A Collaborative Academia-Industry Approach to Programme-Wide Implementation of Building Information Modelling Processes using a Reciprocal Learning Framework

Mark Kelly[1], Jim O'Connor[2], Mark Costello[3] and Gerard Nicholson[4]

Department of Building and Civil Engineering

Galway Mayo Institute of Technology & RPS

E-mail: [1]Mark.Kelly@gmit.ie [2]Jim.OConnor@gmit.ie [3]Mark.Costello@rpsgroup.com [4]Gerard.Nicholson@rpsgroup.com

Abstract

Building Information Modelling or 'BIM' refers to a new collaborative work method used in today's rapidly changing construction industry. BIM places a digital model at the epicentre of the construction process. It is a shared knowledge resource forming a reliable basis for decisions during the life cycle of a facility from earliest conception to ultimate end-of -life. BIM processes allow team members to explore a project's key physical and functional characteristics digitally before it is built, helping to deliver projects faster, more economically and with reduced environmental impact. The UK government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016. Already in Ireland these same measures are being introduced through employer's requirements in advance of 2016. While the move to a 'fully collaborative working BIM environment' is a welcome development it poses a number of challenges for the Irish construction sector that will require considerable up-skilling and training. The higher education sector can play a key role in developing appropriate learning opportunities, both for students and industry stakeholders. Level 2 BIM requirements alter the entire way a project is procured, designed, delivered and operated. It is both a process as well as a deliverable and marks a significant shift from traditional work methods we are accustomed to. This paper will chart the development and integration of BIM processes and learning requirements into the curriculum and research activities in the Department of Building and Civil Engineering at the Galway-Mayo Institute of Technology [ACADEMIC] over the last number of years informed by a close collaboration with RPS Group [INDUSTRY]. This academic-industry partnership has enabled the development of a reciprocal learning framework where industry best practice, curriculum development and research activities have been coordinated and utilised to address the educational challenges posed by the interdisciplinary nature of BIM.

This collaboration between GMIT and RPS has resulted in the development of an industry orientated Higher Diploma in Engineering in BIM (Level 8 on the national framework) to train designers to the highest standard to meet level 2 BIM requirements. The delivery of this Higher Diploma in Engineering in BIM to RPS staff on a pilot basis since 2013 has enabled GMIT to test, further develop and measure progress of this programme on the delivery of large infrastructure and building projects in the UK and Ireland while working in a collaborative BIM environment.

Keywords - Building Information Modelling, BIM, Education, GMIT, RPS, Level 2

I INTRODUCTION

The UK Government requirement for fully collaborative 3D BIM on the procurement of all public projects by 2016 is fast approaching. This is posing a series of unique challenges for the sector in regard to organisational culture, education, training and information management (1). The most recent NBS UK National BIM Survey[1] (2) highlighted some of these challenges, including: a lack of in-house expertise; a lack of training; no client demand;

[1]This is the fifth survey carried out by the NBS, which commenced in 2010. The 2015 survey results were extrapolated from responses from nearly 900 building design professionals in the UK.

cost; and no time to get up to speed. Interestingly, despite these perceived barriers, 92 per cent respondents stated that 'in three years' time, we will use BIM'. This aligned with the view that BIM is the future of construction information (77% agree). However, a clear gap in understanding was highlighted with 67 per cent of respondents agreeing that the 'industry is not clear enough on what BIM is yet' and only 25 per cent stating that 'they trust what they hear about BIM'. These findings suggest that while considerable progress has been made to date, the sector is currently at the midpoint in the adoption curve[2]. Anecdotal evidence from the construction sector in Ireland suggests that while fully collaborative BIM Level 2 implementation on projects is currently rare, elements[3] are being included in public and private contracts even though there is no requirement to do so.

