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BUILDING ENGINEERS- NEW PARADIGMS FOR EDUCATION?

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ABSTRACT
This paper discusses tradition and renewal of the education of building engineers with specialisation in construction management. It has been argued that a shift is underway in knowledge production from discipline based teaching with strict borders between education institutions and industry (mode 1) to interdisciplinary learning under a regime of blurred boundaries between industry and education institutions (mode 2). Using this framework critical examination of the training of Danish civil engineers with a specialisation in construction management based on courses, education material, curricula and participants observation is presented. Moreover a typology of jobs is done. The existing curriculum is described and the position is taken that it already represents a type of mode 2 education profile, since multidisciplinary, problem orientation and problem solving, using real life cases as backbone, the possibility of internship and the criteria for the master thesis all represent integration with industry. It is argued that although a shift from mode 1 to mode 2 does create a new overarching framework, construction management needs a more specific analysis differentiating and prioritising different possible elements in the curricula. Some examples of possible reforms are given.

KEYWORDS
Construction Management, Engineering Education, Curriculum, New Production of Knowledge.

1. INTRODUCTION

The process of building an engineer has been heavily and continuously debated both among professionals and lay people. Building engineers and building engineering are thus at the same time objects of fascination and target for criticisms. Both perceived as realisers of impressive societal infrastructure like the Great Belt fixed link, one of the worlds largest bridge complexes *and* held responsible of lethal accidents at the building sites or too little concern for the environment.

Construction management, which is the focus of the present paper, is no exception for this ambiguity. On the one hand the source of self-esteem coming from "having the rubber boots on", being where the practical issues are solved. And on the other hand continuously target of accusations for bad management (Dansk excellence index 2001).

Construction management curricula are and should be dependent of the construction sector development. Increasingly complex solutions are demanded along with a considerable restructuring of enterprises in the business putting globalisation on the agenda. Moreover, problems with accumulating capital are at present time a central

issue for several of the larger players in Danish construction. Construction management has at the Technical University of Denmark (DTU) been taught integrated with engineering disciplines within production of the built environment. It has however, over a long period of time, developed a multidisciplinary approach combining technical, managerial and social skills.

The paper is composed as follows. The method is presented first. The overarching frame of "new production of knowledge" is presented (Gibbons et al 1994). Then a discussion of construction sector developments is presented, followed by an analysis of needed skills. Then the actual curriculum at DTU is presented. The discussion analyses the match between the curriculum and the developments in the sector. Finally, the conclusion suggests some reform elements.

2. METHOD

The paper is explorative in nature. It bases its considerations on material from inquiries done in other countries and theoretical elements on the new production of knowledge. The empirical part is based on course-descriptions, material and teaching experiences, education material, curricula and participants observation.

The participant observation was made at the course "Building Design and Construction 2", which is an intensive course given in January within three weeks. It was followed in January 2002. The author followed the active teachers, classes and group work exercises. This participation was moreover carried out the secure transfer of experiences between two different members of staff.

The discussion has an element of self evaluation and evaluation of colleagues, where the evaluator is little independent of the evaluated. Nevertheless it has been strived at to mobilise a critical distance to balance the pregiven empathy.

At DTU and in Denmark several investigations have been carried out discussing didactical issues as well as the relation between engineering employment and curricula. Unfortunately these results are not fully integrated in the discussion (see for example the proceeding of SEFI 2001 in Copenhagen, SEFI is French European Society for Engineering Education).

A basic assumption, which is taken for granted here is that management can indeed be taught (see Grint 1995 for a discussion), not putting aside the extreme importance of learning in practice; being and becoming a manager is thus an emergent process (Watson 2001). Developing management skills is central in the curriculum studied.

3. NEW PRODUCTION OF KNOWLEDGE

In the current debate on the knowledge society, knowledge economy and intellectual capital, Gibbons et al (1994)-s contribution has become prominent in the discussion of the role of education and universities (see for example SEFI 2001, Gann 2000, Lea 1999). The main argument of Gibbons et al is that the conditions for production of knowledge in society is changing, implying a new role for universities. The argument is construed as a shift from mode1 to mode 2, which is respectively described as:

Mode 1: Discipline based teaching, clear demarcation between university and industry, universities educates, industry trains, strong criteria for research (peer review).

