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Abstract – This paper presents a case study of how the adoption of BIM-based practices in the AECO industry is being reflected by cultural change in higher education in Ireland.

The silo-mentality that has dominated the AECO sector for more than a century has, despite numerous reorganisations, been replicated in the structures of educational institutions, including in Dublin Institute of Technology since the inception of its founding colleges in the late 1800s.

Most AECO programmes must include content that is external to the programme's specific discipline. Through the School structures of the Institute, delivery of such content is known as "service teaching" and is regarded by some as being of lesser importance than core, discipline-specific content. When new content needs to be fitted into a programme, such as BIM technologies, or when financial constraints reduce contact hours, 'serviced' content is often easier to remove or reduce than discipline-specific content because it typically affects non-School staff.

Such reductions lead to reduced exposure of students to complimentary skill-sets held by other professionals in the AECO sector and increased separation of disciplines. Without deliberate instigation of multidisciplinary and interdisciplinary project work, students are sometimes educated in isolation from the other disciplines with whom they will work during their professional lives. In extreme cases, graduates sometimes have their first interactions with other professionals when they attend their first site meetings or design team meetings on real-world projects.

BIM processes require collaboration at all levels in AECO and it is imperative that current and future students are educated within a structure that equips them with the necessary technical, business, and inter-personal skills.

The establishment of the School of Multidisciplinary Technologies (SMDT) at the College of Engineering and Built Environment (CEBE) at DIT and the adoption of a college BIM Strategy are essential steps towards facilitating this new dimension of collaborative education. The School currently manages a suite of postgraduate and CPD, modules and programmes related to BIM and, although some staff in the School teach BIM-related content on these programmes, the majority of teaching on SMDT programmes is provided by lecturers from the disciplines of Architectural Technology, Building Services Engineering, Civil Engineering, Construction Management, Electrical Services Engineering, Geomatics Engineering, Quantity Surveying, and Structural Engineering.

SMDT is also investing in physical infrastructure, e.g. a Big BIM Room and laptop lab, to support existing activities but also to create the environment in which collaborative working between disciplines, structured initially around BIM practices but moving towards addressing Lean Construction, Sustainability, and N-ZEB agendas, becomes the norm for students as they progress towards graduation and entry into the professions.

Reflective of the industry, the individual staff members currently involved in these programmes have embraced the multidisciplinary setting and operate as a cohesive unit driven to achieve the best learning outcomes for students. However, the supporting structures and infrastructure need to undergo significant cultural change to recognise and benefit from transforming to a leaner model of multidisciplinary delivery.

Keywords – Cultural Change; Lean Construction; Education; Multidisciplinary.

I CONTEXT

During the 1980s a number of courses offered at the Dublin Institute of Technology included an element of integrated project where disparate disciplines who practiced within the built environment worked together towards individual, discipline-specific goals as well as towards a unified end-product. This could easily be aligned with some of the elements of modern-day BIM collaboration. In the 1990s, this project faltered partly because of implementation difficulties within the new Faculty System (the Bolton Street campus became home to the Faculty of the Built Environment while the Faculty of Engineering stretched between the Bolton Street and Kevin Street campuses). Educational and administrative developments, both at DIT and internationally, in the 2000s which reorganised academic years and terms into semesters and subjects into modules, and which supported wider adoption of work placement and an increased focus on individual dissertations all reduced the opportunities for the inclusion of integrated project work within the already-packed curriculum.

At the same time new pedagogies (methods and practice of education) that focussed on “learning outcomes” rather than “course content” [1] and on “problem-based learning” (PBL) by students rather than subject matter teaching by lecturers [2], [3] began to gain foothold. The former change emphasised what an individual student should expect to, and could be expected to, know at the end of a given module/programme (the term ‘programme’ replaced ‘course’). Module descriptors became the document of contracts between the institution and the student, and the environment became more ‘learner-centred’. The latter change created significant opportunities for ‘real-world’ learning but typically, and often because of administrative reasons, problems were identified that resided within individual disciplines rather than between them. In DIT, PBL was very successfully implemented in this isolated context for Physics for Engineers [4], Optics for Science [5], Project Management for Property Economics [6]. Martin et al. [7] reported on applying PBL as a method of enabling students on a Geomatics programme to bring together the learning from the specialist areas of Geodetic Surveying and Remote Sensing but time pressures in the Remote Sensing specialism caused by the introduction of 3 months of work placement onto the 4-year, honours degree programme lead to the scaling back of the PBL format into a single specialism, i.e. Geodetic Surveying [8].