Traditionally, the fragmented and project-specific approach involving multi-stakeholders has led to a scattering of information and knowledge over different processes, trades and people within an organisation. The implementation of fully collaborative BIM aims to address these issues (amongst others) by providing a shared lifecycle knowledge and information resource that will enable complex design and construction analysis (lean construction principles, whole lifecycle costing etc.) and facilitate close cooperation of project stakeholders. The aim of this paper is to examine how higher education can support the construction sector in this transition by detailing how a close academic-industry collaboration led to the development of a new industry-focused third-level programme in BIM.

II REVIEW OF BIM INTERNATIONAL EDUCATIONAL INITIATIVES

Internationally, the role of higher education in moving towards a BIM-enabled construction sector has developed into a continuously evolving research topic with a number of studies examining the transition from CAD to BIM (3-10), the impact on learning environments (11) and innovative pedagogical approaches (12, 13). These research efforts demonstrate that the higher education sector is cognisant of the key role that BIM can play in a more efficient, collaborative and low impact construction sector. The inclusion of BIM in construction-related programmes has gathered significant pace over recent years (14) with Joannides, Olbina and Issa (2012) reporting that over half of American tertiary education institutions claimed to have BIM dedicated courses or to have included BIM content into their existing courses. In addition, a number of countries (Australia, New Zealand and the UK) have developed common BIM educational frameworks (16-18). In Australia, the 'Collaborative Building Design Education using Building Information Modelling (CodeBIM)' project produced and piloted[4] a framework for collaborative building design teaching using BIM entitled IMAC (Illustration, Manipulation, Application and Collaboration) (18). In New Zealand, the University of Auckland in partnership with industry proposed a set of 18 learning outcomes that embraced vocational training, university degree programmes and research activities (17). The UK BIM Academic Forum (BAF) (19, 16) proposed a set of learning outcomes to address strategic, management and technical industry needs to facilitate knowledge, understanding, practical skills and transferable skills. BAF also produced a useful BIM teaching impact matrix, which described the following four levels of engagement (16).

a. Absent – BIM should not affect teaching practice and students do not need to know about BIM.
b. Aware – BIM should not affect teaching practice but students should be aware of it.
c. Infused – Students should understand how BIM will affect their future and be offered opportunities to engage with BIM in discipline and multi-disciplinary contexts.
d. Embedded – BIM is used as a core pedagogical tool in the students' learning experience.

Other notable national efforts[5] include the US where BIM educational initiatives were more specific to individual institutions and were predominantly at undergraduate level (20). In Israel, the Technion-Israel Institute of Technology engaged in an extensive consultation with leading international practitioners and industry to develop 39 learning outcomes covering process, technology and applications (9). Subsequent research in Australia (21) has built on these initiatives to produce a

[2] The NBS 2015 BIM Survey utilized the Everett Rogers' standard adoption curve to categories BIM awareness usage from 2010 to 2015.

[3] Including: an Employers Information Requirements (EIR) document to define all information required by the client; a supplier and supply chain capability assessment to assess competency; a BIM Execution Plan (BEP) to define roles, standard, procedures and project milestones; using a Shared Common Data Environment to improve collaboration; utilisation of analysis software on BIM models; and compliance with standards outlined in PAS 1192-2 and BS 1192.

[4] At the University of South Australia.

[5] NOTE ON SCANDANAVIA, SINGAPORE ETC.

Student Threshold Capability Framework[6] to be used in a curriculum redesign process to address the need for BIM to be seen as a methodological rather than just a technological tool. Recent research in UK examining the current position of BIM education in the UK (22) found that overall levels of BIM maturity awareness were low when examined across the full range of programmes in the Built Environment discipline[7]. In addition, current educational developments appear to be largely focused on the most fundamental aspects of BIM with a surprisingly low level of engagement with industry. This correlates with the finding that 66 per cent of respondents believed that Higher Education Institutions (HEIs) in the UK are currently not keeping pace with BIM skills requirement and industry knowledge demands (22).

In Ireland, BIM educational initiatives to date have mirrored the US approach, in that they have been specific to individual institutions (23-26) with some examples of industry engagement. The next section will provide an overview of one such initiative involving an academic institution (GMIT) and an industry partner (RPS).