Mode 2: Interdisciplinary learning, blurring boundaries between universities and industry, greater collaboration, knowledge production widespread in society, research in context.

Although it always can be debated to what extent such ideal typical descriptions hold, knowledge economy can be interpreted as an economy where the basic training and education of engineers has to shift paradigm into more interaction with industry, and life long learning understandings. It is left aside here that the dictum might be in strong contrast with other contemporary trends. Such as current research evaluation systems, being enforced all over Europe, which are inclined to generate a preference amongst university staff towards formal academic work. Another counter trend would be economical problems in the construction industry. Problems with accumulating

capital would generate a trends towards effective basic production away from research and development activities. The idea is to discuss whether it on the content and practice side gives inputs to reforms of a construction management curriculum.

4. CONSTRUCTION SECTOR DEVELOPMENTS- TOWARDS NEW ECONOMIES

Companies operating in Denmark employ most of the building engineers educated at DTU. The discussion here thus takes point of departure in developments in Denmark and the labour market for engineers. About 11.000 engineers are employed at the consulting engineers and about 4.500 at the contractors and other building sector firms (IDA 2000). Three large contractor companies and three large consultant engineering companies are a large employment market for construction management engineers. But civil engineers with a master degree specialised in construction management also find employment in a diverse array of enterprises and public institutions.

The consulting engineering sector in Denmark has been marked by three major players which have globalised very early and which are among the twenty largest in Europe. Nevertheless the later years have given even more concentration and the commencement of a wider globalisation. Within consulting engineering recent developments include, the UK-based Atkins taking over a 1200 staff unit of railroad engineering, which was privatised from the Danish State Railways. Carl Bro, one out of the three large consulting engineering companies, was recently taken over by a Sweden-based investment firm aiming at restructuring the European consulting engineer business. Carl Bro acquired a 1100 staff Swedish consulting engineer company with Danish and Norwegian subsidiaries immediately after, bringing it total size to 3.200 employees and positioning it as the eight largest consulting engineer in Europe. The large consulting firm become increasingly complex in their portfolio of competence's, but nevertheless, they have to cooperate with the smaller and more specialised consulting engineers, which typically operate locally and on a much more specialised markets (like steel engineering, sound and acoustics and the like).

Similarly in contracting, the multinational Swedish companies Skanska and NCC recently took over the dominance. Two large contractor Højgaard &Schultz and Monberg & Thorsen was then forced to merge into MT Højgaard in 2001. All three companies suffer from problems accumulating capital however, and their present strategies seem to go in various directions. Where taking in increasingly more function and skills for a period at least, Skanska now has outsourced even central areas (precast concrete element assembly) as a response to deficits in 2001. The contractors market thus still is composed of large and small contractors where the large only represent around 15 % (BAT 2001). There are therefore a large amount of small companies, and some -bricklayers for example- will continue to be small companies according to a recent analysis (Clausen & Bang 2000).

The globalisation is probably strongest among equipment and material manufacturers, which also impacts on the division of labour between contractors and consulting engineering. Since the products are becoming increasingly complex and multi facetted, manufacturers of components and contractors increasingly take over parts of the design tasks from the consulting engineers.

Apart from globalisation and mergers, information technology and new forms of management and organisation are important trends. When discussing skills, it is important to note how IT is transforming the needed skills. IT enters into calculation in engineering design, calculations in bidding, calculations on equipments production and many other types of handling of documents and data. This means that the engineers are less directly involved in every step of calculation and administration. The role is rather to understand and check IT-based calculations.

Management innovation encompasses use of partnering, multiskilling, knowledge management and a range of contemporary management concepts such as balanced scorecard (Koch 2002). Elements in the future competitive strategy for construction companies could thus be increased horizontal collaboration in the supply chain, including partnering, the use of IT (Lakka and Kähkönen, 2001) and increased management innovation (Koch 2002).

