Student Experiences in the direct Applicability of their Engineering Education to Professional Practice

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Abstract: *This paper describes on-going work investigating the experiences and perceptions of under-graduate engineering students with aspirations to work in construction engineering in site and project management roles. Construction companies employ many graduate Civil Engineers from Australian universities in a range of construction engineering roles. However, it appears that graduating engineers may have few ideas of the workings of engineering industry, professional roles they will be expected to play and the career options available to them. There is also some evidence to suggest that employers also find this lack 'work readiness' in new recruits perplexing. In the transition to professional practice, employers and new graduates have found a need for a very steep leaning curve to equip newly graduating engineers with the necessary work skills to adapt their engineering degree education to the 'real world'. This paper describes some on going research into the issue and outlines and examines some of the issues that are routinely faced by newly graduating engineers in their transition to professional practice. The paper also discusses proposed course enhancements based on the concept of the Construction Supply Chain as a means of providing exposure to the skills, culture and practices of the construction industry.*

Introduction

Whilst at university the undergraduate civil engineer is bombarded with rigid academic study that enables them to successfully undertake the analytical approach in the design of bridges, roads, dams, buildings and other infrastructure via the studies of the main civil engineering specialties such as Geotechnical Engineering, Structural Engineering and Hydraulic Engineering – all of which are core courses of their degree at university. One topic that is not resourcefully investigated during undergraduate studies is the involvement of the civil engineer within the construction industry. Whatever the career path chosen by the graduate, they will at one stage become part of the construction industry process and need to understand the functions of the industry and the professional levels that the engineer has influence over. Many aspects of the construction process remain obscure or unknown throughout the undergraduate study even though awareness of the subject should be apparent to prepare and allow the student to identify what speciality of the civil discipline they wish to pursue. This paper aims to emphasise and identify the motivation as to why the undergraduate civil engineer needs to be increasingly educated on the construction industry culture and state of the art practice not only so that they can be aware of industry practices and skill sets, but also assist the student in identifying the relevance of curriculum core subjects. Construction is a dynamic industry that involves many levels of influence by a vast number of professionals. Civil Engineers find themselves influencing various stages of the construction process from design and conception, though the construction phase and finally the handover and maintenance of the structure. The newly graduated engineer is increasing expected to be aware of all participants of the construction supply chain with employers in constant demand of graduates that posses an understanding beyond the traditional civil engineering analytical knowledge. Civil Engineering graduates seem to be challenged by the diminishing proportional role of engineering knowledge, as taught at universities, compared to the

knowledge of the Construction Supply Chain (CSC) and the multitude of elements that it is composed of. A major professional role within the CSC is the Construction Engineer that involves an appreciation and knowledge of the culture of such skills as prople management skills, project planning, interpretation of design documentation, tendering and procurement, scheduling, estimating, cost controlling, and the analysis and management of the construction process. In addition to studying these specific elements, the complete study of the CSC and its main professional participants will enhance the undergraduate's confidence in understanding the complexities of the construction industry and preparing them in entering the highly challenging and stressful environment of construction, in which, conventional engineering techniques seem to take a back seat to constructional management and an understanding of all the key attributes, participants and culture of the construction supply chain. This paper describes on-going work to investigate the numerous prerequisite issues that will provide confirmation of the above statements, a questionnaire, initial results and findings, methods of developing the hypothesis into a teaching/educational aid, investigation and breakdown of the construction supply chain (CSC) and an overview of the fundamental skills and roles of the construction engineer.