III THE EVOLUTION OF A COLLABORATIVE BIM EDUCATIONAL INITIATIVE

Since first introducing building and civil engineering students to computing in 1985, the Department of Building and Civil Engineering at the Galway-Mayo Institute of Technology has been committed to providing information technology educational opportunities that were directly relevant to the construction sector. Over the past 30 years, the department has witnessed a gradual progression from the basic AutoCAD[8] packages to ArchiCAD (2001 to 2005) to Autodesk Revit Architecture (2005 onwards). During the development of the B.Sc. in Architectural Technology in 2005, it was decided to fully embed 3D building modelling into the programme in addition to retaining the comprehensive delivery of AutoCAD 2D and 3D. This mode of delivery has enabled graduates to obtain employment with a range of diverse employers including building contractors, engineering consultants, facilities management specialists and design teams. This has encouraged other programmes in the Department (civil engineering, quantity surveying and construction management) to integrate this mode of delivery into their existing curricula. Although, this approach has primarily focused on the technological aspect of BIM, some effort has been made to integrate other elements related to construction process applications, contractual and legal considerations, collaborative working environments, information management and lifecycle analysis. The current level of BIM-related integration in the Department of Building and Civil Engineering at GMIT is as follows:

A. One mandatory module in each of the four years of the B.Sc. in Architectural Technology e.g. CAD 1, CAD 2/BIM, CAD 3/BIM and BIM 4 Architecture.
B. One mandatory module in years' one and two (CAD/BIM 1 and 2) of the B.Sc. in Construction Management plus an elective module 'BIM 1 for Construction' in Year 2. BIM is also included as a topic covered as part of the 'Project Management' module in Year 4.
C. One mandatory module in years' one and two (CAD and CAD/BIM) of the B.Sc. in Civil Engineering. BIM is also covered as a topic in two modules in Year 4, 'Advanced Civil Engineering Software' and 'Environmental and Energy Sustainability'.
D. One mandatory module in years' one and two (BIM for Surveyors 1 and 1) of the B.Sc. Quantity Surveying and Construction Economics. BIM is also covered as a topic as part of the 'Integrated Project' module in Year 4.

A review of this BIM-related curriculum content does illustrate a narrow discipline specific approach, which has utilised existing structures (Rusinko, 2010) to focus primarily on the fundamental technological applications of BIM. This is clearly not sufficient to meet the current needs of industry to support their move towards a collaborative BIM Level 2 working environment. In recognition of this, the Department of Building and Civil Engineering in the GMIT has developed a Level 8 Higher Diploma in Engineering in BIM in collaboration with an industry partner, RPS Group Plc.

RPS is a leading international multi-disciplinary consultancy offering a range of integrated engineering, project management, planning, scientific, environmental and communication services on a cross-sectoral basis to both the public and private sectors. RPS introduced 'Early BIM' into their working systems in 2007, where BIM did not form part of the design process of delivered projects but was used to produce 3D

[6] The Threshold Capability Framework covered five thematic areas: fundamental principles; technical skills; construction project management skills; strategic organizational behaviours; and global market context.
[7] Analysis also indicated that apart from the architecture and construction-related disciplines, low levels of interest were expressed in incorporating BIM into teaching across the built environment disciplines (BAF, 2015).
[8] Starting with AutoCAD 10 in 1987.

visuals and walk-throughs to assist clients at an early stage. Limited progress was being made at an organisational level until 2012, when a BIM working group was set up to address the increasing project requirements in the civil, structural, mechanical services and infrastructural disciplines. BIM software had been used on a number of projects to date but it was recognised that considerable up-skilling was required. In June 2013, a formal request was made to the Department of Building and Civil Engineering in GMIT to develop a new industry-orientated multi-disciplinary Higher Diploma in BIM. The following suite of modules were developed:

a. BIM Virtual Modelling Fundamentals (M)

b. BIM Architecture (E)

c. BIM Structure (E)

d. BIM Infrastructure (E)

e. BIM Mechanical, Electrical and Plumbing (E)

f. BIM Collaboration (M)

g. BIM Project (M)

