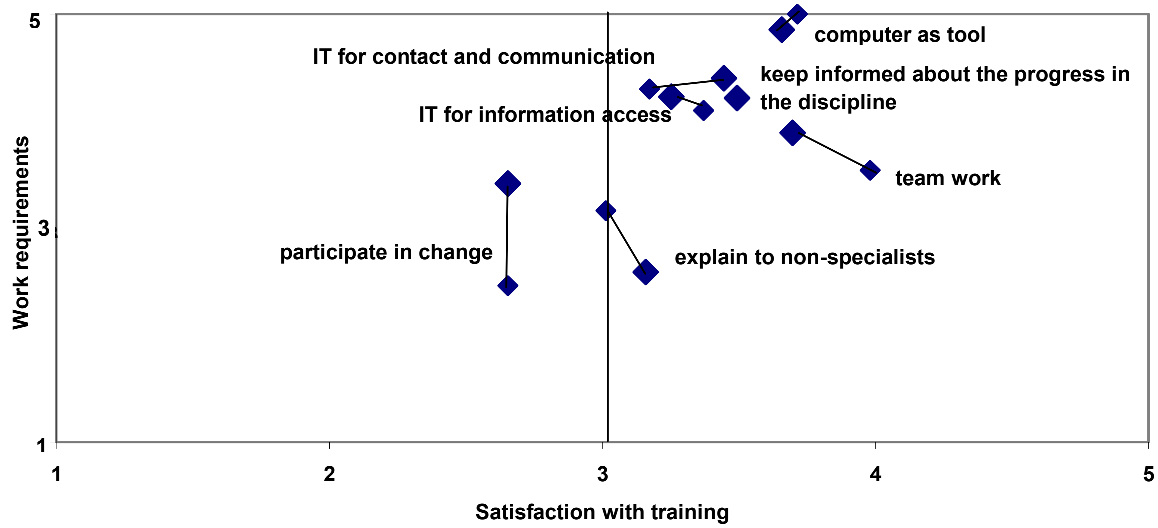

Figure 10. Natural science graduates: Working-life skills (large squares 1998/99, small squares 1996/97).

The patterns shown with regard to *working-life* skills are also distributed across all four quadrants. There is good correspondence for most of the skills of natural science graduates (figure 10), in particular with regard to computer skills ("computer as a tool", "IT for contact and communication", and "IT for information-access"). The requirements to participate in change have increased slightly, but the training has not improved.

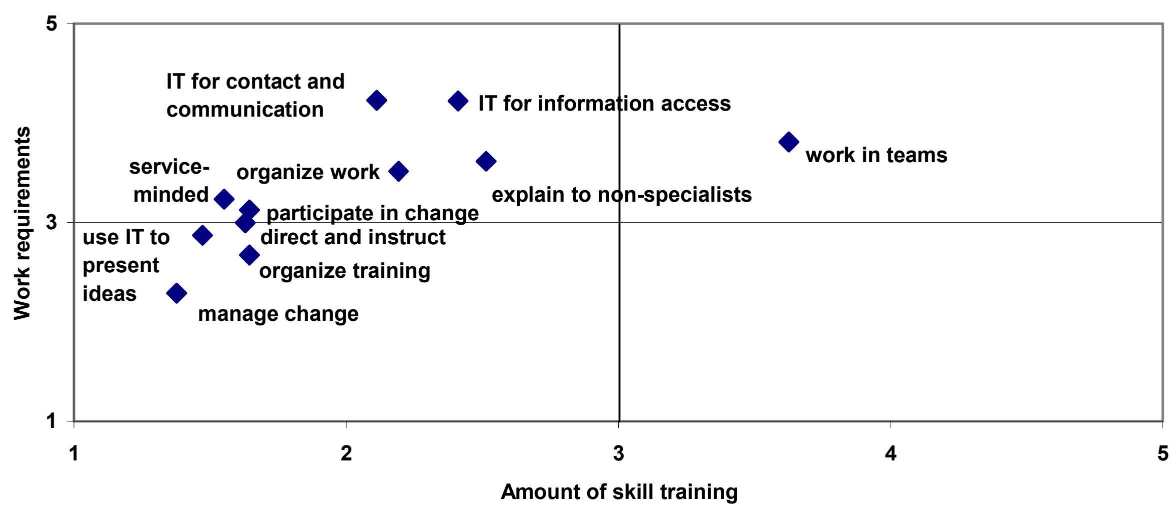

Figure 11. Biology graduates: Working-life skills (Nilsson Lindström & Persmark, 2002).

With regard to biology graduates (figure 11) only one skill falls in the first quadrant, while all the rest fall in the second and third quadrants, with regard to both computer skills and to interpersonal skills required in managing and organizing work.

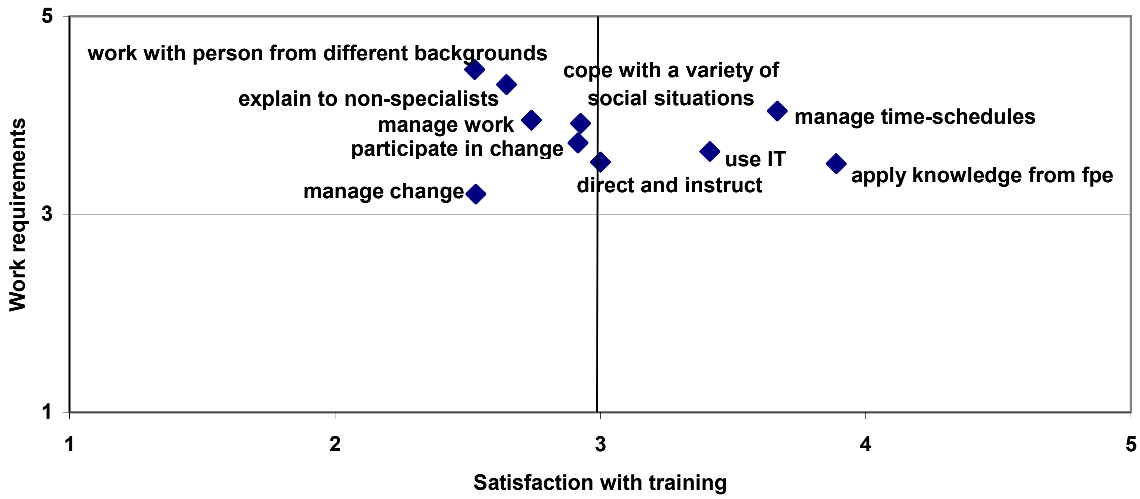

Figure 12. Fire-Protection Engineers: Working-life skills (Fasth & Nilsson Lindström, 2002).

There is a good match with regard to computer skills for graduates in fire-protection engineering (figure 12), but there is bad match with regard to interpersonal skills. The differences in correspondence concerning computer skills for the three groups of graduates may to some extent be explained by the time-periods covered in the studies. With IT and computers becoming increasingly common-place most students will be used to using IT, various computer tools and the Internet. There is, however, still a considerable need to improve the training in interpersonal skills related to managing and organizing work, which also requires providing the students with some formal education in industrial sociology and work organization.

The view of employers

In the studies of alumni in fire-protection engineering and in biology, data collected from graduates were supplemented by asking a few employers about their opinions especially with regard to work requirements. The interview-guides did not divide the skills into groups.

Employers of fire-protection engineers stressed particularly the generic skills and the working-life skills, but they put little emphasis on the academic skills. This is in agreement with the graduates who perceive work requirements concerning generic skills and working-life skills in the upper quadrants. It also suggests considerable agreement on the value of these skills in industry and public administration as well as in universities.

With regard to biology graduates a number of different organizations were asked: two pharmaceutical companies, two local councils, the County Government Board and a consulting firm. There are variations among the answers from these organizations, which clearly depend on the different organizational tasks. Generic skills were stressed by the consulting firm and in the local council, academic skills were stressed by the pharmaceutical companies and the consulting firm. Regarding professional skills, the pharmaceutical companies stressed working in teams and participating in change, while the others also found those skills involving contacts, communication, explaining and being service-oriented important.

Conclusions

It has been argued in this paper that universities are operating in environments, which are becoming increasingly interrelated, and where the rate and variety of change are growing. So, external changes require continual change and reform at several levels in universities. Therefore universities must, first, cope with changes to their organization at an overall level, at the level of schools or faculties, at the departmental level, and with regard to university administration. Secondly, they need to handle changes with regard to programmes of study and course-curricula on an ongoing basis. Within the latter area two types of curricula can be distinguished, one including the subject-oriented education in the chosen core-disciplines, and the other referring to skill training required in order to satisfy work-requirements. Skill training should be an integral part of the didactic methods used.

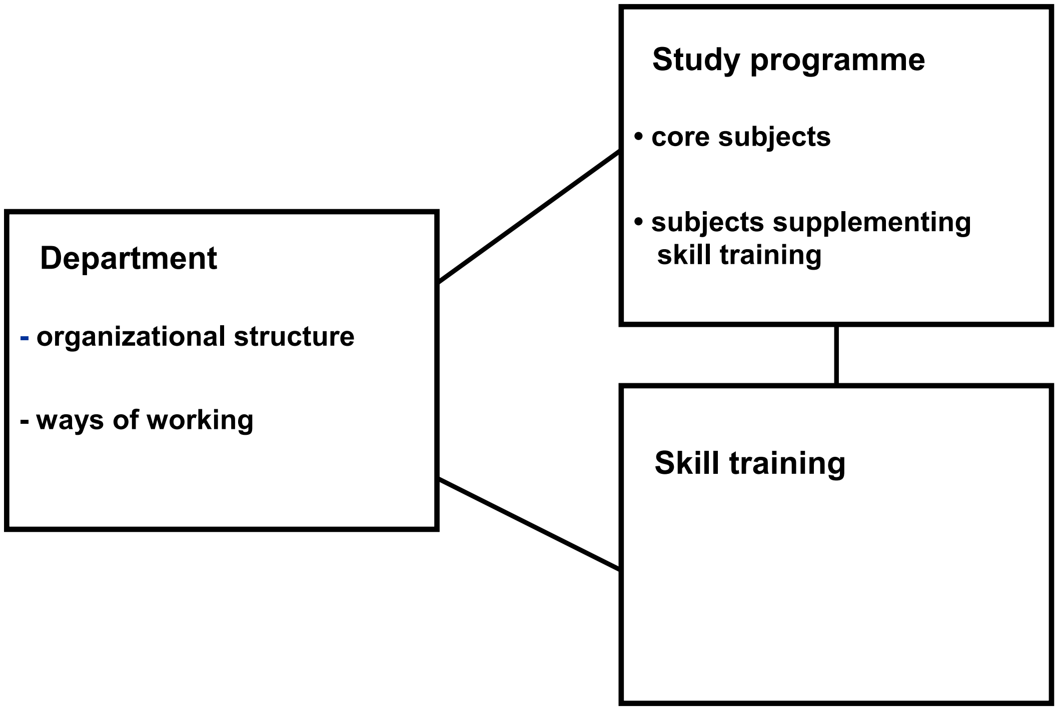

Figure 13. Aligning department-structure, study programme and skill training.

In this paper particular attention has been paid to skill training, by presenting data from three evaluation studies. With regard to generic skills the correspondence between skill training and work requirements is a good one, which also implies that industry and public administration as well as universities agree on the value of generic skills. However, concerning academic skills, and in particular working-life skills, there is considerable need for improvement. Furthermore, improved training in working-life skills should be supplemented with formal education, e.g. in work sciences and work organization.

Finally, changes in curricula require complementary changes regarding the organizational structure, particularly at intra- and interdepartmental levels. It will be difficult to provide students with required training in working-life skills – such as working in teams, manage and participating in change – if departments are not themselves employing these skills in performing their tasks, and thus neither have appropriate experience nor can provide examples of working-life skills (figure 13). The ways of working in a department must be in harmony with the skills taught as part of the subject-oriented studies.