5. TYPES OF CONSTRUCTION MANAGEMENT JOBS

A study of engineering skills in the construction sector from 1982 (Jensen 1982, Jakobsen et al 1982) developed a typology of elements of building engineering work encompassing the following elements

- Innovation
- Specialisms
- Project work
- Administrative
- Project management
- Production management

Jakobsen et al notes that project work is the quantitatively most widespread type whereas innovation is by Jakobsen primarily located at equipment and materials manufactures and as small elements in project work. Jensens analysis of project work lead him to note that "there are very big variations in skills demands"(Jensen 1982:94). Although most new buildings in principle are unique, they do not represent new skill demands per se. Usually a building project represents some levels of repetition and represents relatively low level of skills demands. On the other hand if the innovative element is considerable it can represent high levels.

Drawing on the above typology in combination with (Gann 2000:224-230), Gann& Salter (1999) one can point at the following typical construction management jobs:

- Designer
- Production engineer
- Site manager

The designer is typically employed at consulting engineers or contractors that take on responsibility for the entire building process. In these context the tasks are increasingly complex and multidisciplinary. Alstrup & Andersen (2001) illustrate this by a project for a municipality, which is more than not just the building of a public school but also the integrated development of a new learning concept, IT-support and buildings. Winch has pointed at systems integrator- skills as crucial (Winch 1998). The construction management skilled engineer participating in this context needs to assure constructability and buildability of the design. This knowledge needs to be integrated in the design process along with many others. This task demands social and collaborative skills as well as generalist knowledge on other design tasks.

The production engineer is usually employed at the contractor with the prime responsibility of engineering the production encompassing tasks such as choice of production methods, machinery, operations scheduling etc. There is a large element of administrative work in production engineering especially when calculating bids where prices, wages, expenses for machinery and materials etc. has to be calculated. Most of the engineers will be appointed as project managers, but in most projects the personnel responsibility is limited. The intensive uses of administrative IT such as spreadsheet and standard programs are parts of the work. But also, the organising, acquiring of up-to-date knowledge on all the elements, machines, materials, staff. Technical and administrative skills are thus needed in combination with some social skills.

The site manager or production manager is responsible for carrying out the production at the site. The fine scheduling and logistics is central here. Usually the many operations are carried out by different firms posing importance to coordination and communication between the many involved firms. This demands a combination of technical and social skills. There seems to be an extensive use of young engineers in this role as a kind of apprenticeship before moving into the offices with the production engineers. Interestingly Nielsen finds that on 16 East Danish building sites active in autumn 2001 none of the 18 engineers working as site managers were masters, but bachelors or other shorter engineering educations. They all were between 25 and 34 years old (Nielsen 2001).

It should be noted that many construction management engineers will experience a combination of these three jobtypes, especially if they are employed in the smaller, not specialised, but generally operating, companies.

6. TYPES OF SKILLS

Across the mentioned profiles it seems that a commonality is what Gann & Salter understands as two types of multidisciplinarity. The first type of multidisciplinarity cuts across different technical disciplines: design, building

physics etc. One part of this is production engineering which in itself on the technical side contains a subset of disciplines on building site layout, earthwork, equipment, precast concrete elements, scaffolding a.o.

The second type of multidisciplinarity encompasses skills within social sciences, organisation and management. Necessary management skills encompass project management, innovation management and also soft skills like organising knowledge, collaboration, cooperation, problem solving.

As noted by Jensen and Jakobsen the actual job demands is extremely dependent on the division of labour. In large organisations specialists can be seen as central for its core competencies, whereas generalists are absolutely needed to assure that the specialisms, whether organised internally or in-sourced from outside is sown together providing the customer with a seamless solution.
In small companies generalists either will need to know how to organise knowledge from outside or the company specialise in the belief that others will hire the company and its expertise.