In September 2013, the first of these modules ('BIM Virtual Modelling Fundamentals') was piloted with eight Galway-based RPS staff over a 12-week period. As a result of the successful delivery of this module, RPS expanded this initiative, with training commencing in their Dublin and Cork offices in September 2014. This resulted in the upskilling of over 60 RPS staff in BIM. The 'BIM Infrastructure' module delivery has commenced in all three offices and will be completed by staff at the end of 2015. It is envisaged that participants will complete the remaining mandatory modules, 'BIM Collaboration' and 'BIM Project' to make them eligible for the Level 8 award.

This academic-industry partnership has been a key driver in the delivery of the RPS BIM Strategic Plan, which has established core BIM teams in Dublin, Cork and Galway and developed in-house BIM protocols and procedures that are being used throughout the design, construction and operations phases of projects. This has led to a rethink on how RPS projects are procured, delivered and constructed through the: incorporation of fully coordinated design models; the development of a new BIM working environment across multiple interoperable design platforms; the production of 4D phasing and 5D costing models; improved planning and coordination; and the minimisation of operational and contractual conflict. This has enabled RPS to offer professional services on projects in the UK and Europe resulting in the award of major highways, water and gas projects that has resulted in a 3 per cent increase in profitability. This, in turn has resulted in a significant increase in staff with a particular focus employing 'BIM-capable' graduates (27).

The Department of Building and Civil Engineering had previously provided an industry-focused programme through the Springboard initiative. A Certificate in BIM was delivered to 19 participants during the 2012/2013 academic year[9]. In addition, the Department formed a research partnership with a local building contractor, Carey Developments Ltd., in 2012 to investigate, via a Master's degree (by research), the application of BIM on small-scale construction projects in Ireland (28).

Due to the success of these initiatives, the Department of Building and Civil Engineering now intends to deliver the Level 8 Higher Diploma in Engineering in BIM in a part-time mode from September 2015. It is envisaged that this will provide an opportunity to upskill other industry stakeholders such as building contractors, quantity surveyors, project managers, sub-contractors, designers, facility managers etc., as well as GMIT academic staff. The flexible delivery of the programme (Figure 1) consists of three mandatory modules (BIM Virtual Modelling Fundamental, BIM Collaboration, BIM Project) and one elective from the four on offer. In addition, each module (excluding the BIM project) is also available as individual minor awards.

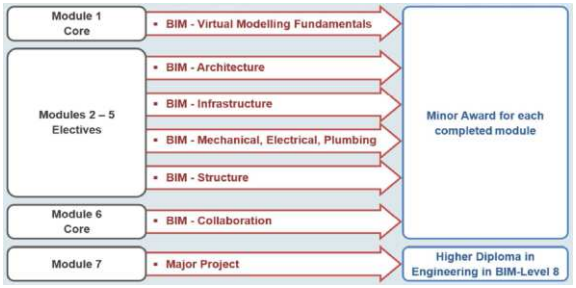

Figure 1: Higher Diploma in BIM Programme Structure

While the new Higher Diploma in Engineering in BIM offers a more holistic approach focusing on use of 3D tools to develop a BIM model that will enable the collaborative and effective[10] use of information, it still is (from a pedagogical point of view), a compartmentalised discipline-specific approach (albeit utilising a new structure). The Department of Building and Civil Engineering recognises the need to embed BIM as a methodological tool (London, 2015) across their

[9]The certificate evolved from the existing CAD/BIM 2 module from the B.Sc. in Architectural Technology.