References

Agersnap, F. (1976): Strategi: Analyse – Planlægning – Organisationstilpasning [Strategy: Analysis – Planning – Organizational adaptation]. Nyt Nordisk Forlag Arnold Busck, Copenhagen

Burns, T., Stalker, G. M. (1961): The Management of Innovation. Tavistock

Cohen, M. D., Sproull, L. S. (eds., 1996): Organizational Learning. Sage

Davidow, W. H., Malone, M. S. (1993): The Virtual Corporation. Structuring and revitalizing the corporation for the 21st Century. HarperBusiness

Fasth, E., Nilsson Lindström, M. (2002): Brandingenjörer i arbetslivet – en undersökning av dem som genomgått brandingenjörsutbildningen och några av deras arbetsgivare. [Fire-protection engineers in working life – a study of graduates from the fire-protection engineering study programme and some of their employers]. Report No 2002:213, Office of Evaluation, Lund University

Foss, N. J. (2003, forthcoming): Selective Intervention and Internal Hybrids: Interpreting and Learning from the Rise and Fall of the Oticon Spaghetti Organization. *Organization Science* (draft at www.cbs.dk/staff/nicolai-foss/working-paper-page.htm, retrieved 10 August 2003)

Galbraith, J. R. (1973): Designing Complex Organizations. Addison-Wesley

Galbraith J. R. (1994): Competing with Flexible Lateral Organizations. Addison Wesley

Hedberg B., Dahlgren G., Hansson J., Olve N.-G. (2000): Virtual Organizations and Beyond: Discovering imaginary systems. Wiley

Higher Education Act *from* www.eng.hsv.se (the legal framework), retrieved 10 August 2003.

Högskolelagen *from* www.hsv.se (lag och rätt), retrieved 10 August 2003.

Kanter, R.M., Stein, B.A., Jick, T.D. (1992): The Challenge of Organizational Change. How companies experience it and leaders guide it. The Free Press, New York

Kotter, J. P. (1997): The New Rules. Eight business breakthroughs to career success in the 21st century. The Free Press, New York

Nilsson Lindström, M., Persmark, L. (2002): Biologer i arbetslivet. En alumni- och avnämarundersökning. [Biology-graduates in working-life. A study of alumni and employers]. Report No 2002:216, Office of Evaluation, Lund University

Ohlsson, Ö., Rombach, B. (1998): Res Pyramiderna. Om frihetsskapande hierarkier och tillplattningens slaveri. [Raise the Pyramids. On liberating hierarchies and the enslavement of flattened structures]. Svenska förlaget, Stockholm

Røvik, K. A. (2000): Moderna Organisationer: Trender inom organisationstänkandet. [Modern organizations: Trends in organizational thinking]. Liber

What are the questions?

Arne Jakobsen, Technical University of Denmark

I shall relate my speech to the title of the conference. I will briefly report some results from research related to professional competence and then, on this background, suggest what could be the questions to which reform(s) might be the answer.

Science students' conceptual understanding

In 1999 we concluded an investigation into students' conceptual understanding (Jakobsen et al, 1999). In about 15 courses, mostly at the Technical University but also at The Agricultural University and Aalborg University, we tested students' understanding of the concepts, principles, models, and methods that the teachers pinpointed as the most important ones employed in the courses. The tests were carried out in close proximity to the final course examination and the answers to the tests were evaluated and graded on the scale which was also used for the official exams. The position of each student according to her results in the examination and the test is illustrated in figure 1.

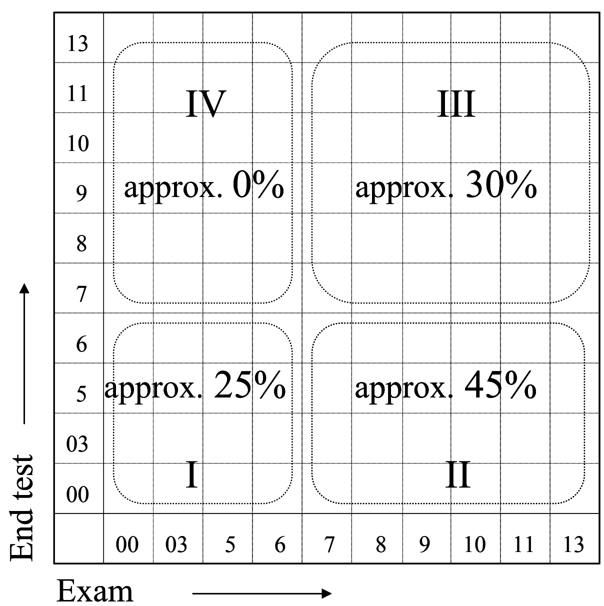

Figure 1. Students' understanding of concepts (end test) related to their written exam results (exam). Below 6: failed, 6: passed, 7: below average, 8: average, 9: above average, 10: good, 11: excellent, 13: extraordinary.

Almost the same picture occurred in all courses: One quarter of the students did well in both exams and tests, another quarter did poorly in both and the rest, almost one half of the students, demonstrated an unsatisfactory understanding of the concepts etc. tested in the test although they passed the examinations, some even with high marks.

Other investigations, employing more or less similar methods, have produced very much the same results. So it is not the three Danish universities involved which are particularly poor; it is a problem which seems to be universal. The notions of deep versus surface learning that were introduced at the same time as these investigations were carried out can be employed to describe the nature of the problem: What the investigations illustrate is a rather large extent of surface learning.

We also interviewed groups of students about their problem solving in the tests and exams and their ways of studying and found among other things that for too many students their engagement was almost exclusively focused on the passing of examinations, not on the scientific challenges.

I will go back to the beginning of the 1980's when many research projects into professional competences (at that time: qualifications) were carried out. In 1982 Agersnap and Skjøtt-Larsen presented a study of the qualifications of graduates from the Copenhagen Business School and the graduates' application of these qualifications. The study involved contacts with more than 1.000 graduates in the form of surveys, interviews, and direct observation. In the final report (Agersnap and Skjøtt-Larsen, 1982) it was, among many other findings, concluded:

"We have seen one instance where materials from the business school training was used directly. If the (business school) teaching is used at all it is as a background for the use of simpler methods. ... It is a dramatic result. Much of the educational work is directed at providing students with a tool box they can go out and use. This form of utilization we have seen in only one instance." (My translation)

Similar studies in medicine and engineering were conducted at that time. Although the results were not as dramatic as the abovementioned they generated the same general picture: Very limited direct use of theory in the form taught in the university programmes. When I have chosen to report the business school study it is because the formulations are so concise and the results so illustrative.

It is a dramatic result when you find only one out of thousand graduates who actually uses their education in the expected way. But what I want to focus on is the understanding of the role of university education in building professional competence: That educational work is directed at providing students with a tool box they can go out and use directly.

I shall contrast this understanding of the role of university education with a more decidedly academic understanding and have chosen a formulation by Thomas S. Kuhn (1970) in relation to his theory of exemplars:

"The resultant ability to see a variety of situations as like each other (……..) is, I think, the main thing a student acquires by doing exemplary problems whether with a pencil and paper or in a well-designed laboratory. After he has completed a certain number (…….) he views the situations that confront him as a scientist in the same gestalt as other members of his specialists′ group. For him they are no longer the same situations he had encountered when his training began. He has meanwhile assimilated a time-tested and group-licensed way of seeing". (My translation)

My point is to illustrate that we had and, I think, still have very contradictory understandings of the very role of university education. This is problematic as these understandings form the basis for much educational planning and curriculum development, although in a very unclear way.

In the 1980s and 1990s a discussion started on direct/indirect use (of theory) and a line of research into indirect use was initiated. Or, as it was formulated in the Business School report mentioned above, research into what we more concretely should understand by the "use of theory as background for the use of simpler methods." In these discussions two hypotheses were stated:

The hypothesis of "*two worlds apart*": Theory taught in universities and knowledge used by professionals constitute two different worlds with no or little coherence.

This is a rather pessimistic view considering how much time and money is spent on university education. We have a more optimistic one:

The hypothesis of "*restructuring*": Theory taught in universities and knowledge used in practice are so different that candidates after their studies have to restructure their understanding from a theoretical to a practical context.

At our center at the Technical University we have made a preliminary study of engineering problem solving which seems to confirm the restructuring hypothesis: That theory in the form taught in universities cannot be identified when studying professionals' problem solving and is not acknowledged when professionals explain their problem solving. However when we analyze their reasoning, we can see that it implicitly reflects a theoretical understanding.

The last investigation I shall mention was concluded in 2000 at the Danish University of Pharmaceutical Sciences (Jakobsen and Adrian, 2000). The study was supported by the Centre for Educational Development in University Science (DCN).

Students at the midpoint of their studies were tested on their understanding of basic scientific concepts and principles, mainly physical chemistry and biology. The test questions were formulated as problems related to practical pharmacy, i.e. problems practicing pharmacists might be confronted with.

The answers to the test were poor. However, when the students were interviewed afterwards and led to realize that the tests were about basic scientific concepts they had been taught 1-2 years before, they did manage to show some knowledge about and understanding of the concepts. Still, they could not solve the tests or even identify the concepts when given in a pharmaceutical context. The results illustrate a problem which is fundamental and often discussed in relation to professional training programmes like engineering, medicine and the like and which I think also has bearings on other university educations. I shall call it the problem of *multi-paradigmatic educations*.

When students begin a traditional education in engineering they have to take courses in physics, mathematics, and chemistry and they are taught by teachers who to some extent, in Kuhn's words, see situations in the same 'gestalt' as other members of their specialist groups. The students then take courses in various engineering subjects for which the same holds true. The teachers of the various subjects have different pictures and stress different understandings of the same phenomenon, and they use different nomenclatures. My colleagues at my centre are just about to finish a study which shows that teachers/scientists in the different subjects or disciplines attach rather different meanings to the same scientific concepts. And yet, we expect students to be able to use the understanding they get in one course in other courses!

We get many new scientific specialties, and the way we bring them into study programmes is often 'by pure addition': We add them to the curriculum without actually integrating them. We have realized that for example engineers need understanding of business, economics, leadership, organizational and social problems and we often just add courses in these disciplines without integration. We should not be surprised that students have serious problems in obtaining an integrated understanding. [See also the contribution of Bowden, p. 9, and Workshop 3, p. 147, in this publication].

The questions

On this background I shall pose some questions to which the answer might be reform(s):

- *How do we engage students in scientific challenges – not just in passing exams?*
- *How do we plan study programmes so that the need for restructuring is reduced?*
- *How do we change programmes so that students have the opportunity to get an integrated understanding?*

And a more fundamental question:

- *What is the role of university education in building professional competences?*

Conclusion

My conclusions are:

We certainly need reforms. Not just structural reforms but reforms directed at answering the most fundamental questions about professional competence. Also, as a background for reforms, we need further understanding of fundamental issues about education, professional work and competence. We need research and not least critically evaluated experiments.

We are speaking about a sector where tens of thousands of students, probably at the age when they are most capable of learning, and thousands of highly educated teachers are involved in producing competence.

We are told that knowledge-competence is our most important resource. Yet the resources we put into development of higher education – into the professionalization of teaching and into research are, indeed, very limited.

We see that the educational discussions and the discussions going on in universities today primarily concern the same problems as they have done for a long time. This is to some extent natural since some questions from time to time need new answers; however to a high degree the same arguments are used as was brought forward in the last century and even back in the 19th century!

AND we do need means to accomplish a shift in the fundamental understanding of education and competence among teachers engaged in a scientific career and among leaders in universities.

References

Agersnap, T. and Skjøtt-Larsen, T. (1982): Civiløkonomer som medarbejdere og ledere - Sammenfatning og Perspektiver. [Business school graduates as employees and leaders – conclusions and perspectives]. Rapport nr. 5. Copenhagen Business School.

Jakobsen, A. and Adrian, C. (2000): Undersøgelse af studerendes forståelse og anvendelse af grundfaglige begreber, som de optræder i farmaceutisk sammenhæng. [An investigation into the comprehension and application of basic scientific concepts by pharmaceutical students, tested in a pharmaceutical context]. The Danish Pharmaceutical University, Copenhagen

Jakobsen, A., Rump, C., Clemmensen, T. and May, M. (1999): Kvalitetsudviklingsprojektet "Faglig sammenhæng". Hovedrapport. [The Quality Development Project: "Coherence within Programmes". Main Report.] Center for Didaktik og Metodeudvikling, DTU, Lyngby

Kuhn, T.S. (1970): The Structure of Scientific Revolutions. Second edition. University of Chicago.

If reform of university science education is the answer - what was the question?

Bjarne Lundager Jensen, The Confederation of Danish Industries

Let me begin by thanking you for inviting me today. The theme of the conference is a question saying: If reform of university science is the answer - what was the question? In my opinion the question could be:

"How do we get world class university science while at the same time improving education and teaching radically in a dialogue with the stakeholders? And hereby I mean both companies and students."

But why do enterprises and industry organisations advocate reforms of science education? And why is it so difficult for universities to change direction?

Industry as a university stakeholder

A large number of stakeholders of universities are busy condemning the universities for not preparing themselves for the challenges of the 21st century. But generally speaking, instead of asking which norms and values are needed this debate is much focused on research, the need for basic funding, and expensive equipment. In doing this we are keeping the challenge of education a low policy issue.