Example of the issue from literature

The issues described above are receiving world-wide attention. For example, the academics at the Polytechnic University of Brooklyn N.Y, have become increasingly aware and alarmed by the rapidly changing engineering practices and recognised that traditional engineering education was faced with great challenges and opportunities. In light of rapid changes and the impacts of information technology on the engineering and construction industry it was becoming increasingly seen that engineering graduates required not only their traditional analytical training but also were demanded to have knowledge of the construction industry to allow a more seamless integration into their selected professions. The university determined that the engineering curricula needed to adopt new strategies in educating engineering professionals of tomorrow by complimenting their engineering education with a transfusion of information technology and construction process automation concepts through drastic reorganisation of classes and academic curricula (Christodoulou, 2004). Further, they were conscious that the new generation of civil engineering graduate needs to be introduced to the Construction industry and skilled in their abilities to integrate and participate in the many levels of its process - A generation that can successfully combine conventional engineering knowledge with elementary understandings of information technology, management and financial principals. It was seen that the valuable integration of such diverse knowledge would assist future civil engineering graduates to successfully tackle the professional challenges of the construction industry and become efficient and productive professionals who will, in turn, assist the development of the construction industry and be greatly appreciated by employers and colleges. One such tool that was seen to integrate all of the above concerns was a system called the Fully Integrated and Automated Project Process (FIAPP). This system recognised that there was a need to include a new course that would expose students to the benefits derived from true integration and automation of activities found in civil engineering. The proposed academic course sequence offered to engineering students was based on the course outlined initially proposed by Griffis and Sturts (Griffis, 2000) in a report to the Construction Industry Institute (CII) The subject incorporated both academic concepts and hands-on practices through a real life case study. Christodoulou noted that students considered the course to be one of the most 'eye-opening' and interesting subjects that they studied. It was reported that a number of the students later contacted the university requesting collaboration between the institution and their construction firms and indeed construction firms requested in house delivery of FIAPP to their early career engineers. The material explored and the academic setting proved to be extremely practical in displaying the need for the integration of and coordination of architect, engineers, town planners, estimators and project management. Students were able to better understand the mechanics and cycles involved in design/bid/built construction project. It was felt that the undergraduate students gained the most benefit from this course due the integration of concepts they acquired during other undergraduate studies.

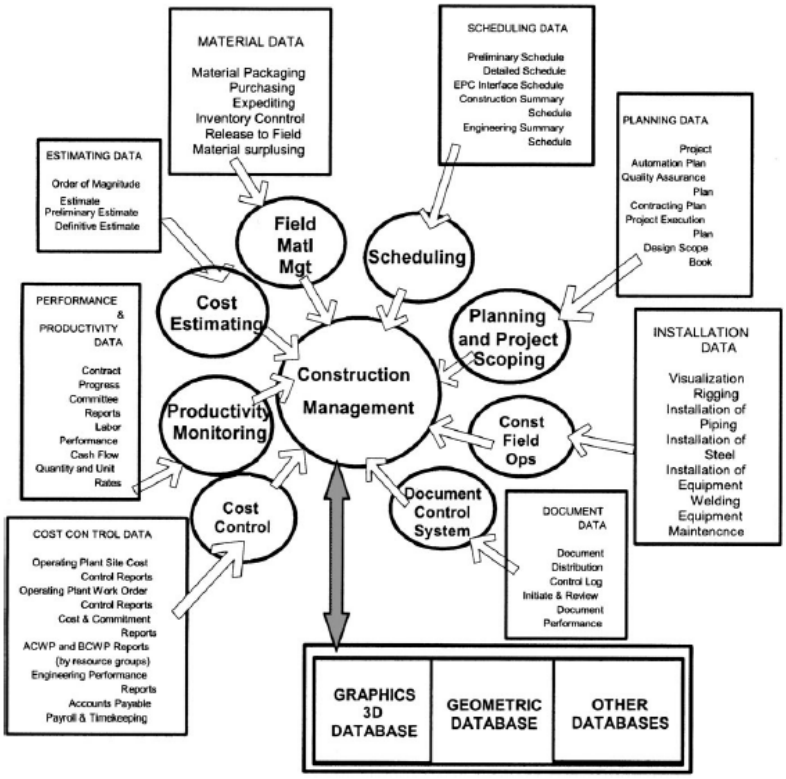

Figure 1: FIAPP concepts (Griffis, 2000)

Questionnaire, Results and Findings

The work described here describes the preparation, execution and analysis of a questionnaire that is aimed at Civil Engineering students to provide insight into whether the University of Wollongong's Civil Engineering curriculum would gain strength from implementing a course that educates undergraduate in the professional roles of a Civil Engineer working in construction industry. The questionnaire is designed to gain data on the following issues:

Current civil engineering curricula – theoretical versus practical;

The relevance of traditionally taught civil engineering subjects compared to real world applications and design;

Level of student interest in and knowledge of construction industry;

Students awareness of the construction supply chain and specialities that lie within it (ie does the undergraduate have an understanding of consultants, construction managers, contractor etc)

Does the undergraduate civil engineer feel that they are being appropriately educated and therefore prepared to enter work force (in whatever career they endeavour)?