Despite the obvious potential of PBL as an enabler of interdisciplinary co-operation, it was rarely deployed in that context and many students never engaged with any students from outside of their core discipline over the duration of their education. This was particularly the case for students on programmes without work placement.

Into this environment in the late 2000s and early 2010s has come the new paradigm of the BIM collaborative process and its associated methods and techniques. This cultural change for the construction sector needed to be accommodated within the education of under- and post-graduate students in built environment-related programmes, but how?

Section II examines the current set-up of the College of Engineering & Built Environment (CEBE) in DIT in relation to these programmes. It also gives an overview of the organisation of Schools, programmes, finances, and student data resources. Section III identifies some of the limitations of the existing structures in relation to achieving collaboration between programmes and disciplines. Section IV discusses the culture of BIM and how it, placed within CEBE’s School of Multidisciplinary Technologies (SMDT), has been positioned to assist with interdisciplinary collaboration at all levels. Section V presents the current status of the implementation. Section VI proposes a future path for BIM-driven change and how this is already expanding to include beneficiaries such as Lean Construction and Nearly Zero Energy & Sustainability education.

II CURRENT CEBE SET-UP

The College of Engineering & Built Environment (CEBE) was set up in 2013 as one of four colleges in the Dublin Institute of Technology. Almost all of the divisions in the new College were previously based in either the Faculty of Engineering or the Faculty of the Built Environment. An important concept during the reorganisation of the institute was to reduce the duplication caused by isolated education of students and segregated operation of researchers within specific disciplines, through the adoption of cross-cutting themes. The organisational structure focussed on schools, rather than on departments, as the operational units. While this has created some difficulties, particularly for less high-profile disciplines, it has also created opportunities for interaction across broader discipline groupings than would previously have been typical.

CEBE extended the concept of cross-cutting themes by setting up a School of Multidisciplinary Technologies (SMDT). The remit of the School is to support and facilitate the development of commonality between the other six discipline-based schools (Figure 1). Most of the School's staff specialises in teaching outside of their original discipline and they have expertise in areas of maths, science, and computing, particularly for engineers.

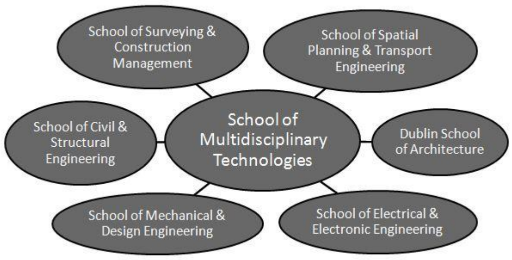

Figure 1 Schools in the College of Engineering & Built Environment, DIT

The School operates the common level 7 and level 8 Engineering programmes from which students can progress to eight or seven specific qualifications, respectively. It also runs applied Engineering Computing programmes and, most importantly here, took over the management of all multidisciplinary BIM programmes from the Dublin School of Architecture, where they were originally based when initiated as Continuing Professional Development options in the college.

a) Administration

Although there is some variation, the following is a description of the typical organisation of discipline-specific programmes in CEBE. Currently, students register on programmes and programmes are linked to individual schools. Schools are allocated funding on a per student basis. Schools try to deliver as much of the content of their programmes as possible by their own school staff as this is the most financially efficient model for the School. Expertise from outside of the School's core discipline is accessed via a model of "service teaching". This means that the School "owns" the module, i.e. receives the income from the students, and they pay an hourly rate to another school to provide a staff member to deliver that module. This has the advantage of giving access to expertise from across the entire Institute. However, this type of teaching is regarded by some as being of lesser importance than discipline-specific content.

It is possible for students to take modules from other programmes in other schools and colleges. However, the uptake of this option is small, partly because of the stringent accreditation requirements of many engineering and built environment-related programmes, which specify exactly the constituent elements of an approved qualification, and partly because of administration (keeping track of marks) and timetabling issues. Where students have smaller workloads, e.g. visiting Erasmus students, such options are frequently taken.

III LIMITATIONS

The discipline-specific schools, as currently defined in the College of Engineering & Built Environment, serve the market reasonable well within their specific domains.

However, in relation to change on programmes, when new content needs to be fitted into a programme or when contact hours need to be manipulated for educational or administrative reasons, 'serviced' content is often easier to remove or reduce than discipline-specific content because it typically affects non-School staff.