Despite an excellent production of knowledge, citations, peer reviewed articles, universities are at constant war with their stakeholders. A war in which the universities are in a very difficult position facing rather large challenges as well as having to tackle opposite expectations from students, companies, society and politicians.

Companies are important stakeholders of universities. One of their major interests is to increase the number of highly educated employees. What we have in common is the need for attracting the best and brightest young people.

To sum up: The most critical factor for knowledge-based companies is excellent brains and hands that can transform science and technology into new production. This trend one surely sees in the job market for science graduates. The private sector is hiring a greater and greater share of the university graduates (Master) and postgraduates (Ph.D.) and to meet future needs it will require that universities increase the number of students at Master- and Ph.D.-level.

Competition in the knowledge based economy

Unfortunately Denmark and the EU are not keeping apace with either the USA or Asia in producing the necessary number of highly educated people and scientists.

Trends show that the share of scientists in private companies in the EU is decreasing in favour of employment in the public sector. In total, the labour market for academics in the EU shows a lower growth rate than in the USA and Asia. Until 2006 the USA expects a 40 percent increase in the employment of scientists; an increase which roughly equals the labour force in the EU altogether.

Industry and universities share a common interest in overruling this negative trend. But this is definitely easier said than done. First, young people show less and less interest in science and technology. Second, the political system is having serious doubts about whether or not investments in science and education on a high quality level will pay back. Third, science faculties have been hesitating for too long in making the changes in the teaching that are necessary for meeting the demands of modern students and society.

One of the major challenges is that science society is in fact a rather closed club for privileged people who have been reproducing themselves for decades without noticing the major social change in the real world.

The bright youngsters of today often prefer to graduate in social sciences and humanities. These studies are much more prestigious and appealing to students nowadays. This is a development we have to turn around. Therefore we need to rethink university science education and teaching.

This is not only the responsibility of the universities but also of high schools and companies.

The companies' need for science skills

Companies need to be more active in showing young people how they can make a "sexy" science career, and to be more explicit and definite in defining what competences they demand from their highly skilled science workers in order to compete globally.

I admit that this is a very difficult task.

We looked into what kind of needs the companies have when it comes to recruiting people in science. We interviewed a number of companies which all have a strong focus on research and development (R&D). And the survey showed us that companies have a strong focus on professional scientific qualifications.

The companies want highly skilled people in science who

- have fundamental scientific and technical qualifications at a high level
- can apply their knowledge from university in R&D
- can co-operate across boundaries, i.e. have multicultural competences
- can innovate and create both individually and in teams
- are able to learn and adapt.

If we look further into the companies' stomachs we can think of competence in four dimensions (cf. figure 1):

- Professional understanding
- Problem understanding
- Relation understanding
- Market understanding

The major point is that the companies' professional understanding is still centrally related to a wish for more focus on problem solving and understanding of how to work things out.

The Need for Science Competencies in Companies

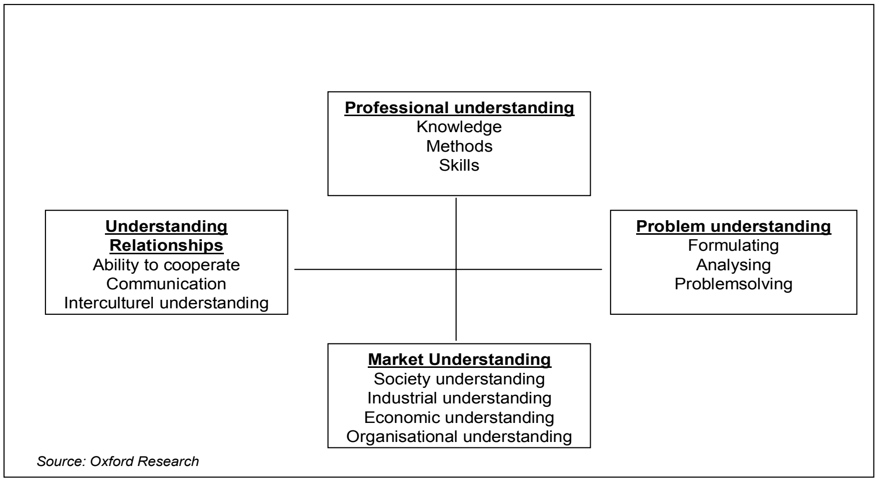

Figure 1. Four competence dimensions that on behalf of The Confederation of Danish Industries have been identified by Oxford Research

So what do these recommendations mean in practice for the teaching at the science faculties and universities. I am not sure, but let me give it a try!

Reforms and challenges

First and foremost: We do not need to replace science lectures with superficial lectures in business economics, marketing strategies, or human development. Let me make this very clear. Companies do not need easy solutions. Companies need even more excellent scientific skills.

I believe that we need to focus on the following three areas:

First, we need to focus more on teaching-skills by putting more emphasis on experience in teaching when hiring staff to university positions. The point of departure here is not the companies' demands but the students' need for a better and a more dedicated teacher. [See also the contribution of Gibbs, p. 53 and 68, and the reports of the four workshops in this publication.].

Secondly, we need to develop bachelor studies which have a clear progression and curriculum, where the students work with real problems and hands-on both in labs and in companies. [See also the contributions of Bowden, p. 9, Olerup, p. 89, and Jakobsen, p. 112, in this publication].

Thirdly, we need to build up a system that rewards good teaching and helps the less skilled teachers to develop their methods and teaching competences. This is not only a question about training but also about culture. The reason why I focus on reward is that I would like to see in Denmark what I have experienced in the US: At Stanford University the top five professors compete about getting to teach first year students because it is the most prestigious teaching job. I would like to see the same enthusiasm in Denmark. [See also the contribution of Gibbs, p. 53 and 68, in this publication].

I think that such a development demands serious reforms and changes. In this discussion it is vital to make more room for education and teaching at all university levels, so that we can continue to have both competitive research and better learning environments.

Obviously, this takes a profound cultural change of behaviour which it is far too great to go into details about today. However, I think that it will be one of the most interesting discussions in the time to come.

Section 2 – Plenary Discussion

Early in the conference the participants were divided into ten groups. In two sessions, one Thursday and one Friday, these groups were requested to prepare a number of questions to be answered or debated at the end of the conference by a panel consisting of

Bjarne Lundager Jensen, The Confederation of Danish Industries (DI)
Graham Gibbs, Director, Centre for Higher Education Practice, Open University, UK
Jens Oddershede, Vice-Chancellor, University of Southern Denmark
John Bowden, Senior Policy Advisor to the Vice-Chancellery, RMIT, Australia

The resulting 19 questions were grouped by the organisers under the following four headings:

Rewarding teaching
Reform processes
Competence
Bachelors
The new University Act in Denmark

Convener of the panel debate was Camilla Rump, the Technical University of Denmark. The report by Kathrine Eriksen, University of Copenhagen, appears in this section. The questions raised by the conference participants prior to the debate are listed in figure 1.

Prior to the debate the panel members were given about half an hour to prepare their answers and contributions.

The report outlined below is based on the taped version of the debate, and is *not* a direct transcript of it. Thus, the report is not completely exhaustive, neither is it always strictly verbatim. It attempts, however, to give as accurate an account as possible of the main points raised by the panel members.

Rewarding teaching

1. *What can DI specifically do to reward good teaching at universities?*
2. *What will the vice-chancellors do to increase the prestige of and interest in teaching – and what have they already done? (→ Rector SDU)*
3. *How can one reward universities that reward good teaching?*
4. *What should universities do to put pressure to bear at the ministerial level to allocate more funds for educational development? (→ Rector SDU)*
5. How do we retain the very best teachers in the higher education sector (high schools, bachelors, and masters)? Attractive careers?
6. *How many resources (time/money) should universities invest in the continued development of university education and teaching?*
7. *Do we need active researchers as teachers at the bachelor level?*

Reform processes

8. *How, specifically, can a top-down approach to educational reform foster the vital bottom-up execution of these reforms?*
9. *Which mechanisms exist for the introduction and implementation of competency/capability based curricula/programmes?*
10. *Which (dis)advantages do you see if a "4 block/year" structure is introduced at all DK-universities?*

Competence

11. *Are there any differences between competencies in the DI-sense (cf .the presentation of Lundager Jensen, DI) and in the Niss-sense (cf. the presentation of Niss and the KOM- project)?*
12. *Do you believe that in a three-year programme it is possible to educate bachelors with competencies in both professional knowledge and problem solving?*
13. *Are we going to see small private universities in western Europe as a general answer to the problem that the old public "supertanker universities" are too slow in adapting to the rapidly changing needs of modern society?*

Bachelors

14. *What role should the industry play to make B.Sc. graduates more "attractive*"? *(→ DI)*
15. *How does DI see the role of bachelors in the future, compared to those holding a Masters or Ph.D.?*

New University Act in Denmark

16. *If "freedom under responsibility" is an attractive feature in a university career – how do we ensure this (also in view of the new university act)?*
17. How can the new university act support more efficient teaching of higher education science?
18. Internationalization: If internationalization = English language spoken, and we only have an English science language in the end, how do we teach science at lower levels in Danish?
19. Can we expect financial support to science teachers and technicians teaching in English?

Figure 1. Questions raised by ten groups of conference participants. Abbreviations: →: Directed to. SDU: University of Southern Denmark. KOM: Competencies in Mathematics. DI: The Confederation of Danish Industries. Questions in italics were addressed by the panel: John Bowden, RMIT, Australia, Graham Gibbs, Open University, UK, Jens Oddershede, Vice-chancellor/Rector, SDU, and Bjarne Lundager Jensen, DI.

Questions addressed to the panel

Besides the fact that question 13 (Q13) was the very last question addressed to the panel the questions were discussed in the order listed. The comments of the panel members were as follows:

Rewarding teaching

Q1: What can The Confederation of Danish Industries specifically do to reward good teaching at universities?

Bjarne Lundager Jensen, The Danish Confederation of Industries
I will answer this in three parts: First, universities must emphasise educational skills when they are hiring new staff members. Second, teachers have to work more on improving their teaching and they should do that in teams. Education today is seen as a private matter, a view which will not hold in the future. Third, DI can, and is willing to, co-finance or sponsor new scholarships directed towards education, maybe not now but in the years to come.

Graham Gibbs, Director, Centre for Higher Education Practice, Open University, UK
In the UK we have something called the Partnership Award – the "such and such company" Award for x. Here companies sponsor prizes for teams of academics who are working actively to develop teaching.

Q2: What will the vice-chancellors do to increase the prestige of and interest in teaching – and what have they already done?

Jens Oddershede, Vice-Chancellor, University of Southern Denmark
First we have to answer some additional questions, namely those of how we define good teaching and how we assess it. We must start by monitoring the teaching. Once we know the good teachers *then* we can reward them. The obvious rewards are, of course, money and promotion. For instance, we could institutionalise special professorships for teaching the main qualification criteria of which would be excellence in teaching. Other possibilities include salary increases and awards. We could use these incitements to a larger extent than we do today.

Anyway, I think the focus on teaching has increased quite a bit over the last years. When I was a student absolutely no attention whatsoever was paid to teaching. One measure of improvements to teaching is an increase in the pass rates. In Denmark the percentage of students enrolled in a particular study programme that will end up getting their final degree has almost doubled in the last ten years. It may be a coincidence – but this development actually started when the "taximeter system" was introduced [eds.: the Danish funding scheme where universities are funded according to the number of passing students].

John Bowden, Senior Policy Advisor to the Vice-Chancellery, RMIT, Australia
I will just mention that quantitative measures of output can be misleading. We must focus on what students actually learn – on the qualitative aspects.

Jens Oddershede
Anecdotally I will mention that some teachers actually base their criteria of quality on students failing: The higher the percentage of student failures the better the course!

Q3: How can one reward universities that reward good teaching?

Graham Gibbs
In England a new programme has just been announced in a government white paper from January 2003. A substantial amount of money has been earmarked for salary improvements to academics.

However, this opportunity for additional funding is only available to universities that allocate all of the money to excellent teachers. Thus, only universities that have developed mechanisms for measuring teaching excellence can have a share of this additional funding.

Jens Oddershede
We should support ideas like this. It should be communicated to the Ministry. For the time being we don't have incentives like this in Denmark. The focus has been on quantity instead, cf. the "taximeter system".

Q4: What should universities do to put pressure to bear at the ministerial level to allocate more funds for educational development?

Jens Oddershede
I certainly wish I knew the answer to that! I think we need to make the legislators aware that teaching is actually a prerequisite for research. In order to upgrade research

we must upgrade education. That is one point that the Danish Rectors Conference tries to draw attention to.

Q6: How many resources (time/money) should universities invest in the continued development of university education and teaching?