7. THE PRESENT CURRICULUM

The Technical University of Denmark encompasses four main faculties in engineering; mechanical, chemical, electronic and building. Building engineers is a relatively small curriculum at DTU based on headcount. Between 80-90 students commence each year. Construction management is but one branch within the building engineer education, but is on the other hand represented in most of the student curricula in the beginning (the basic courses are obligatory), whereas less continues and fewer specialise in Construction management. Most of the building engineer students thus build up generalist knowledge on production management based on a few courses, whereas a smaller group chooses to specialise in construction management. Counted on the number of master thesis (see figure 1 below) roughly 10 % specialise at the construction management group with topics which are more or less “clean” construction management issues.

Construction management has at the Technical University of Denmark been taught integrated with engineering disciplines within production of the built environment. It is today placed at BYG.DTU, a 200 staff institute covering a broad range of building engineering disciplines such as building physics, design and urban planning.

Both the teaching and the research has been multidisciplinary for around thirty years within a broad engineering paradigm, including elements of architecture, sociology, organisation theory, management, but with relatively little emphasis on law and economics, compared to other construction management curricula abroad (Harris & Macaffer 2001, Hansson 2001).

Present courses in construction management are 8 out of 96 formally given at the Department for civil engineering. The figures in parenthesis are the ECTS- points, (ECTS stands for European Credit Transfer System), where one student year equals 60 ECTS-points.

- Building Design and construction 2 (5)
- Project Management (Construction) (5)
- Project Risk Management in Construction (10)
- Technology and working Environment in the construction industry (5)
- Industrial Production concepts in Construction (10)
- Management of IT in Construction Companies (10)
- Advanced IT for Construction (10)
- Knowledge Based Systems in Construction (5)

DTU also offer general management and organisation courses and cross-disciplinary courses. And construction management offers joint courses with other engineering areas in knowledge management and technology management.

Internship in building companies is optional and unfortunately only used by a smaller group of students.

Given the amount of points offered in construction management it is clear that a specialisation need more content. The students that do this usually use their master thesis as main activity in this specialisation. The master thesis is 30-50 ECTS-points and often lasts ½ a year. In Table 1 is entered the number of thesis in the last ten years.

Table 1: Number of master Thesis' at Construction management the last ten years

Year	92	93	94	95	96	97	98	99	00	01
Number	12	13	14	9	5	11	8	10	8	6

All master thesis are carried out in cooperation with external companies which usually acts a case field for the empirical part of the master thesis projects. In some cases a normative element is included providing the enterprise with advise and sparring on how to develop. It is a general criterion for the thesis that it should balance theoretical and empirical elements.

7.1 Building Design and Construction 2

As an example of a course "building design and construction 2" is discussed here. The course is a basic course and usually placed at the first year. The course covers the production phase, whereas "building design and construction 1" covers design of a building.

The course teaches engineering disciplines related to the production phase and represents the first type of interdisciplinarity (the technical). The students are led through a bidding process starting with a given building and a real estate and ending with a tender, where the best bid is selected. A member of staff gives the course in cooperation with an external practitioning engineer. As background material and backup is used a basic book in production engineering (Anlægsteknik- Anlægsteknikerforeningen, 2001) and material indicating prices on material, equipment and workforce. Key learning of the course encompasses an overview and general mastering of a row of calculation techniques and norms, but importantly also the ability to exercise judgement and make planning choices on an unclear, non-complete and changing basis. The practice orientation is strong since the backbone case is using a real-world real estate and a urban plan for the area. The judgement throughout the work is moreover built on dialogues with the external practitioner which acts as supervisor in the group working occurring everyday on the course after the lecture. Questions like how big is a parking lot, what is the price of a siphon trap, how can we obtain earth balance are all dealt with in a direct dialogue manner, often accompanied with practical anecdotes and narratives. For examples when explaining why it might not be effective to hire the largest possible excavator ("where can you park all the lorries needed to transport the produced earth"?!).

There is however also elements that show that it is indeed a clinical example and not a full practical exercise, since certain design issues that represent a discipline, are allowed to be handled through common sense. There is in other words a need to limit the course to a certain part of building engineering and not take too much on board.