Such reductions lead to reduced exposure of students to complimentary skill-sets held by other professionals in the AECO sector and increased separation of disciplines. Without deliberate instigation of multidisciplinary and interdisciplinary project work, students are sometimes educated in isolation from the other disciplines with whom they will work during their professional lives. In extreme cases, graduates sometimes have their first interactions with other professionals when they attend their first site meetings or design team meetings on real-world projects.

Staff and management are not currently incentivised to seek solutions that reduce operational costs between schools, i.e. at College or Institution-wide levels. Some elements of the financial administration of the Institute appear to actively discourage the very concept of interdisciplinary cooperation that the cross-cutting themes of the reorganisation and the setting up of the School of Multidisciplinary Technologies were instigated to achieve.

This mirrors, to some extent, the context of the construction / built environment sector without BIM, where the multitude of professionals, contractors, and sub-contractors required to successfully design and complete a large construction or infrastructure project operate separately and, sometimes confrontationally, in order to secure their portion of the income and/or profit.

This structure is also highlights the absence of ‘lean’ concepts with people waste created by “poor allocation of work to labour” and sometimes “poor disctibution of personnel” [9].

In the construction sector, firms seek to utilise change orders as a means of recovering costs not adequately covered at tender stage. In education, no exact parallel occurs but where students receive inadequate exposure to other disciplines when it might be appropriate for them to do so, e.g. early in their programme before discipline biases have been developed, the impact is felt later when students do not have sufficient foundational knowledge to understand and solve interdisciplinary problems. This creates unintended costs as students have to receive more support than might otherwise have been necessary. There is no means by which this cost can be recovered within DIT’s financial model.

IV BIM CULTURE

As with the RIBA’s Digital Plan of Works for BIM, the initial stage of cultural change began with the adoption of a strategic direction as set out in the College of Engineering and Built Environment BIM Strategy document [10]. The strategy related to undergraduate and postgraduate provision, as well as staff and space resourcing.

The co-ordinators of undergraduate programmes where BIM is relevant agreed to the aim that students learning pathway aligns with the following structure (Figure 2):

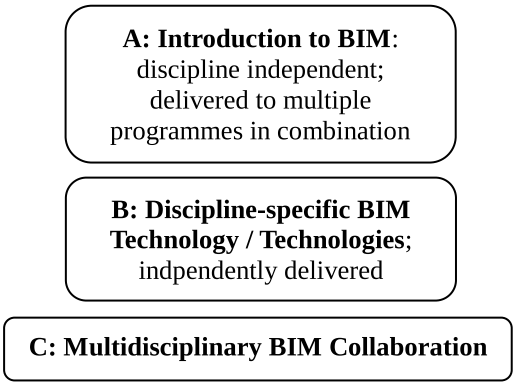

Figure 2 CEBE BIM Strategy for undergraduate programmes

The Introduction module establishes the concepts of multidisciplinary collaboration in design, construction, and management that underpin BIM. The technologies that enable collaboration and that are utilised by each discipline are also identified in overview. A small collaborative project, where students undertake different roles within the BIM team, not necessarily those of their own profession, forms an integral part of the module. The module is also designed to demonstrate the requirement that all construction professionals need to understand each other’s contributions to BIM, and the technologies and processes that they use to achieve this.

Individual programmes make decisions about the amount and level of “lonely” BIM that they undertake with their students. Some programmes, such as Architectural Technology and Geomatics/Geographic Science [11], introduce BIM technologies during the first year and develop students knowledge to a high degree of competence over subsequent years. Typically these programmes integrate the BIM technologies with associated discipline-specific BIM processes with other modules, and/or with integrated projects. For example, BIM is an integral element of Architectural Technology’s Technical Design Studio modules [12].

Depending on the timing and duration of elements such as work placement and dissertation, students undertaking their 5^{th} or 6^{th} semesters will be afforded the opportunity to undertake a collaborative multidisciplinary project with students from related programmes. The duration and level of the project will depend on the capacity within each programme but careful management will be required to ensure that the relative effort between collaborative team members will be appropriate shared and rewarded. At Liverpool John Moore’s University, Dianne Marsh reported that a lack of consistency of engagement and of standardisation of assessment in collaborative projects run between AT, QS, Building Surveying, Building Services Engineering, Civil Engineering, and Real Estate Management students lead to significant problems in the roll out of collaborative BIM [13]. The option of utilising the multidisciplinary BIM projects as alternatives to work placement in special circumstances or as the foundations of individual dissertations also exists within the strategy.