Graham Gibbs
Universities do spend a lot of money on R&D [eds.: research and development]. However, almost everything is spent on research. If one compares industry and universities in terms of distribution of R&D budgets on different activities, universities are embarrassed by such comparisons. There is definitely a scope for a more rational distribution of the budget.

Reform Processes

Q8: How, specifically, can a top-down approach to educational reform foster the vital bottom-up execution of these reforms?
Q9: Which mechanisms exist for the introduction and implementation of competency/capability based curricula/programmes?

John Bowden
My answer to question 8 is related to question 9 so I'll take them together. Top-down processes do not work alone, neither do the bottom-up ones. However, a combination of top-down and bottom-up processes does work. A collaboration process is needed. But reforms must happen over a long period of time, it is a long process of interaction, and anchor persons are needed to secure the process.

People with sufficient time allocated to interact with all parts of the university and who can get people to reflect and discuss the themes are needed. One also needs to have a rector who actually understands the pedagogical approach taken. S/he has to be able to argue for the reform; and it is impossible to argue for something one doesn't understand.

Further, if reform plans are to be successfully executed they must be in keeping with the corporate plan. Everybody must become engaged in discussing the future of the university in general. Pedagogical strategies must be developed in connection with this general discussion. It's a holistic approach that is needed and one in which everybody is able to make a contribution.

At RMIT where we eventually succeeded in getting every department convinced that they should adopt the capability based curricula we had everybody engaged in a general debate on the university profile. RMIT is the University for the work place and the capability oriented curricula are in keeping with this profile.

The capability reform was aimed at making graduates better to do their jobs on the labour market later on. So, the message was not 'You have been teaching badly and must improve yourself', but rather that everybody should be able to reflect upon how we best could develop all activities according to our general profile, including our teaching.

Graham Gibbs
In the UK we have teaching and learning strategies. Some are bound to be top-down ones and they don't work. However, mechanisms do exist to link top-down to bottom-up. One example from Liverpool: All departments were engaged in recognising the problems they were currently experiencing. Extra funding was then made available; but only to the departments that would develop a local strategy for handling the identified difficulties. In this way every department engaged in the kind of debate John Bowden is talking about.

At the web-site (www.ncteam.ac.uk) I mentioned in my talk this morning you can find case-stories where different strategies for engaging teachers in pedagogical development are employed.

Q10: Which (dis)advantages do you see if a "4 block/year" structure is introduced at all DK-universities?

Graham Gibbs
Both advantages (e.g. increased flexibility) and disadvantages are connected to the block structure. Unfortunately in Britain where all teaching was modularised into smaller chunks about 15 years ago none of the advantages happened and instead all the disadvantages (fragmentation of knowledge, massive assessment loads etc.) became dominant. Now, there is a move back towards larger course chunks in order to ensure coherence.

John Bowden
If the goal is to make students learn more than just fragmented bits of knowledge, to make them integrate things and bring things together across courses then we must find ways of e.g. coalescing courses with each other (e.g. maths and chemistry) and, I'll argue, for assessing across courses. There is a danger that a 4 block structure is a step

in the opposite direction and will support a shallow surface approach to learning. So if the learning is tied to the blocks my advice would be: Don't do it. If however, the learning processes happen across the blocks then it might be OK.

Jens Oddershede
To return to the bottom-up/top-down discussion I'll say that the introduction of block structure is a top-down approach. As block structure is a political issue in Denmark where some universities are adopting the structure and some are not, I will refrain from making clear statements in favour of one or the other.

When I was teaching in the U.S. for some years I had a chance to compare their block structure to the Danish semester structure. Both had advantages and disadvantages. A block structure makes students work actively since they are always close to an exam, however less deep learning takes place; whereas semester structure produces lazy students throughout the year (but perhaps it was just my fault as a teacher). Anyway, if for no other reason it may sometimes be good to break up the system in order to force teachers to rethink their whole approach.

Graham Gibbs
A plea for your implementation: What *can* make modularised courses work is to secure the flexibility and the freedom to structure the size and shape of the courses as to meet the goals and demands that are appropriate for the various subjects (subject areas).

Competence

Q11: Are there any differences between competencies in the DI-sense (cf. the presentation of Lundager Jensen, DI) and in the Niss-sense (cf. the presentation of Niss and the KOM-project)?
Q12: Do you believe that in three years it is possible to educate bachelors with competencies in both professional knowledge and problem solving?

Mogens Niss, Professor, Roskilde University, Denmark (ex auditorio)
I don't know the details of the DI-competences. In the KOM-project we focus on subject matter competency. It appears that the DI-competencies are broader. Probably they are supplementary.

Bjarne Lundager Jensen
I hope there are no big differences. The KOM-project is on a more sophisticated level, very inspiring and we have tried to work along some of the same lines.

Many people ask DI how they can formulate everything in terms of competencies that suit the industry's needs. But we must find a reasonable balance between on one hand the scholarly university tradition and on the other hand the labour market. DI does not have the right solutions. As I often say to universities: Don't do what the companies say or want. But, please, listen more carefully to them!

John Bowden
As I see it, competencies in the Niss-sense are actually capabilities applied to a discipline area rather than to a professional outcome.

As for the DI-competencies of professional knowledge and problem solving they should not be seen as separate entities or additive issues. Problem solving is learned through the way you learn the content.

It is the integrative approach which is important. If it is seen as separate entities you cannot learn it in three years but if an integrative approach is adopted then it *can* happen, also here!

Q13: Are we going to see small private universities in western Europe as a general answer to the problem that the old public "supertanker universities" are too slow in adapting to the rapidly changing needs of modern society?
(Question forwarded from the competence section).

Jens Oddershede
I don't think we'll see new small *general* universities in our part of the world; corporate universities yes, but general ones no. They are simply too expensive to create. Instead, if we are not able to educate good scientists and engineers, companies will move to other countries where better graduates can be recruited for less money: India, China, and Thailand, for instance.

Graham Gibbs
With the notable exception of the University of Phoenix which is the fastest growing university in the world and a for-profit university, I think you are absolutely right. At the University of Phoenix students who have failed at other universities do well due to lots of support, feedback, and group work; all the things they didn't get in the universities where they failed. But it is business studies and other areas where people are ready to pay a lot and it is relatively cheap to provide the education. So otherwise it is not likely. Instead I think companies will make universities provide highly specialised up-date courses in areas interesting to the companies and where

universities have the necessary expertise. But universities have to be fast on their feet to benefit from this development. Demands will be constantly changing.

Bachelors

Q14: What role should the industry play to make B.Sc. graduates more “attractive”?
Q15: How does DI see the role of bachelors in the future – compared to those holding a Masters and Ph.D.?

Bjarne Lundager Jensen
Industry doesn’t want to play any role! We do not see the bachelors as an employable group in the Danish labour market. I talk about bachelors because we want to improve their education as they go on in their education to become Masters or Ph.D. Since science will not in the future recruit only the very bright minds (they are more attracted to social science) we must improve the bachelor degree in terms of teaching, in terms of better progression and the development of better problem solving competencies. We have to rethink the system in order to attract more students and reduce drop-out rates.

John Bowden
Industry should be more open-minded and value different graduates. If a 3 + 2 university programme is *genuine* then industry must be open towards the bachelor candidates and to the improvement to the industry that an integration of them might trigger.

Bjarne Lundager Jensen
I think you are in some ways right but in my world this is theory. The industry wants Ph.D.s, not even Masters! The industry requires high-level qualifications.

Jens Oddershede
In the Anglo-Saxon world there are almost no jobs for Masters only Bachelors and Ph.D.s. Maybe it is impossible to structure a market to hold three graduation levels.

Graham Gibbs
If you ask companies what they want, you get a lot of different answers. I don’t think they have a clue what they want. It depends on who you’re asking. Also, once we have worked hard to improve e.g. the collaboration skills of our graduates that industry has been calling for, industry starts to say that they’ll train them themselves anyway since we don’t do it the right way. We get inconsistent messages from companies.

Bjarne Lundager Jensen
You also find very different points of view inside universities. So we need a dialogue. In Denmark and Germany we do not have a tradition for hiring Bachelors.

New University Act in Denmark

Q16: If "freedom under responsibility" is an attractive feature in a university career – how do we ensure this (also in view of the new university act)?

Jens Oddershede
The new act will not limit the freedom of individual researchers. A good manager will not try to limit individual freedom. The freedom to pursue the research areas that we want to pursue will remain. As for management the New Act will hopefully bring about a more effective management, a development that can influence teaching to the better. I think that many of the problems we are currently encountering with bad teaching have to do with management. A new type of management could be more capable of rewarding good teaching and research and of dealing with bad teaching, also when it involves criticising colleagues.

Bjarne Lundager Jensen
I just hope that a new management will be able to make university careers more attractive. In the long run it is not good if the private sector takes all.

Camilla Rump, Convener
Thank you very much for your contributions.

Section 3 - Workshops

In this section we provide a summary of the four workshops of the conference. None of the reports claims to provide an exhaustive account of what happened during the two to three hours long sessions. Still, we hope that these reports will give the participants an overview of the discussions that went on in the workshop in which they took part themselves and an idea of what happened in the other three workshops.

Workshop 1 – Peer Instruction

Conveners: Peter Ditlevsen, University of Copenhagen, Denmark, and
Poul V. Thomsen, Aarhus University, Denmark

Reporter: Sebastian Horst, University of Copenhagen

Workshop Format

Peer instruction gets students involved during class through activities that require each student to apply the core concepts presented by the teacher, and then explain these concepts to their fellow students. Most teachers applying peer instruction use it in large lectures, though many have also found it to be an effective approach for engaging students in small classes as well.

The aim of the two workshop lecturers was to share their experiences with peer instruction and discuss these with the workshop participants. Both lecturers have a background in physics. Poul V. Thomsen is Director of the Centre for Studies in Science Education at Aarhus University and has been engaged in science education for many years. Peter Ditlevsen is Associate Professor at the Niels Bohr Institute, University of Copenhagen, where he teaches introductory physics for undergraduates (mechanics, "Fysik 11"). In this course, with more than one hundred students in the class, Ditlevsen used peer instruction in 2002. Three of his colleagues have investigated the use of peer instruction at this course (Andersen et al. 2003).

After a brief introduction and presentation of the workshop participants, Poul V. Thomsen presented some ideas about learning and teaching, particularly focussing on the needs for activity in learning processes. The main part of the workshop consisted of a practical example of peer instruction conducted by Peter Ditlevsen, followed by lively discussions. The workshop progressed in Danish and informally with lots of dialogue and discussions during the presentations. This report does not attempt to cover all the matters discussed.

Learning and the need for activity

Poul V. Thomsen started out by presenting the constructivist view of learning in which knowledge is not something you just acquire but something you construct through an active process. He didn't find it relevant to initiate deep discussions on different definitions of constructivism in this workshop. However, the basic idea is to consider the human being as an open and self-regulating system with cognitive structures. Exposed to an input, e.g. a question, this system will create an output based on its existing cognitive structures. This is what happens in ordinary oral examinations during which the student's cognitive structures are "investigated" stepwise by the examiners. In the view of Poul V. Thomsen, this is not a very interesting use of time. He finds it much more interesting to change, with the right input, existing cognitive structures within the students.

A variety of research illustrates the difficulty in changing students' existing cognitive structures. It often takes teachers big efforts over a long period to induce fundamental changes in the way students perceive the world. A good example is Newtonian mechanics. Many people, including some of those who have studied physics, face difficulty in applying this "basic way" of understanding everyday life experiences.

According to Poul V. Thomsen, there are two fundamentally different ways to learn new things: assimilation and accommodation. Assimilation describes the process of incorporating new knowledge into existing cognitive structures. "This is not really making you any cleverer", as Thomsen put it. He then described accommodation, i.e. the process in which the learner's existing cognitive structures are changed or new structures created.

The cognitive structures, or mental models, regulate the way we perceive the world around us, deal with problems, and decide what actions to take. However, Thomsen stressed, it is also a well-known fact that the mental models are often inconsistent with each other – and this goes for all humans. Somehow, this fact conflicts with the ideals of natural science and research according to which inconsistency is something we attempt to avoid. Nevertheless, it is important to acknowledge that by the hand of nature human beings are not "created" to automatically test the (in)consistency of their mental models. It is claimed, Thomsen continued, that our mental models have the function to minimize mental work, and this is probably true. The problem is, however, that in order to learn you *have* to do mental work; the less mental work, the less learning. An Australian project tried to deal with this by constantly changing the teaching method every four or five lessons. The aim was to make it difficult for the students to minimize their mental work. However, this is not seen many places and especially not in the Danish High School (gymnasium), as Poul V. Thomsen knows it.