8. DISCUSSION

Juxtaposing the present curricula with the argument of "mode 2 knowledge production" it seems that the existing curricula already represents a type of mode 2 education profile, since the following elements characterise the curricula:

- Multidisciplinarity
- Problem orientation and problemsolving
- Learning how to organise knowledge to assemble a solution to a complex problem
- Using real life cases as backbone,
- The possibility of internship
- The criteria for the master thesis

These all represent integration with industry and a downplaying of strong discipline-orientation. It might be so in other sectors of university teaching and research that a shift from mode 1 to mode 2 does create a new overarching

framework, but construction management needs a more specific analysis on differentiating and prioritising different possible elements in the curricula. The main contemporary dilemmas relates to how to prioritise technical versus managerial skills, and which technical and managerial skills to prioritise. Actually Gann & Salter in a UK-context also finds that the interdisciplinary index (already) is higher for construction management compared to civil engineering, architecture, building service and surveying (Gann & Salter 1999:33).

The multidisciplinarity is established mostly by offering course- modules with different approaches. The module approach and teaching based on ”one faculty member- one course” leaves partly to the students to establish coherence and connections.

Engineering production teaching seems to put too much emphasis on existing norms and routines and too little on performance improvement and rationalisation. This contrasts with Riis et al (2001:4) which argues that students should be taught to seek solutions that are far from existing solutions. Construction management as a whole do to a certain extent treats innovation and possible process and performance improvements. It is asserted however that this element could be strengthened.

Using Harris & Macaffer (2001) basic book in construction management as comparison between the two flagged curricula, they have a number of overlapping. Harris & MacCaffer contains a more business, economics and management oriented version of construction management, whereas the DTU curriculum encompasses a more technical orientation in combination with management closer to the building project process.

It can along with Gann & Salter (1999) be discussed whether the striving for multidisciplinarity has led to too broad a profile. It should be noted that the construction management curriculum also serves as the only possible place to combine building engineering and management in a broader sense. It is thus maybe necessary to offer a broad profile, whereas the typical student then will develop a more focused profile only taking onboard the relevant courses (like for example project management).

Actually some issues are currently on the agenda for future inclusion. The curriculum currently contains little law and economy, little logistics and little on globalisation for example.

9. CONCLUSION

As concluded in the discussion, construction management at DTU operates in integration with industry and downplays of strong discipline-orientation. It is therefore not in the construction curriculum that a shift in paradigm, a shift from mode 1 to mode 2, create a new approach. The emphasis on practical competencies and the interaction with industry can be enhanced however through expanding the point into post-doc education and training. The department is currently developing a master in construction management aiming at developing practice competencies for engineers employed in construction with more than three years experiences. If such a curriculum is realised the interaction between industry and the university will be enhanced and could be a platform for developing a community of practice.

The basic education in construction management needs a more specific analysis on differentiating and prioritising different possible elements in the curricula. The main new elements could be logistics and globalisation, which is an issue of different technical norms and engineering cultures, more than an issue of language, which DTU already give courses in.

It is likely that construction management will have a stronger strand of appropriation of general management concepts (such as Balanced Scorecard) especially in management of the firm (in contrast to managing building projects). This trend could lead to a reform as outlined by Hauck (1998), which point at the need for a larger theoretical background in management and social sciences and describe how construction management was coordinated with management of technology at Colorado State University.

Another important issue is the continued coordination between research and teaching. Present research represents a strong industry and practical element. Nevertheless further enhancement of this feature is considered.

The present environment for reforms is contradictory. On the one hand fruitful, because there seem to be more understanding of the need for new initiative and change. And on the other hand unsecure since the economic situation of the technical university and the university sector is presently unclear, a new government has announced cutting in the sector and DTU-s own situation as privatised "business university" is still to be clearer.

This is actually highlighting another weakness in the knowledge economy debate, since traditional economy still has quite a lot of power it seems!

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