[10] Using BIM to analyse time (4D), cost (5D) and facilities management (6D).

programmes and will utilise the Higher Diploma as a vehicle to do so. In addition, the current lack of interdisciplinary or transdisciplinary learning experiences for students within the current programmes on offer does provide an opportunity to develop a series of initiatives that will foster deep engagement in collaborative working environments. Previous research (29-32, 25) has found that although interdisciplinary and transdisciplinary educational approaches pose many challenges, there is a clear need for this applied approach to fully understand the role and applicability of BIM in the lifecycle of the built environment. To address these gaps, the authors propose the use of a reciprocal learning model as a tool to fully embed BIM across all programmes in the Department.

IV A RECIPROCAL LEARNING MODEL FOR BIM

The proposed reciprocal learning model is based on the utilisation of real-world local construction projects (as case studies) to inform third-level curriculum and pedagogical development, research activities and industry best practice (Figure 2).

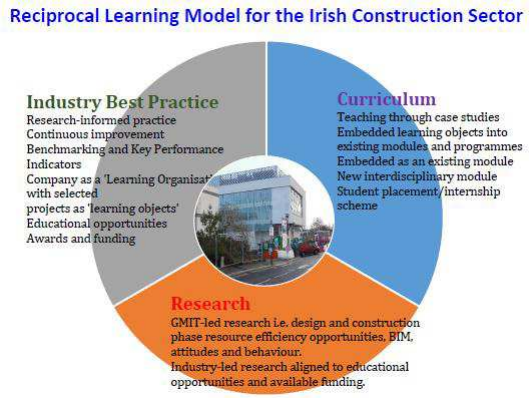

Figure 2: Proposed Reciprocal Learning Model for Academia-Industry Collaboration

The model aims to build on existing and develop new industry partnerships to identify a series of case studies that will inform the development of curriculum content and facilitate the discovery of research-informed best practice. This will involve a series of capacity-building exercises including:

A. A Department review of the current curriculum, learning outcomes and assessment strategies to determine the level of BIM integration.

B. An analysis of current attitudes to and awareness of BIM within the Department. This will help identify any upskilling or training needs as well as any significant barriers.

C. A series of exploratory workshops to identify current (and possible future) industry BIM requirements.

D. The selection of suitable case studies to build on the work of Nicholson (2013) and explore the applicability of BIM during the lifecycle of construction projects in the Galway region. This participatory action research approach will enable academic staff to engage directly with industry stakeholders, which will in turn, inform the curriculum through the development of a series of learning objects resulting from evidence-based research e.g. comparing traditional waste estimation techniques with BIM-enabled tools. These learning objects i.e. PowerPoint slides, videos, podcasts etc. will then be made available to all academic staff in the Department to allow for an incremental diffusion of BIM-related content into the existing programme structures. The mandatory 'BIM Project' module on the Higher Diploma will also be used as a vehicle to develop these learning objects with the students acting as co-producers.

E. A collaborative working environment theme will be embedded throughout all programmes via multi-disciplinary group exercises as part of the 'Learning and Innovation Skills' module in Year 1, the 'Integrated Project' modules in Years 2 and 3 and a final-year multi-disciplinary project involving students from all programmes. It is proposed to pilot a multi-disciplinary project in 2016 with students from the Architectural Technology, Quantity Surveying and Construction Management programmes to explore the challenges and opportunities that exist with this form of pedagogical approach. This will involve extensive industry participation through a series of guest lectures and workshops and will be based on one of the research case studies.

These initiatives will inform the preparation of a BIM strategy and implementation plan for the Department, which will be developed during the 2015/2016 academic year. This holistic approach will be incremental to allow for a BIM ripple of diffusion, where the dissemination of evidence-based findings will enable an inclusive approach within the Department.

V CONCLUSIONS

The use of BIM requires a paradigm shift in how we design, construct, deliver and manage the built environment over its whole lifecycle. This presents an exciting opportunity for the higher education sector to explore innovative pedagogical approaches utilising BIM as a core methodological tool on all construction-related programmes. It also offers a perfect collaborative platform to engage with industry stakeholders to analyse the applications of BIM on real-world projects and allow for an exploratory learning space to rethink the way we do things. The traditional fragmentation of the construction supply chain is currently a significant barrier to implementation in the sector. This is also evident in structure of construction-related programmes in higher education, where the compartmentalisation of programmes into discipline-specific silos does not allow for immersive learning experiences in a collaborative environment.