The Force Concept Inventory (Hestenes et al. 1992) is a tool testing students' concepts in mechanics. It consists of 30 multiply choice items. The students are tested both prior to and at the end of a specific course with the aim to measure students' gain from the course. The inventory has been used in several studies, on thousands of students taking undergraduate physics classes. It turns out that traditional teaching with normal lectures followed by the teacher's or instructors' comments to the students' problem sheets ("opgavegennemgang") gives a gain in the order of 20%. By changing only one lesson per week from this format to students' problem solving in groups you can get a much higher gain, up to around twice that figure.

At Aarhus University, the Force Concept Inventory was used to measure students' gain in a course employing traditional teaching in which special attention was paid to facilitate student problem solving *not* by telling them the answers but trying to push them just in the right direction every time they asked for help. The results were similar with a gain around 40%.

Thomsen mentioned this to underscore the importance, and the effect, of students being active in their learning processes. However, he also stressed that one question is, of course, how to make over a hundred students active at the same time in a lecture. This is not a trivial question at all! Nevertheless, it is not impossible, as we heard from Peter Ditlevsen and his experiences with peer instruction.

Examples of peer instruction

The idea of peer instruction originates from Eric Mazur who has developed peer instruction as a tool and written numerous texts on this topic (e.g. Mazur 1997). See also the website of the Mazur Group of Harvard University below. Mazur (2003) explains:

"*One problem with conventional teaching lies in the presentation of the material. Frequently, it comes straight out of textbooks and/or lecture notes, giving students little incentive to attend class. That the traditional presentation is nearly always delivered as a monologue in front of a passive audience compounds the problem. Only exceptional lecturers are capable of holding students' attention for an entire lecture period. It is even more difficult to provide adequate opportunity for students to critically think through the arguments being developed. Consequently, lectures simply reinforce students' feelings that the most important step in mastering the material is memorizing a zoo of apparently unrelated examples.*

In order to address these misconceptions about learning, we developed a method, Peer Instruction, which involves students in their own learning during lecture and focuses their attention on underlying concepts. Lectures are interspersed with conceptual questions, called ConcepTests, designed to expose common difficulties in *understanding the material. The students are given one to two minutes to think about the question and formulate their own answers; they then spend two to three minutes discussing their answers in groups of three to four, attempting to reach consensus on the correct answer. This process forces the students to think through the arguments being developed, and enables them (as well as the instructor) to assess their understanding of the concepts even before they leave the classroom.*

We have taught two different levels of introductory physics at Harvard using this strategy and have found that students make significant gains in conceptual understanding (as measured by standardized tests) as well as gaining problem-solving skills comparable to those acquired in traditionally taught classes. Dozens of instructors at other institutions have implemented Peer Instruction with their own students and found similar results. Peer Instruction is easy to implement in almost any subject and class. It doesn't require retooling of entire courses or curricula, or significant expenditures of time or money. All that is required is a collection of ConcepTests (available on Project Galileo [www.galileo.harvard.edu]) and a willingness to spend some of class time on student discussion." (Mazur, 2003)

Peter Ditlevsen had decided to illustrate peer instruction in practice in the workshop. He gave a short lecture on the human eye and colour perception in which he included a couple of questions for the workshop participants to try out peer instructions themselves. He distributed a piece of paper with the numbers 1-8; later to be used as voting sheets. Having explained some of the functions of the human eye, Ditlevsen asked us "Why do stars appear white on a bright, starry night?" As learners we could choose among the following four possible answers:

1. All visible objects on the sky emit light in all frequencies and are therefore white.
2. Only white light has the capability to travel through the atmosphere.
3. The light intensity of the stars is too low for us to see the real colours.
4. At night, no objects are able to have colour.

After one minute of individual reflection, each participant voted for one of the four statements. Several different answers appeared. Then the participants started discussions in groups. After a few minutes of group discussions, a second individual vote was taken. This time nearly everybody answered correctly (no. 3). Academics apparently have a tendency to start discussions about the correctness of questions rather than just accepting the arguments of the teacher for the right answer. Accordingly, this example started a major discussion about the topic of colour perception, and it illustrated that the participants easily became engaged in the topic by just one simple question. Peter Ditlevsen did a few more examples on colour perception; a short lecture followed by a question with a number of answers to choose from, then a pre-vote, discussion in groups, vote again and finally a conclusion. Each time the result was enthusiastic discussions!

Some comments from the workshop discussions on peer instruction

- It is not always easy to stop the discussion when it is well under way.
- Sometimes it works well if all the answers to select from are wrong.
- Questions that appear a bit provoking are likely to start great discussions.
- Having just a little private discussion with another student makes the students capable of speaking out load and arguing about the subject/topic. This includes students that normally would not participate in an open discussion.
- The questions and peer instruction make it positive to discuss things, including wrong ideas. However, it is very important that the teacher is aware of the crucial importance of creating a climate that makes it all right to say something potentially "wrong".
- In large classes, it is not always possible to know if it is only the brightest ones who contribute to the group discussion.
- It is very important that questions and answers are well formulated, simply to avoid "noise" in the discussions.
- It may be difficult, but it is very important that the teacher allows the discussion to last long enough. It is not always easy for teachers to keep quiet for a while and not interrupt too early!
- Data compiled by Erik Both at the Technical University of Denmark indicate that peer instruction gives better examination results. However, his survey also indicates that male students gain more from peer instruction than females! This gender aspect needs further investigations.
- The questions must concentrate on key elements of the curriculum/topic, simply to avoid students focusing too much on less significant course elements. It takes much time to develop good, clear and relevant questions and possible answers for peer instruction.
- Of course, there will be less time to lecture if you are doing peer instruction every 10-15 minutes or so. However, the mental work done by the students compensates well for the loss of lecturing time. The students learn more from being active themselves than from listening to a teacher lecturing at them.

References

Andersen, A.C., Machholm, M. and Olsen, L.F. (2003). Kammeratlæring på førsteårskursus i mekanik [Peer-instruction in introductory mechanics]. CND's skriftserie, nr. 6. Centre for Science Education, University of Copenhagen.

Hestenes, D., Wells, M. and Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher*, Vol. **30**, March 1992, 141-158

Mazur, E. (1997). Peer Instruction: A User's Manual. Series in Educational Innovation, Prentice Hall, Upper Saddle River, New York

Mazur, E. (2003). Peer Instruction. Cf. http://mazur-www.harvard.edu/education/pi.html (retrieved June 23, 2003)

Workshop 2 – Competencies

Conveners: Mogens Niss, Roskilde University, Denmark, and Niels Grønbæk, University of Copenhagen, Denmark

Reporter: Jessica Carter, University of Southern Denmark

Workshop format

The competency workshop was arranged as a follow-up to the keynote presentations by Mogens Niss and Niels Grønbæk [p. 29 and 37 in this publication. See also the contribution of Bowden, p. 9, and Workshop 3, p. 147].

The aim of the workshop was to make the participants discuss their own possible applications of the notion of competency. The workshop was conducted around a handout with three quotes referring to competency, all three of them referring to actual statements expressed in discussions about the notion of competencies amongst mathematics teachers at university level. Each quote was followed by suggestions for topics to be discussed. The participants started out by reading one quote (theme) at a time and then discus the three themes. Below follow the quotes, questions and main points of the discussions.

Theme 1: Application of the notion of competency in different subjects

Quotation 1:
This is typical for mathematicians. You give them a concept like competency and soon after they turn it into an axiomatic system and start checking it for redundancies, consistency and the like. When finished you have a system / theory … that you, due to its level of abstraction and generality, may apply in many seemingly different learning environments. But you never get dirty hands.

Questions:
- Is this true in relations to the competency question? To what extent can
- this be done in relation to other subject matters?
- the mathematics model (KOM) serve as a scheme for other subject matters?
- Can the mathematics model be applied at many (all) levels of the educational system?
- How would the model look in your subject matter?

Discussion:
On this theme two main issues were discussed: The application of the notion of competency in other subjects, and the nature of the notion itself.

To the question of whether the concept of competency was useful in other subjects one participant noted that it was difficult to transfer the notion of competencies as described in the "KOM-report" to specific teaching sessions, particularly if one does not take the reports' descriptions literally but wants to rethink them in the view of another subject.

Another participant (teaching mathematics) remarked that he had recently tried to use the notion of competencies as a tool to rethink a course he was teaching. Instead of using all eight competencies, he selected two of them when he designed the course programme. These were the "*model handling competency*" and the "*problem handling competency*". The main benefit of this was that it made it possible to think the course in a different way. This way of thinking also appeared to be useful at various meetings discussing which capabilities in mathematics other departments expected the students to achieve. The meetings revealed that it was not so much specific knowledge of certain topics that was required, but rather different capabilities (competencies).

There were no general conclusions as to whether the notion of competencies is useful in other subjects than mathematics. However, in spite of obvious exceptions, it seemed as if the participants agreed that this could very well be the case. Amongst the exceptions subjects of a more phenomenological type were mentioned.

Concerning the nature of the notion of competency itself, a participant asked Niss whether it was a theoretical or a practical notion, i.e., whether it was theoretically deduced or funded on empirical studies of students' behaviour. This question was considered of importance if one asks how competencies can be revised. Another question in line with this one concerned the relation between content and competencies.

Niss began his answer to the latter with a quotation from the mathematician Halmos: " When walking it does not make sense to ask which leg is more important". Thus, the two – content and competences – cannot be separated. He continued by stressing that the eight competencies in the "KOM-report" are defined independently of specific content matters. Later, the content is introduced as orthogonal to the competencies, i.e., competencies may be seen as "bringing content into action".

To the question regarding the origin of the (KOM) competencies, i.e. whether it was a theoretical or practically/empirically based notion, Niss answered that it was neither of the two. Rather, he perceives the KOM work as a pragmatic way of finding out what we (mathematicians) do, and that the reception of the KOM report has revealed that the description of the competencies is an articulation of things already known by many. Further, Grønbæk emphasised that the KOM descriptions are not to be perceived as a canonical description of mathematics. There might as well be other descriptions. Rather, he perceives the eight competencies as a tool, and as long as it works the nature or origin of them does not matter.

Finally, the notion of competencies was compared with the notion of skills. In geography the notion of skill is often used, for instance, as the skill to interpret a map. According to Niss this particular use of the term skill would denote the same as the notion of competency, although he would suggest that the concept of competency in general would denote something more complex than a skill or aggregate of skills. Niss also underscored that the notion of competencies in the "KOM-report" should be distinguished from the competencies/skills the industry requires of its employees, e.g. "adaptability" ("omstillingsevne"). The main difference is that the notion of competency in the "KOM-report" is related to a specific subject.

Theme 2: Competency in relation to teaching and curriculum planning

Quotations:
Let us consider a society in which there are master carpenters who educate carpenters. Due to various more or less complicated political and sociological circumstances there is also a group of citizens who make their living by analysing educators.

This group does a fine job for instance when dealing with guidelines for handicraft teaching at various elementary educational levels.

Lately though they have attacked the master carpenters who to their great astonishment are informed that they have no understanding whatsoever of what they essentially are doing when they educate carpenters. As an example: The masters believe that they train prospective carpenters to put nails into boards so that the construction is durable. But no, no … what they really do is giving prospective carpenters

- *Handling of nails competency*
- *Handling of hammer competency*
- *Hit-the-nail-on-head competency*

…

And now it is demanded that the masters must define what they are doing in these term, and possibly to relate it all to thoughts about 'the specific carpenter universe', 'interdisciplinary understanding', 'perspective, analytic criticism', …

In this situation I believe that most master carpenters would react along the lines of "Get lost … If you believe that I can learn anything new about putting nails into boards from someone who never has put a stick into a turd without damaging both, then rethink! When I teach an apprentice to put nails into boards, then I know at which point he is capable and his constructions will last. Assessing this is easy for me. For instance, when he has finished building a house, all I have to do is check that it remains standing. It is similar with other tasks."

At the moment I feel like one of these master carpenters. Is it possible to progress with competency descriptions and at the same time reduce this feeling in me?

Questions:

- To what extent do you subscribe to the above perceptions of teaching and learning?
- Do you experience similar conflicts with a competency based curriculum planning as quoted?
- How would a shift to competency based curriculum planning relate to "our" present perception of "ourselves" as teachers with a science based gospel?

Discussion:

The first comment concerning this quote was that the form of teaching it represents is the master-apprentice principle. However, the last 30 years of research has shown that you cannot just put knowledge into the minds of students. The students themselves have to create their own knowledge, which is essentially what the constructivist learning theories say. According to this participant, this is typical for academic (theoretical) learning which is different from learning a craft, although the master-apprentice principle of learning might be appropriate in certain situations also at universities, e.g. when Ph.D. students are trained to become researchers. [See also Workshop 1, p. 134, in this publication].