At postgraduate level, current delivery focuses on individual CPD modules on the technologies of the disciplines of Architecture, Architectural Technology, Civil Engineering, Construction Management, Electrical Services Engineering, Geomatics Surveying/Engineering, Mechanical Engineering, Structural Engineering, and Quantity Surveying, as well as collaborative programmes at Postgraduate Certificate, Postgraduate Diploma, and Master of Science levels. These build on CPD Diploma programmes which began in 2012 as rapid upskilling mechanisms for construction professionals affected by the economic downturn.

In the true spirit of BIM collaboration, members of staff from 6 of the 7 Schools in the College formed a project team to develop and deliver, firstly, the CPD Diplomas and, subsequently, the MSc suite. As a result of the range of expertise available within this project team, waste was reduced through reuse of content where possible, and the competences of individuals and professions were appropriately represented and adopted. Again this is representative of the value of BIM, where all stake-holders are engaged at an early stage in a project, e.g. the client and/or Facilities Manager participate in Design Team meetings, thus reducing the occurrence of errors that might otherwise not be noticed until handover or another similarly-costly stage.

V IMPLEMENTATION OF BIM DRIVEN LEAN TRANSFORMATION

As is frequently mentioned, the 2016 mandate in the UK does not specify BIM. Rather it states that: "Government as a client can derive significant improvements in cost, value and carbon performance through the use of open sharable asset information" [14]. This principle can equally be applied to the cultural change required in education to facilitate BIM.

Until now, the major cultural changes that have been achieved in CEBE via BIM have been enacted at postgraduate level and with delivery outside the standard teaching week of 9-6, Monday to Friday. Although the programme team for the Applied Building Information Modelling & Management MSc suite comprises mainly core teaching staff, much of the delivery is undertaken by part-time lecturers who teach as a means of returning the benefit of what they have learned into the industry. In order to achieve the benefits of BIM at undergraduate level, BIM processes and technologies need to be adopted and taught on all relevant programmes by full-time, teaching faculty.

To support this change, School of Multidisciplinary Technologies has validated modules for the delivery of elements A and C of Figure 2. It is also investing in the development of a Big BIM Room, where students will have the necessary physical space within which to collaborate effectively in multidisciplinary teams. This room will also be of significant benefit for postgraduate BIM education and for other collaborative learning. For example, in the United States, all final year, level-8-equivalent engineering students must undertake a team project. This is done as part of a 3-year programme and the availability of this facility could help with adoption of techniques that would result in the education of high quality engineers at a faster rate than is currently possible.

To enable students to undertake BIM education on a flexible, part-time basis that fits around work and other commitments, DIT enables students to take modules over an extended period with exit qualifications after weeks, months, or years of study. This is equivalent to the sharing of asset information where the asset is BIM education and knowledge.

The new modules that have been validated by School of Multidisciplinary Technologies also include flexibility to include Lean Principles within projects. As elucidated by John Ffrench at a Lean Construction Institute Ireland event, BIM is the enabler for the process of Lean Construction which makes it possible to reduce waste, achieve cost efficiency, and derive value in construction. BIM implies Lean but is most effective when driven by champions of lean principles.

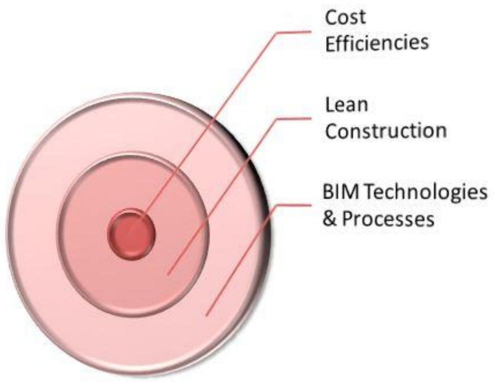

Figure 3 The link between cost effective construction & built environment operations, lean techniques and BIM (courtesy of John Ffrench, Lean Construction Institute)

VI FUTURE PATH FOR CEBE

The work of changing the culture of silo-based education has only begun. As the market changes, so too must the educational environment, particularly vocationally-focussed education such as offered at DIT.

The transformation of the DIT from an Institute of Technology into a Technological University following merger with the Institutes of Technology in Tallaght and Blanchardstown offers a unique opportunity for cultural change that is not often available to an institution of the scale of the DIT.

An agreed founding principle for the structure of the Technological University is that Schools will be based around disciplines. Targets may be set for numbers of students and income generation targets per school. The future of the School of Multidisciplinary Technologies in that context is uncertain but an arrangement such as currently in place for the Graduate Research School, where students are registered jointly between the GRS and the discipline-specific school, may be necessary to enable CEBE, and DIT, to deliver the high-quality, collaborative education that is required by our graduates and by industry.

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