In Ireland, the higher education sector has responded with the development of stand-alone and integrated modules and programmes at both undergraduate and postgraduate level. The GMIT, through its close collaboration with RPS, has made a significant contribution to these efforts with the development of the Higher Diploma in Engineering in BIM. The Department of Building and Civil Engineering is keen to build on this good work to further embed BIM as a pedagogical methodology across all its programmes through continued collaboration with industry to facilitate multi- and transdisciplinary authentic learning experiences for students, academic staff and industry stakeholders. There is also a unique opportunity for the higher education sector to build on their good work to date to develop a national BIM educational framework that will cultivate a community of practice[11] that will demonstrate and shape BIM best practice and position Ireland as one of the international leaders in this area.

REFERENCES

[1] Khosrowshahi F. and Arayici, Y. (2012) Roadmap for implementation of BIM in the UK construction industry, Engineering, Construction and Architectural Management, 19(6), 610-635.

[2] NBS (2015) *National BIM Report 2015*.

[3] Berwald, S. (2008) From CAD to BIM: The Experience of Architectural Education with Building Information Modelling, Proceedings from the American Society of Civil Engineers, 1-5.

[4] Casey, M.J. (2008) *Work in Progress: How Building Information Modelling may unify the Civil Engineering Curriculum*, paper presented to the 38th ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY.

[5] Denzer A.S. and Hedges K.E. (2008) From CAD to BIM; Educational strategies for the coming paradigm shift. AEI 2008-Building Integrated Solutions, Proceedings of the AEI 2008 Conference, Denver, Colorado, USA, 1-11.

[6] Kim, J. (2012) Use of BIM for Effective Visualisation Teaching Approach in Construction Education, *Journal of Professional Issues in Engineering Education and Practice*, 138, 214-223.

[7] Pikas, E., Sacks, R. and Hazzan, O. (2013) Building Information Modelling Education for Construction Engineering and Management 1: Procedures and Implementation Case Study, *J. Constr. Eng. Manage*., 139(11).

[8] Sacks, R. and Barak, R. (2010) Teaching building information modelling as an integral part of freshman year civil engineering education, *J. Prof. Issues Eng. Educ. Pract.,* 136(1), 30-38.

[9] Sacks, R. and Pikas, E. (2013) Building Information Modelling Education for Construction Engineering and Management 1: Industry Requirements, State of the Art and Gap Analysis, *J. Constr. Eng. Manage*., 139(11).

[10] Weber, D. and Hedges, K. (2008) From CAD to BIM: The Engineering Student Perspective, Proceedings from the American Society of Civil Engineers, 1-8.

[11] Hedges, K.E. and Denzer, A.S. (2008) *How a Collaborative Architecture influences Structural Engineering Education*, paper presented to the Structures Congress 2008, Vancouver, Canada, 24-26 April 2008.

[12] Burr K.L. (2009). Creative course design: a study in student-centred course development for a sustainable building/BIM class, *Proceedings of the 45th Annual Conference by Associated Schools of Construction,* Sulbaran T. and Sterling C. (Eds.), University of Florida, Gainesville, Florida, USA. April 1-4.

[13] Evans, N. and Counsell, J. (2009) Web-Mediated Student Peer Group Assessment of Building Information Modelling Performance, paper presented at VIZ09 - Visualisation in Built and Rural Environments, Banissi et al. (Eds.), Barcelona 15-17 July 2009.

[14] Wong, K., Wong F.K.W. and Nadeem, A. (2011) Building information modelling for tertiary education in Hong Kong, *Journal of Information Technology in Construction*, 16, 467-476.

[11] The CITA BIM Education Forum provides a perfect platform for the development of this community of practice.