Another comment pointed to the irritations inherent in the quote. The view was that a similar reaction would be expected from several mathematicians when subjected to this new concept of competency. What mathematician wants to do is to work with mathematics and not be bothered with various buzz-words, it was claimed.

Addressing a comment from one of the participants regarding the necessity of matching competency based learning with assessment/evaluation, Niss informed about one of the motives he had for starting to look for competencies. One of Niss' Ph.D. students wanted to study what the good students were able to do in order to assist their weaker fellows. The students who were considered to be the best students were defined so from their examination results. In the study these students were given a set of problems that were slightly perturbed in comparison with the ones the students were used to handle. It turned out that the "good" students were not able to solve the problems. Thus, after all, it was indicated that students who did well at examinations were not necessarily the best students. [See also the contributions of Bowden, p. 9, and Jakobsen, p. 112, in this publication]. One of the conclusions Niss emphasised from this study was that a focus on certain competencies which also were reflected in the assessment of the students would reveal such discrepancies. More importantly, he said, we should be concerned about the goals and aims we want to pursue.

A question was also raised about "who has competencies?" A current Ph.D. project distinguishes between "action competency", which is something that pupils have, and "educational competency", which is something that the teacher has. One could also distinguish between competency of a group and of a person, or even between a person and a person with his/her tools (hammer, glasses, books etc). However, these questions were not further discussed.

Theme 3: Getting "dirty hands"

Quotations:
Whether it is possible to describe courses in terms of competencies depends primarily on one's ability to define these terms. And since we are at a Natural Science Faculty, it is permitted to insist that defining a competency is equivalent to describing empirical conditions to determine presence of a particular competency. In other words

Definition of competency = Objective method of assessment?

I would also like to continue the sceptical line and ask if the constructors (of competency concepts (ed.)) are able to describe which problems one imagines solved by 'the concept of competency' instead of the old well-known concept of curriculum contents?
For many years the course descriptions of Mathematics 1 and Mathematics A were almost identical because the courses dealt with the same topics; most people are of the opinion that the courses were (very) different, but that was untold.
However, the problem is that the more theoretically one defines a course by means of competency concepts the more one separates the different disciplines.

Questions:

- Recall an authentic situation in which you are the course responsible teacher and think of a specific subject matter context. It could, for instance, be the course you will be teaching next term. Consider a specific issue or topic from this course.
- What would a competency-based description of this issue/topic look like? What are the 'problems' you aim to solve? Please be as specific and concrete as possible.
- On which aspect of 'subject matter handling' will you focus?

Discussion:
In this part of the workshop, the conveners urged the participants to "get dirty hands", i.e., to describe a specific course, preferably outside mathematics, in terms of competency-based teaching.

Two courses/course components were discussed.

The first was a master course on "history of geometry" to be conducted in the autumn term, 2003. The responsible teacher underscored that the course is not a mathematics course, not even a natural science course. One of the competencies aimed at in this course is the ability of the students to reflect on their subject, mathematics. Mathematics changes dramatically during the historical period covered by the course. During the course students will make some presentations on which they will be assessed. These marks will be included in the final mark that also includes the result of an oral examination. The main discussion centred on how we as teachers assess the competency of being able to reflect on a subject/topic, here mathematics. One suggestion was that the students should be given different papers to discuss, extract and present. However, no conclusions on the assessment criteria were made. Another participant commented that although it is a history course it requires that the students already possess certain competencies in mathematics. How would these competencies contribute?

The second and final problem we discussed was related to the competencies that are in play in connection with the experimental coursework ("laboratorieøvelser") in physics and chemistry. What are the most important competencies in this case? Here a distinction was made between the ability to *interpret the results* obtained from an experiment and the ability to *design and complete* an experiment. Some of the participants were of the opinion that students do not have enough time during their studies to develop both of these competencies! It also appeared that different universities in Denmark gives different priority to competencies related to experimental work. Common to all of them, it appeared, is that interpretation of results is considered to be an important competence. However, is was agreed, besides the ability to interpret results students should attain the competency of designing experiments, at least during their final year when they prepare themselves for their master thesis. A physicist or chemist should have a design competency.

In general, the workshop participants agreed that competency discussions may form a good and firm platform for discussions and decision-making in relation to learning and teaching, both for teachers and students.

References

Niss, M. et al. (2002): Kompetencer og matematiklæring. Ideer og inspiration til udvikling af matematikundervisning i Danmark. [Competencies and the learning of mathematics. Ideas and inspiration related to the development of mathematics teaching in Denmark.] Ministry of Education (Undervisningsministeriet), Copenhagen.

Workshop 3 – Capabilities-driven curriculum

Convener: John Bowden, RMIT, Australia

Reporter: Rie Troelsen, University of Southern Denmark

Workshop format

This workshop focused on the notion of a capabilities-driven curriculum, what it entails, and how it could be organised and implemented [See also Bowden's contribution, p. 9, in this publication]. Bowden initiated, however, the workshop by stressing that the group could equally well discuss other aspects of the concepts of capability and capability-driven curricula. The following themes were agreed to as an agenda for the workshop activities.

How do we make a curriculum programme? What are the roles of the physicists or chemist, and how can they interact with staff from the field of educational pedagogy and planning? These interactions do not happen very often at Danish universities. Clarification of the concepts of capability and competency, and how they relate to the American discussion on outcome based curriculum planning?

The transition from the 3rd to the 4th year at university, i.e., from bachelor to master levels. What are the capabilities needed in a particular subject at the transition from the 3rd to the 4th year of study?

The following report outlines the main points of the discussions. However, it is not to be seen as a detailed coverage of all the issues raised during the workshop.

Theme 1: How to make changes in curriculum planning

The debate about competencies, at least in Denmark, is mainly words on paper, i.e., an academic or political discursive issue with relatively few practical examples. [See, however, Workshop 2, p. 140, in this publication and the "KOM-report"]. According to Bowden, we need to perceive curriculum development as a systematic process that includes a mixture of both subject oriented concerns and educational, pedagogical perspectives. It is not a question of pedagogy and educational matters on the one hand and subject matters on the other, he stressed. Rather, curriculum change includes the complex integration of the two and at *all* levels of the whole educational programme:

planning, implementation and evaluation of the educational process. Discussing curriculum change, Bowden underscored the importance of considering and integrating questions and problem areas such as the following:

- What are we aiming at? What is the content, both in regard to subject areas and the capabilities we want the students to develop and achieve?
- What are the evaluation forms? How can we assess that we achieve what we want?
- In which ways do we want to teach? How do we want the students to work with their learning processes in class?

These questions have to be addressed not only at the general level, i.e., at the level of the various bachelor or master programmes (chemistry, physics, nanotechnology, etc.), but each and every time teachers are planning and implementing specific courses within these programmes. If coherence between the general programme and the specific courses is not aimed at, *and* achieved, then concepts such as competency or capability-based curricula planning just become fancy words changing nothing, particularly not for the students concerned.

Based on his experiences from RMIT[7], Bowden illustrated the process of curriculum change by focusing on two equally important stages. First, he stressed, we need a will to change and to make reforms. Basically, this is a political decision. Secondly, we need to do it at the operational level. This second phase is, of course, hard as university staff is busy people. You have to find a way to pass the barrier that it is hard to make changes, Bowden said.

Regarding the political decisions and their dissemination amongst staff, Bowden explained that this took 4-5 years at RMIT when capability based curriculum reforms were implemented in the 1990s. This phase included, for instance, that faculty staff, at meetings related to teaching and planning, were asked to consider questions such as: "In your programmes, do you think the assessment criteria of your courses address the goals set?" Having stimulated *and* influenced the general debate amongst staff about capability thinking in relation to curriculum planning for some years, eventually the Rector of RMIT decided to make it a policy issue for the university. A common ground had been established.

Bowden used an example from the Faculty of Business at the RMIT to describe some of the processes that the university and its staff went through. The faculty wanted to

[7] http://www.rmit.edu.au/

design a new degree programme in general business subjects based on a capability driven curriculum. In cooperation with the teachers/researchers in the field, the programme planners worked in an iterative process moving backwards from the views stated by industry and/or businesses. That is, the input to the new programme and course plans did not only come from the industry or companies, but also from teachers and students engaged in similar programmes, including teachers in other countries. Eventually, the programme team could construct the courses in more detail, and because decisions had been iteratively agreed no course teacher or team were surprised by what their course would aim at and contain.

In this particular case, the programme team came up with a diagram similar to the one illustrated in figure 1. The diagram outlines the capabilities students should achieve during their bachelor years. Any of these capabilities had to be unpacked in terms of what it meant at various levels. Therefore, several meta-guides were developed in cooperation with the responsible teachers for the various courses. Table 1 illustrates one of these meta-guides.

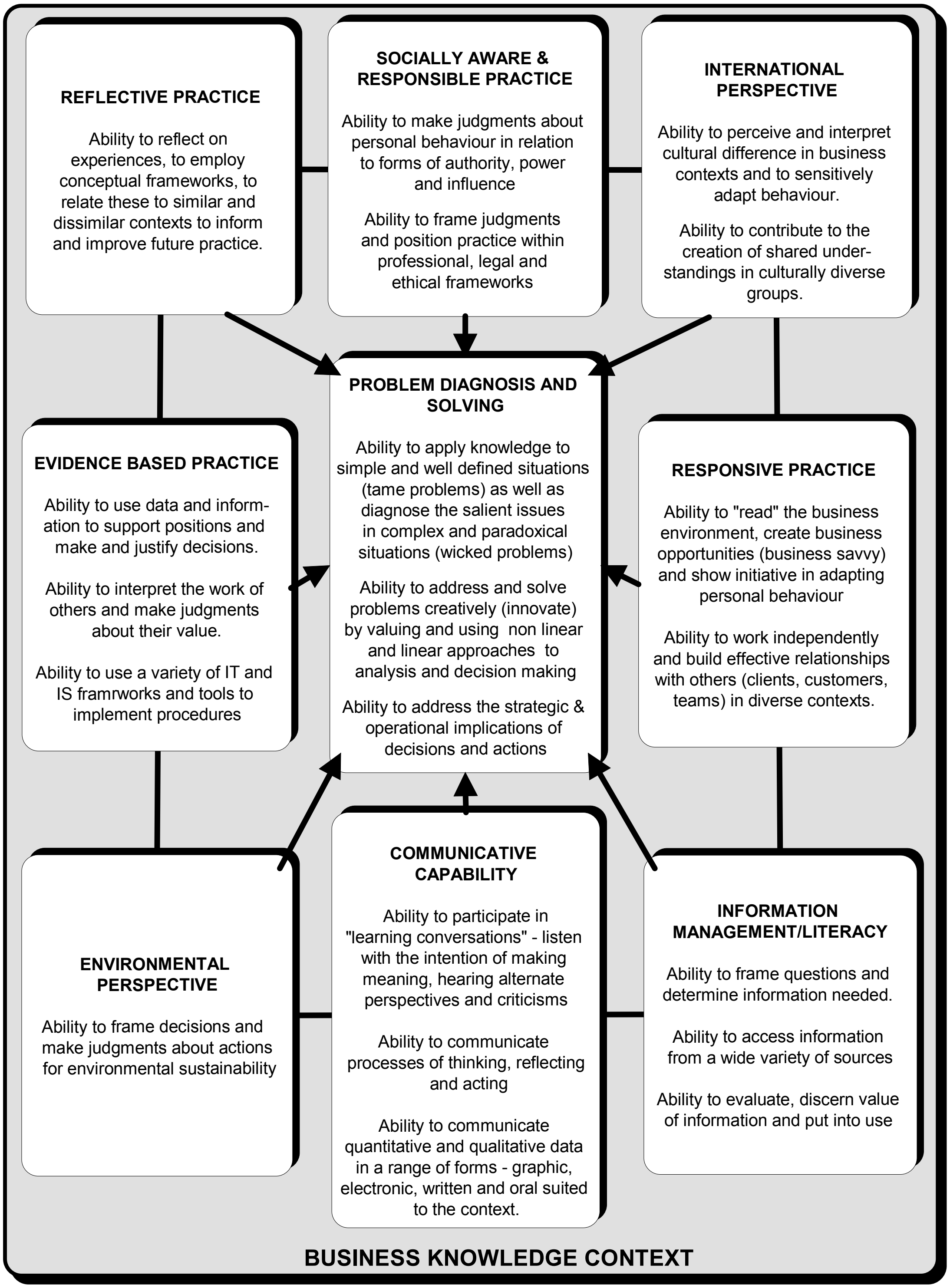

Figure 1. Bachelor of Commerce Capability Statement at RMIT.