Is the undergraduate aware of the career avenues open to then once graduated or even conscious of what areas they can specialise in?

Does the undergraduate believe there is a current course within the core curriculum that educates them in the importance of the integration and automation of what they are learning or have been previously taught?

Open-ended questions are added to investigate students' interpretation of existing courses in relation to their perceptions of professional practice. This is in no way intended to criticise the current curriculum or question academic teaching but instead to discover whether student civil engineers current perception of their education is well informed and realistic, with a view to eventual professional engineering roles in construction industry. Existing UoW courses on construction industry organisation and practice, will be used as the platform for investigation. The authors note that learning outcomes of these courses are listed as covering the following: Plant and equipment in Civil Engineering practice; Construction processes and quality control; Tunnelling in soft ground and rock; Coffer dams and caissons; Harbour works; Dewatering and grouting methods; Performance monitoring and observational design; underpinning and restoration techniques; formwork and scaffolding (UoW Faculty of Engineering Handbook, 2009). Yet a course that educates the civil engineer in the areas of people issues, project planning, cost estimating, scheduling, interpretation and management of design documentation is not present. The questionnaire targets a variety of undergraduate students ranging from 2nd, 3rd and 4th year studies; this will investigate and consider when students should be introduced to a newly proposed education unit that is outlined below.

The initial results have been very interesting and will be reported in detail elsewhere. Some representative comments that summarise the main findings so far are reported below.

From a 3rd year part-time student recently having taken employment as a cadet engineer working in a construction company: 'I learned more in the first 3 months in my work than I did in the previous 3 years of uni studies'.

From a second year student: "I am becoming disillusioned with my studies and thinking of a change of career path' I thought civil engineering would be about building stuff but all we seem to do here is mostly a lot of mathematical structures, mechanics and scientific stuff, a lot of which I already studied at school anyway.

From 3rd year student: 'My dad is a civil engineering consultant. He is a drainage expert. We don't seem to do anything like the work he does but he says its all necessary if we want to be professional construction engineers.'

From a 4th year student: 'I'm really enjoying my thesis in Project Management which is applied to a real-life construction project where I get to visit the site and talk with practicing civil engineers. I am very excited about the prospect of a job doing this type of work. It does not seem to have much to do with my last 3 years of study but I think it will help me when I start to apply for real jobs'.

Proposed Course enhancement: The Construction Supply Chain (CSC)

The second part of this paper considers a suitable vehicle by which holistic ideas for the education of civil engineers in construction industry can be conveyed. A great deal of work is thus now taking place in developing ideas on the 'Construction Supply Chain' (CSC) (For example, Ander, 2007, Oakland and Marosszeky, 2006). The CSC philosophy is appropriate in this case because it considers an arrangement of stakeholders in a construction process as a flow of materials, people, equipment, information and finance that has to provide a quality level that is acceptable to the customer. CSC can be utilised to teach ideas on how each of the stakeholders functions individually. Even more importantly, CSC provides a teaching model to show how those functions are integrated together to form a holistic view of construction process and thus how relationships are formed and maintained by the different stakeholders to create value as a whole for the benefit of all stakeholders in the CSC. (Vrijhoef & Koskela, 2000):.

Construction projects are made up of several key CSC players, namely, designers, consultants, main contractor and subcontractors – all of which are coordinated via the Design and Construct project flow chart, illustrated below by Dola, 2008:

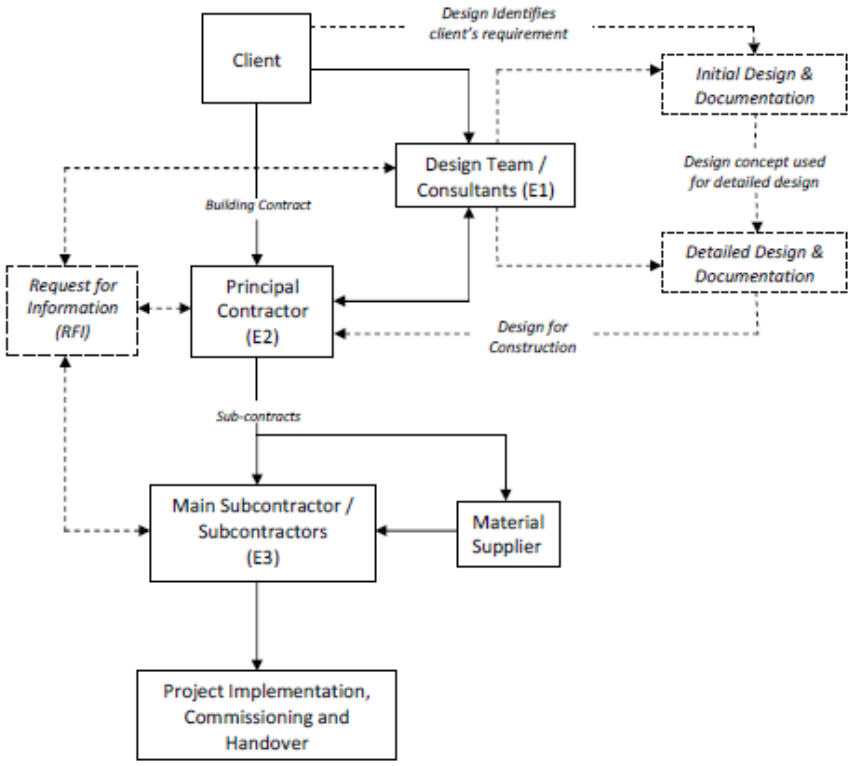

Figure 2: The General Process of the Design and Construct Process (Doloi, 2008)

The three stages where civil engineers have crucial influence are "Design Team (E1)", "Principal Contractor (E2)" and "Main Subcontractor / Subcontractors (E3)" (*element* has been abbreviated to *E*). Our research has shown that undergraduates seem to have little perception of this influence or how to integrate into those functions. It seems they expect to learn these things on the job, almost by osmosis, although newly graduated civil engineers will very likely take up roles in any of those functions. Throughout every stage of the project an engineer is required to have their 'finger on the pulse'. Thus a Construction Engineer's role during the construction process is considered to be that of the upmost importance and can be construed as the epi-centre.

Teaching the Introduction and Evolution of the CSC.

Construction Industry needs to be taught as a dynamic and multifarious procedure, which engages interactions of client, design team/consultants, principal contractor, contractors and suppliers. Our work here proposes to teach this process, variously phased to account for conception, design, construction and commissioning, handover and defects liability period. Using these parameters, the construction supply chain can be taught as "the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer" (Christopher, 1992). CSC is not to be taught as a collaboration of businesses with business-to-business relationships but a network of various institutions and associations, which encompass the flow of information, materials, services or products and the flow of finances between all parties. (Xue, Wang, Shen, & Yu, 2007).

A graphical view by Jin and Li (2008) of the framework and prime elements that make up the CSC is shown in figure 3.

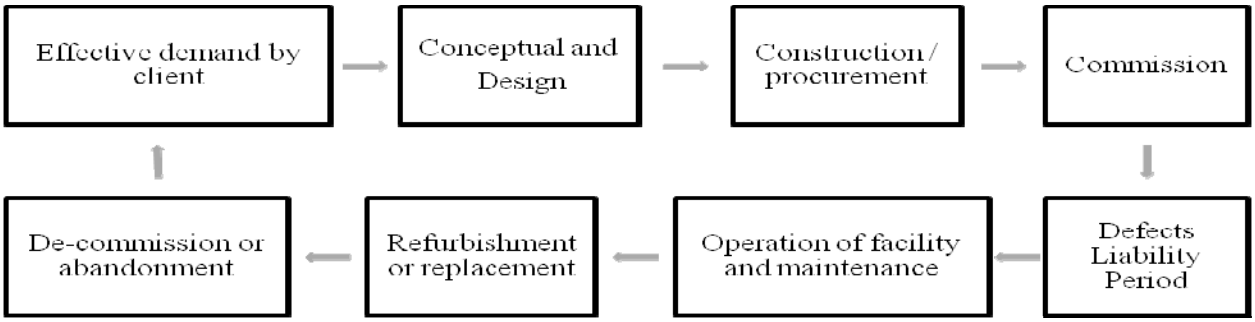

Figure 3: Key phases of construction supply chain (Jin & Li, 2008)