[15] Joannides M.M., Olbina, S. and Issa, R.R.A (2012) Implementation of Building Information Modelling into Accredited Programmes in Architecture and Construction Education, *International Journal of Construction Education and Research*, 8(2), 83-100.

[16] BIM Academic Forum (BAF) UK (2013) Embedding BIM (Building Information Modelling) within the taught curriculum.

[17] Miller, G., Sharma, S., Donald, C. and Amor, R. (2013) Developing a Building Information Modelling Educational Framework for the Tertiary Sector in New Zealand, in Bernard, A.; Rivest, L. and Dutta, D. (Eds.) *Product Lifecycle Management for Society*, Springer Berlin Heidelberg, 409, 606-618.

[18] Mills, J., Tran, A., Parks, A., Kelly, S., Smith, E., Jupp, J. et al. (2013) *Collaborative building design education using Building Information Modelling* (CodeBIM), Final Report 2013, Australian Government Office for Learning and Teaching, Canberra.

[19] BIM Academic Forum (BAF) UK (2012) Embedding BIM (Building Information Modelling) within the taught curriculum.

[20] Wu, W. and Issa, R.R.A (2013) *BIM education for new career options: an initial investigation*, paper presented to BIM Academic Workshop, Jan. 2013, Washington D.C.

[21] London, K. (2015) *Global Passport through Co-Integration of Construction Immersive Environments*, RMIT Learning and Teaching Investment Fund Final Report.

[22] BIM Academic Forum (BAF) UK (2015) Current Position and Associated Challenges of BIM Education in UK Higher Education, prepared for BAF by Underwood, J. and Ayoade, O.

[23] Behan, A. (2013) *Update on the BIM Education of Geomatics Surveyors*, Proceedings of the CITA BIM Gathering Conference, 163-168, 14-15 November 2013, Hore, A.; McAuley, B. and West, R. (Eds.).

[24] Kinnane, O. and West, R. (2013) *BIM introduction into the curriculum of Civil and Structural Engineering students: A project-based active learning approach*, Proceedings of the CITA BIM Gathering Conference, 175-184, 14-15 November 2013, Hore, A.; McAuley, B. and West, R. (Eds.).

[25] Thomas, K., Chisholm, G., Dempsey, B., Graham, B. and Stubbs, R. (2013) *Collaborative BIM Learning via an Academia-Industry partnership*, Proceedings of the CITA BIM Gathering Conference, 201-206, 14-15 November 2013, Hore, A.; McAuley, B. and West, R. (Eds.).

[26] McGovern, E. and Behan, A. (2014) Geomatics and Developments in BIM Education in Ireland, paper presented at the FIG Congress 2014 'Engaging the Challenges – Enhancing the Relevance', Kuala Lumpur, Malaysia, 16-21 June 2014.

[27] RPS (2014) *The RPS BIM Revolution*, CPD Employer of the Year Submission 2014/2015 to Engineers Ireland.

[28] Nicholson, G. (2013) *Investigating the Application of BIM on Small-Scale Construction Projects*, Proceedings of the CITA BIM Gathering Conference, 49-60, 14-15 November 2013, Hore, A.; McAuley, B. and West, R. (Eds.).

[29] Cribbs, J., Hailer, J., Horton, P. and Chasey, A. (2015) *Enhanced collaboration between construction management and architecture students utilising a building information modelling environment*, Proceedings of the 9th BIM Academic Symposium, April 7-8, Washington D.C.

[30] Demirdoven, J. (2015) *An Interdisciplinary Approach to integrate BIM in the Construction Management and Engineering Curriculum*, Proceedings of the 9th BIM Academic Symposium, April 7-8, Washington D.C.

[31] MacDonald J. and Mills, J. (2013) An IPD approach to construction education, *Australasian Journal of Construction Economics and Building*, 13(2), 93-103.

[32] McCuen, T. and Pober, E. (2015) *Process and Structure: Performance Impacts on Collaborative Interdisciplinary Team Experiences*, Proceedings of the 9th BIM Academic Symposium, April 7-8, Washington D.C.