Generic Capabilities	Foundation	Level 1	Level 2	Level 3
GC1: Reflective practice – ability to reflect on experience	Introduction to Organisational Behaviour Business Frameworks	Business Simulation Business Case Studies	Bus. Logistics Business Enterprise	Leadership & Mgt Industry Project
GC2: Socially aware/responsible practice - make judgments about personal behaviour vis a vis authority & power	Introduction to Organisational Behaviour	Org'ns & their Env's	Leadership & Mgt	Industry Project
GC3: Socially aware & responsible practice - frame judgments & practice within professional, legal & ethical frameworks	Introduction to Organisational Behaviour Macroeconomics Legal f'works & f'mentals	Business Simulation Game Business Case Studies	Management Accounting The Business Enterprise	Seminars in Int. Business Industry Project
GC4: International perspective - 'see' & interpret cultural difference & to adapt behaviour	Business Frameworks	Business Simulation Game	Org'ns & their Env's Business Case Studies Legal f'works & f'mentals	Seminars in Int. Business
GC5: International perspective -contribute in culturally diverse groups **GC10**: Responsive practice - Work independently **GC11**: Responsive practice - build relationships with diverse others including working in teams **GC14**: Communicative capability - participate in learning conversations	Introduction to Organisational Behaviour Business Frameworks	Business Simulation Org'ns & their Env's	Leadership & Mgt Business Enterprise	Seminars in Int. Business
GC6: Evidence based practice - use data & information to support decision making	Business Computing Macroeconomics	Business Statistics Business Simulation Game	Legal Frameworks and Fundamentals Org'ns & their Env's Business Case Studies	The Business Enterprise Industry Project

Table 1. Meta-guide for the generic skills in a bachelor programme in Commerce Business at RMIT.

According to Bowden, it is important that the whole programme is based on the same ideas. Only in this case will the various courses fit into the overall picture; there will be a red thread through the entire programme. Otherwise, at best the students will experience that the individual courses are loosely tied together with little pieces of cotton. His conclusion was: Only when you have an overall strategy, a range of generic capabilities and a meta-guide that all the involved planners and teachers have agreed to, is there a reasonable chance that the actual teaching in the various courses will live up to the original ideas.

The time issue in designing a new curriculum
One of the problems in changing a whole curriculum is the lack of time. Bowden outlined how resources at the RMIT had been set aside to release key personnel, not everybody, for the reform process, and to develop realistic work plans for all staff to prevent work overload due to the reforms. One has to acknowledge that the planning process is time consuming, he stressed. Included in the time management planning, Bowden claimed, one has to re-think the concept of lecture time. There are ways of managing the teaching and learning processes which do not entail that teachers' workload is increased. Bowden referred to his keynote presentation [see p. 9 in this publication] in which he mentioned an example of reducing the lecturing time in a course on physical chemistry. By reducing the lecturing time by three hours a week and the contact time with the students by two hours, simply to give the students more "free" time to do mental work, the quality of learning increased enormously. A lot of time is wasted on lecturing, Bowden stressed.

According to Bowden, a more efficient way of spending teaching time than lecturing is, for instance, to hand out notes at the beginning of a semester and then spend most of the teaching time on tutorials and a few lectures. The latter could concentrate on explaining those difficult aspects students point out as troublesome during the tutorials and assignments. [See also the contributions of Gibbs, p. 53 and p. 68, in this publication.]

Theme 2: Clarification on the concepts of capability and competency

It is the experience of Bowden that people in Australia often face difficulties in understanding and accepting the theory of capability. However, as Bowden sees it, the concept has a lot in common with the concept of competency outlined by Niss [cf. his contribution, p. 29, in this publication]. The notion of capability originates from the area of professions and theory of pedagogy, while the competencies Niss refers to originate from analyses of a specific subject, namely mathematics. Still, in spite of the differences in their origin, Bowden finds many similarities between the two concepts. If one applies the theory of capability to general degree programmes (as opposed to professional degrees) one gets very close to the thinking outlined by Niss.

The workshop participants agreed that the intention of introducing both concepts in a curriculum discussion is to clarify the goals and aims of our teaching. Rather than describing a specific educational programme by listing the content to be covered, the specification of goals by means of competencies/capabilities attempts to describe what it means to master the processes that are characteristic to a specific subject (mathematics, chemical engineering, etc.). Put differently, competencies/capabilities, ideally, describe how a person studying a particular subject changes during his/her study. They answer the question: What should the student be capable of?

This, Bowden emphasised, is different from the outcome based descriptions used in America, e.g. by ABET© (Accreditation Board for Engineering and Technology)[8]. The idea of ABET in relation to engineering is to describe what students have to live up to during their study. This is done by about 13 scores or statements that give an idea of what an engineer has to be able to do. One of the criteria is for example "the ability to work in teams". One might be concerned about statements like this, Bowden claimed, because they are taken out of a context and has no content attached to them. At best they invoke processes of interpretations, e.g. by making various engineering institutions focus on teamwork, perhaps even taking teamwork seriously. Basically, outcome based descriptions are to be considered as political statements of intent rather than designed to provoke questions as to how one actually organises the curriculum and the learning processes of the students. [See also the contribution of Lundager Jensen from The Confederation of Danish Industries, p. 118, in this publication].

In Australia, for instance at the RMIT, up until five years ago all these "personal things" about teamwork, communication skills etc. were seen as important, although little was done about them. If it happened, it was done on the sideline to a content based activity. What the discussions on competency in the Niss-sense[9] and capability in the RMIT-sense[10] achieve, Bowden stressed, is to underline that capabilities cannot and should not be separated from subject content. Capabilities and the actual content (topic areas) are deeply integrated. [See also the contribution of Grønbæk & Winsløw, p. 37, and Workshop 2, p. 140, in this publication.]

[8] http://www.abet.org/
[9] Niss, M., Jensen, T.H. et al. (2002): Kompetencer og matematiklæring. Ideer og inspiration til udvikling af matematikundervisning i Danmark. [Competencies and the learning of mathematics. Ideas and inspiration related to the development of mathematics teaching in Denmark.] Ministry of Education (Undervisningsministeriet), Copenhagen
[10] http://www.rmit.ed.au/

Content focus contra capability focus

Many teachers would argue that students need a (large) tool-box of factual knowledge before they can engage in any kind of project which would develop certain capabilities or competencies. However, Bowden claims, content is the means by which you develop a certain capability. While a content based curriculum designs the learning experiences within a content framework, a capability based curriculum designs the content so that it fits the goals and aims of the learning processes (i.e. the capabilities to be achieved). That is, the question is not about absence or presence of content, but a question of framing the learning processes according to the set goals.

Assessment of capability and competency

Another discussion that arose in relation to capabilities concerned how we assess to what extent the goals has been achieved. Bowden outlined an example from a 4th year physics course in Australia. The students were carrying out a one semester long project in industry. The students both had a tutor from the university and one from the company with which they co-operated. It was part of the project that students should apply capabilities acquired during their previous years at university and that experiences gained at the industrial company would be integrated in their studies back at the university. Communication capabilities formed part of the evaluation. In this regard, the students had to write three reports about their project: one for a non-academic and non-professional group of people, one for the board of directors of the company, and one for the employees who should implement what the students had designed. Further, back at the university, they had to write an essay about how the three reports differed. Thus, the student were not only assessed in relation to their actual communication capabilities (cf. the three reports) but also in relation to a meta-level at which they had to reflect on the different communication strategies. According to some of the workshop participants similar assessment strategies could easily be transferred to a Danish context. For instance, at the University of Southern Denmark where students can choose to do their bachelor or master projects in co-operation with industrial companies or other organisations[11], such projects can be assessed in the described way.

Based on these and other examples the workshop discussions went in several directions: To what extent can students evaluate themselves? How do traditional demands on accuracy in the procedures and in relation to what is being assessed relate to assessment of capabilities? To what extent do we apply formative and summative assessment? A full account of the debate will not be provided here. Many participants

[11] See “Viden til Vækst” (En: “Knowledge for Growth”) at http://www.videntilvaekst.dk/

agreed, however, that we should aim at maximizing the formative aspects of our assessment procedures in order to strengthen the learning process for students and teachers and at minimizing the summative evaluation, although it was acknowledged that we as university teachers have a dual responsibility. Accreditation (grading and selection) forms part of the game. [See also Gibbs' contribution, p. 53, 68, and Workshop 4, p. 157, in this publication.]

As an example of a way to support both the learning process and the accreditation aspect we discussed the use of (electronic) portfolios. If the university supplies the various parts of a student portfolio with the necessary stamps (date, level) etc., over time the portfolio can support the individual learning process, the student may learn from mistakes and progress, and fulfil various accreditation needs. Finally, within some subjects and/or professions, the portfolio is or could be an important source of information for prospective employers.[12]

Problem based learning approaches as a means to develop capabilities
Another debate related to the theme of capabilities/competencies came up in relation to teaching strategies such as problem based learning (PBL). Some participants suggested PBL as a means to move away from content based courses and towards a more capability/competency based way of thinking curricula and teaching/learning processes. It was, however, generally agreed that it could be highly problematic to create universities solely based on PBL or, for that matter, to believe that PBL is the answer to everything. There are no easy solutions to most of what we discuss in relation to capability/competency based curricula, including or excluding PBL. We need to look constantly at the goals to be achieved and to design the learning environments accordingly. Sometimes PBL may form part of the programme, sometimes not.

Theme 3: Transition from 3rd to 4th year at university

Due to a lack of time, we didn't go far into this theme. In a Danish context, some felt that it was even more important to look at the transition from high school (gymnasium) to university, as the Danish tradition, so far, has been to perceive the transition from bachelor to master level studies as an imposed artificial benchmark in what is considered to be a five- or six-year university programme. However, it was well recognised that this situation is radically different from the one found in

[12] For a Danish audience reference is made to Jakobsen, A. and Lauvås, P. (2001): Eksamen – eller hvad? Former for summativ evaluering i professionsuddannelser. Samfundslitteratur.

countries like the UK, Australia and the US. [See also the Panel Debate, p. 123, in this publication.]

Nevertheless, it was predicted that, in the future, also in Denmark we will find more students with say a bachelor in biology or chemical engineering who would like to enter a master programme in physics, perhaps even at another university. However, as already mentioned, we didn't have much time to look at what consequences this might have for the way in which we arrange the university curricula and the teaching/learning processes.

Workshop 4 – Assessment of Student Learning

Convener: Graham Gibbs, Open University, England

Reporter: Kathrine Eriksen, University of Copenhagen, Denmark

Workshop Format

In this workshop Graham Gibbs focused on the issue of student assessment. He did not merely present the workshop participants with a list of ideas for “proper assessment”, but concentrated the activities around the interplay between assessment and students’ learning. Rather than seeing assessment as an instrument for control and discrimination (selection, rating), Gibbs accentuated the potency of assessment as a learning guide and enforcer.

Gibbs wanted to engage the participants from the very beginning. We were split into groups of 3-5 persons and Gibbs regularly interrupted his presentation by letting the groups discuss and subsequently present the issues raised either by him or in the groups. In his own presentation Gibbs introduced the “eleven conditions under which assessment supports learning” listed below and elaborated on in the paper “*How assessment influences student learning”* [p. 68 in this publication].

Throughout Gibbs’s presentation and the group discussions the workshop participants were asked to reflect upon various aspects of assessment in the context of a course they had been teaching themselves. To assist these reflections Gibbs handed out an “assessment review checklist” [see p. 162]; a questionnaire by which a course can be assessed against the eleven conditions presented by Gibbs.

This workshop report includes summaries of Gibbs’s presentation and the common discussions. It does not include the individual group discussions or details related to the “eleven conditions”. The latter are extensively described in the paper mentioned above.

Gibbs’s “eleven conditions under which assessment supports learning”

1 Assessed tasks capture sufficient study time and effort
2 These tasks distribute student effort evenly across outcomes and weeks
3 These tasks engage students in productive learning activity
4 Assessment communicates clear and high expectations to students

5 Sufficient feedback is provided, both often enough and in enough detail
6 Feedback focuses on learning rather than on marks or students themselves
7 The feedback is provided quickly enough to be useful to students
8 Feedback is linked to the purpose of the assignment and to criteria
9 Feedback is understandable to students, given their sophistication
10 Feedback is received by students and attended to
11 Feedback is acted upon by students to improve their work or their learning

The power of assessment

Gibbs began the workshop by presenting the background for his own interest in assessment as a research topic and focal point for educational development. Several studies, including some of Gibbs's own, of British and American students and their perspectives on their own educational lives have revealed that students spend an enormous amount of time decoding assessment demands and developing strategies for handling assessments successfully.