Following its materialisation in manufacturing industry as part of the JIT system, conceptualisation of the CSC concept has evolved into a self-governing topic of industrial management theory that is especially relevant to an efficient and competitive construction industry and was recognised and discussed in literature (e.g. Bechtel & Yayaram, 1997 & Cooper et al, 1997). Western scholars such as Burbridge and Forrester provided initial improvements to understanding of supply chain thinking. (Towill, 1992). Literature therefore points to a state of the art and very topical and appropraite emphasis for the teaching or work skills to civil engineers, although it is true that construction companies have adopted this thinking much more lately than other engineering enterprises.

Conclusions

Initial results of a survey of current undergraduate civil engineering students point to some concerning issues relating to work readiness of civil engineering graduates. This survey is not yet complete and will be dealt with in more detail elsewhere. However, initial indications are that these students appear to be well versed and extremely capable in theoretical concepts and design and civil engineering technology but have limited perceptions of the actual work they will be involved in when they become employed in construction project work. Business skills in understanding the importance of adding value for customers through the integrated construction supply chain appear to be very underdeveloped. It also appears that students recognise that much of their academic work, whilst essential in developing their problem solving, technical and intellectual abilities has little direct application to work in construction industry. Students find exposure to concepts of the Construction Supply Chain (CSC) in a practical context to be very enlightening and they value the experience. The construction supply chain is put forward as a suitable means of exposing students to an integrated exposure to a broad range of practical skills they will require as professionals working in the construction industry because it is a converging supply chain that efficiently directs all materials to the construction site where the objective of supply chain players is to assemble and complete the facility as a whole, thus providing optimised value for the customer and other stakeholders involved. The work reported here is pointing to an essential need for newly qualified professional engineers to be exposed to this state of the art business thinking.

References

Ander, E. e. (2007). A process for developing partnershps with subcontractors n the construction industry: An emperical study. *International Journal of Project Management , 25*, 250 - 256.

Bechtel, C., & Yayaram, J. (1997). Supply chain management: a strategic perspective. *International Journal of Logistics Management 8 , 1*, 15-34.

Christodoulou, S. (2004). Educating the Civil Engineering Professionals of Tomorrow. *Journal of Professional Issues in Engineering Edustaion and Practice* , 90 - 94.

Christopher, M. (1992). *Logistics and Supply Chain Management: Strategies for Reducing Costs nd Improving Service.* London : Pitman Publishing.Construction Industry Institute (CII). (1997). Cooper, M. C., Lambert, D. M., & Pagh, J. D. (1997). Supply Chain Management: more than just a new name for lagistics. *Internation Journal of Lagistics Management 8* (1), 1-13.

Doloi, H. e. (2008). Analysing the novated design and construct contract from the clients, design teams and contractor's perceptive . *Construction Management and Economics* , 1181 - 1196 .

Faculty of Engineering . (2009). *CIVL394: Construction - 2009 Undergraduate habdbook*. Retrieved May Monday, 2009, from The University of Wollongong:

Griffis, F. H. (2000). *Three-dimnesional computer models and the fully integrated and automated process for the managment of construction".* Research rep. Austin, Texas: Construction Industry Institue.

Jin, C.-h., & Li, Q.-m. (2008). Study on a multiagent Construction Supply Chain Management System. *WiCOM '08. 4th International Conference*, (pp. 1 - 5).

Oakland, J. and Marosszeky, M., Total Quality in the Construction Supply Chain, *Butterworth*, 2006

Towill, D. R. (1992). Supply Chain Dynamics: The change engineering challenge of the mid 1990's., *206*, pp. 233-245.

Vrihoef, R., Koskela, L., & Howell, G. (2001). Understanding Construction Supply Chains: An Alternative Interpretation. *Proceedings 9th Annual Conference International Group of Lean Construction.* Singapore.