To get the workshop participants engaged in contemplating this power of assessment Gibbs presented a case-story and asked the groups to discuss it. In brief, the case illustrated just how powerfully an apparently minor twist in assessment can influence student behaviour and learning: When the assessment of students' problem sheets was changed from teacher evaluated over no assessment at all to peer marking the final examination results went from an average of 55% (correct answers) over 45% to 85%!

The question to the workshop groups was: Why did it work? Why did a change in the assessment procedure of students' problem sheets from teacher to peer marking without any other changes in, for instance course content, lecture format etc., shift the exam results so dramatically? The group responses illustrated some of the issues at stake not only in this particular case but also at more general level: Different formats of assessment support very different aspects of student learning. Aside from producing social pressure that will make students work hard in order not to make fools of themselves in front of their peers, peer marking will also engage students in active, reflective assessment of their own work and that of other students; a process which is rather educative in itself.

Good quality learning activity

Thus the first group discussion opened the discussion of Gibbs's main message, namely that different conditions of assessment affect the effects of assessment profoundly. In the following presentation Gibbs elaborated on this by introducing in detail the first four points from his list of eleven conditions under which assessment influence students' learning. For more details, please consult Gibbs' paper [p. 68]. The first four conditions all relate to the role of assessment in generating enough good quality learning activity, distributed evenly across the term. The main issues were that through assessment procedures students can be 'forced' to spend the time on the course which is actually required for 'real' learning to take place. Yet, if the assessment demands have not been explicitly communicated to students or if the assessment demands contradict each other, e.g. in relation to the final exam or coursework assignments, students may spend a lot of time on the course without supporting genuine learning. The workshop participants were asked to score a course of their own in relation to the four "conditions for learning time generation" in the assessment checklist [p. 162], and we went on discussing these issues and the development of students' understanding of quality through explicit communication of standards and expectations. It was, for instance, pointed out that students often experience very different standards in different departments or even in different courses in the same department without the differences being explicated. Gibbs underscored that the main responsibility of the educators is to make these standards explicit. This will teach the students to look for "quality cues" and act accordingly as they become able to decode the different standards themselves. To support this point Gibbs referred to some examples from the vast body of empirical evidence that he drew on throughout the workshop. Further, a workshop participant mentioned that a competency based curriculum description can act as a tool for making the learning goals and assessment demands explicit to students.

Feedback and feed-forward

Gibbs went on to address the last seven of the eleven conditions. These all accentuate assessment as a feedback mechanism students can benefit from in their own learning process. Several conditions influence the quality of this feedback. According to Gibbs, quality is to be understood as the degree to which the feedback supports the learning process. Again, I will refer to Gibbs' own paper for details [p. 68] and merely present some highlights from the discussion.

A major point in Gibbs's presentation was the importance of the *time factor*. If students are to find feedback helpful and even worth paying attention to, the feedback must be delivered promptly. In Gibbs's interpretation the definition of good feedback often involves a trade-off between quality and time. If the provision of "good" feedback in terms of exhaustiveness etc. becomes so time consuming that students only get it weeks after the assignment was handed in it is seldom worth the effort as students rarely pay attention to it after all. Often the "quick and dirty" feedback is better than the "slow and perfect" one, Gibbs claimed.

Another main point was the *role of marks*. Studies show that marks may have a negative influence on students' benefit from feedback. Marks are often associated with judgment of the person whereas good feedback is concerned with actions and learning. Often, Gibbs pointed out, feedback is used merely as a justification of marks. In terms of learning improvements this type of feedback is useless to students since it only looks backwards. According to Gibbs, good feedback feeds forward to future challenges.

After individual scorings on the assessment review checklist [p. 162] and group discussions in relation to the scoring we went into a plenary discussion of the differences between the British and the Danish educational systems.

Well chosen assessment methods

First, Gibbs presented an on-going project he is involved in: The Assessment Experience Questionnaire. This questionnaire has been developed to serve as a diagnostic tool and asks students how they have perceived the feedback they have got in a given course. Based on the students' responses to the questionnaire, tactics for improving the feedback procedures are then discussed with the teachers. Further, as part of the project a list of assessment tactics meeting each of the eleven conditions has been developed. This list was handed out to the workshop participants [see p. 163]. A project report, the "diagnostic tools", the "cures" or assessment tactics, and a number of illustrative cases in which the "cures" have been successfully employed is available at http://www.open.ac.uk/science/fdtl/pub.htm

Gibbs went on to illustrate some of these tactics through a couple of case-stories. One of these made a particular impression on the workshop participants and caused a great deal of discussion: In a particular course in which the pass rate was very low, the teachers adopted a new strategy. Prior to the course, the strategy was accepted by the students. Students were divided into learning teams of four. They were to sit individually for the final exam. However, their final mark would be calculated as the average of the four individual marks achieved by their learning team! The strategy worked: The average examination result went up so dramatically that extra external examiners were called in to confirm the results! This case made some participants raise the question of how far one is allowed to go in order to influence student behaviour. During the heated discussion, Gibbs stressed that he primarily shared the case with us to illustrate his main messages: Assessment does indeed influence students' learning and by contemplating assessment formats in relation to course goals we can become capable of providing much firmer support mechanisms for this learning.

Finally, within the working groups, the participants were requested to consider how exactly this could be realised in their own courses and to share their wishes for future assessment improvements.

Judging from the participants' eagerness to discuss new strategies it appeared that through his dynamic mix of thorough theoretical reflections and convincing empirical data Gibbs indeed succeeded in getting the workshop participants to think about assessment in general and their own assessment strategies, in particular in novel ways!

For further information on assessment and other learning and teaching strategies reference is made to "Strategies for Learning and Teaching in Higher Education – a Guide to Good Practice" June 01/37, 2001. The Higher Education Funding Council for England (HEFCE), www.hefce.ac.uk

Assessment Review Checklist

		Extent to which condition is met			Evidence
		Well	Partly	Poorly	
How well does assessment on this course generate enough good quality learning activity, distributed evenly?					
1	Assessed tasks capture sufficient study time and effort				
2	These tasks distribute student effort evenly across outcomes and weeks				
3	These tasks engage students in productive learning activity				
4	Assessment communicates clear and high expectations to students				
How well does feedback to students support their learning?					
5	Sufficient feedback is provided, both often enough and in enough detail				
6	Feedback focuses on learning rather than on marks or students themselves				
7	The feedback is provided quickly enough to be useful to students				
8	Feedback is linked to the purpose of the assignment and to criteria				
9	Feedback is understandable to students, given their sophistication				
10	Feedback is received by students and attended to				
11	Feedback is acted upon by students to improve their work or their learning				

Conditions under which assessment supports student learning – and tactics that meet these conditions

<table>
<tr><th colspan="2">Assessment factors and related Conditions</th><th>Possible tactics to address problems where conditions have not been met</th></tr>
<tr><td colspan="3">Quantity and distribution of student effort</td></tr>
<tr><td>1</td><td>Assessed tasks capture sufficient study time and effort</td><td rowspan="2">More assignments and/or assignments distributed more evenly across the course and across topics.
To cope with marking load:
• Completion of assignments as a course requirement, without marking
• Sampling of assignments for marking (e.g. from a portfolio)
• Mechanised and computer-based testing
• Self and/or peer marking

Exam demands that are unpredictable and/or sample everything, so that students have to study everything</td></tr>
<tr><td>2</td><td>These tasks distribute student effort evenly across topics and weeks</td></tr>
<tr><td colspan="3">Quality and level of student effort</td></tr>
<tr><td>3</td><td>These tasks engage students in productive learning activity</td><td rowspan="2">Larger scale open-ended assignments that are challenging and induce a deep approach

Assignments involving interaction/collaboration with other students, in or out of class, and social pressures to deliver

Clear specification of goals, criteria and standards and ‘modelling’ of products

Student internalisation of these goals, criteria and standards (e.g. through student marking exercises, public presentation and critique of work)

Avoidance of ‘multiple guess’ question tests and exams passable by memorisation, that induce a surface approach and Highly challenging exams requiring ‘performances of understanding’</td></tr>
<tr><td>4</td><td>Assessment communicates clear and high expectations to students</td></tr>
</table>

[continues at the following page]

Quantity and timing of feedback		
5	Sufficient feedback is provided, both often enough and in enough detail	**Regular assignments,** starting early **Quality standards** for volume and quality of feedback Tutor briefing/training/monitoring **concerning volume and nature of feedback** **Mechanised feedback** where mechanised tests are used **Trade off of quality of feedback against speed** of return (e.g. peer feedback, model answers, sampling of assignments to produce generic feedback) **Development of student self-supervision** that involves ongoing feedback to self as part of learning conversations (meta-cognitive awareness and skill)
7	The feedback is provided quickly enough to be useful to students	
Quality of feedback		
6	Feedback focuses on learning rather than on marks or students themselves	**No marks**, only feedback. **Feedback structured** around goals, criteria and standards, explaining marks (e.g. using feedback sheets), not focussing on student characteristics **Tutor briefing/training/monitoring** concerning quality of feedback **Development of students' ability** to understand feedback, and of tutor's awareness of student difficulties in understanding feedback
8	Feedback is linked to the purpose of the assignment and to criteria	
9	Feedback is understandable to students, given their sophistication	
Student response to feedback		
10	Feedback is received by students and attended to	**Faster feedback** Tutor feedback only on aspects **students request** Student **discussion of use of feedback** **Two-stage assignments** where feedback on stage 1 helps improve stage 2 **Two stage tests** where test 1 informs about areas needing revision for test 2. **Integrated multi-component assignments** (e.g. stages of a project, elements of a portfolio of evidence) where each assignment contributes to a larger whole. Requirement for students to **demonstrate** (or marks for demonstrating) **response to feedback in subsequent assignments** Greater emphasis on **generic feedback** of value to other topic areas
11	Feedback is acted upon by students to improve their work or their learning	

Annexes

Conference Program

	Thursday May 22, 2003
09:30 - 10:00	Check-in and coffee
10:00 - 10:30	Welcome - introduction
10:30 - 11:45	**John Bowden**, RMIT, Australia: Why do we need reforms, which, and how do we implement them?
12:00 - 12:30	Initiation of group discussions
12:30 - 14:00	Lunch
14:00 - 15:15	**Mogens Niss**, RUC, **Niels Grønbæk**, KU, The need for reform: Perspectives on the result of education - students' competence in mathematics
15:15 - 16:00	Coffee and "walk and talk"
16:00 - 18:00	Workshops
18:00 - 18:30	Break
18:30 - 20:00	Dinner
20:00	Surprise-entertainment

	Friday May 23, 2003
09:00 - 10:30	**Graham Gibbs**, Open University, UK Discussant: John Bowden, RMIT Incentives for teachers: How should we reward active participation in reforms?
10:30 - 11:00	Coffee
11:00 - 12:00	**Agneta Olerup**, Lund University: **Bjarne Lundager Jensen**, DI; **Arne Jakobsen**, DTU, Industry requirements and management support: Opportunities for educational improvement
12:00 - 13:00	Groupwise formulation of questions for panel
13:00 - 14:30	Lunch
14:30 - 15:30	Panel debate Panel members: John Bowden, Graham Gibbs, Bjarne Lundager Jensen (DI), Jens Oddershede (President, University of Southern Denmark)
15:30 - 16:00	Conclusion

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Nr. 7: If reform of science education is the answer- what were the questions?

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At most Danish universities dramatic changes of the natural science programmes are underway. These changes are carried out both in response to external forces, and to internal ones, such as the need to rethink curriculum and pedagogy.
But while the answer – structural reforms – is clear, the major questions remain open: What is the aim of modern natural science education? How can the teaching methods and curriculum structure best support all this? How are changes of teaching practices best initiated? How does the university teacher improve his or her own teaching?
These questions were addressed at the third May Conference of the Centre for Educational Development in University Science (Dansk Center for Naturvidenskabsdidaktik, DCN), 22 – 23 May, 2003, in Korsør, Denmark.
This publication contains presentations given at the conference by keynote speakers. Further, it includes extensive reports from the four conference workshops and from the concluding panel debate.

'**Naturvidenskabsdidaktik**' er det teoribaserede, disciplinerede arbejde med at vinde indsigt i naturvidenskabelig tænkning, læring og undervisning. Centrets mission er, gennem forskning, undervisning og formidling, at bidrage til denne indsigt og dens udmøntninger i kvalitetsløft på alle tre felter for det naturvidenskabelige fakultets videnskabelige medarbejdere og studerende.

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