Trivarsity, interdisciplinary BIModelling/Management (BIM) workshop: an action research international example

ROBERTSON, Frances Josephine <http://orcid.org/0000-0003-2995-5540>, MULLER, Ernest, CHISHOLM, Gordon, OLNER, Geoffrey and DUXBURY, Liane Sharon

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Trivarsity, Interdisciplinary BIModelling/ Management (BIM) Workshop:
An Action Research International Example

Frances Josephine Robertson, Sheffield Hallam University, Sheffield, UK
Ernest Muller, VIA University College, Horsens, Denmark
Gordon Chisholm, Waterford Institute of Technology, Waterford, Ireland
Geoff Olner, Sheffield Hallam University, Sheffield,UK
Liane Sharon Duxbury, Sheffield Hallam University, Sheffield,UK

ABSTRACT

This article demonstrates the evolutionary development of a series of inter-varsity, interdisciplinary, collaborative architectural design/management workshops, using industry-standard BIM software, within a community of academics, students and practitioners in Danish, Irish and UK architectural technology (AT) universities. This article, per the authors, proposes that the current digital revolution in the architectural, engineering, construction and operations/owner-operated (AECO) sectors, necessitates a planned change process to simulate 21st century, interdisciplinary, professional practice in academia. The action research methodology of this is outlined. After each of the four dynamic and cyclical stages, the reflective practitioners discuss their development of the professional curriculum: defined as an active-learning process. The students are active collaborators: joint change agents in a process of transformational learning as future employees and ambassadors for the benefits of collaboration utilizing information communication technologies (ICTs).

KEYWORDS

Architectural Technologist Emerging Role in BIM Adoption, Collaborative BIM Workflows, Constructive Alignment of AECO ICT Education and Practice, Simulated Cloud-Based Collaboration

INTRODUCTION

The negative effects of adversarial attitudes among those from Architecture, Engineering, Construction and Operations/Owner-operated (AECO) backgrounds in the industry has been highlighted by various reports advocating the need for inter-disciplinary working skills from those entering practice. The education of those in the AECO sector is determined in collaboration with professional bodies and educational quality assurance agencies (e.g., QAA, 2014; QQI, 2016) that ratify this recommendation. This presents a challenge for Higher Education Institutions (HEIs) to devise opportunities for collaborative working across disciplines, traditionally educated in 'silos' and, more importantly, to

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encourage innovation in the assessment of the learning involved. The challenge often necessitates an attitudinal shift within the educators in HEIs, often accused of mimicking and perpetuating said adversarial behaviours in practice, and accustomed to autonomous working (Schein, 1972). The educators in this research came together initially, through International Congress on Architectural Technology (ICAT) networking and Erasmus exchange, as professionals who aim to use their research to improve their and their students' effectiveness as practitioners. They identify a feasible 'specific change target' to instigate a change process towards collaborative design and information management education (Schein, 1972): a collaborative Building Information Modelling/Management (BIM) project to simulate the problems of 21st century, inter-disciplinary practice. This takes the form of a yearly tri-varsity, inter-disciplinary, fictitious collaborative design workshop using BIM and cloud-based information communication technologies (ICTs), devised in collaboration with Danish, Irish and UK architectural technology (AT) HEIs, professional practitioners and software developers. The workshop introduces collaborative (BIM) workflows to the students across the three institutions; primarily with students from Architectural Technology (AT) and Construction Management programmes, but later includes Sustainable Energy Engineering (SEE4) and Quantity Surveying (QS4) students. The multi-national approach allows staff and students to experience and learn from the implementation of BIM within other institutions and to appreciate and learn from the nuances of each AT programme.

This article presents the cyclical process of the development of the workshop following its inception through its four evolutionary sessions to date; Sheffield Hallam University (SHU), March 2015; VIA University (VIA), October 2015, Waterford Institute of Technology (WIT), November 2016, and SHU, November 2017. In seeking to explore the implementation of effective strategies in the application of ICTs in architectural technology practice, during and at the end of each workshop the collective use their findings to generate possibilities for change which are then implemented and evaluated as a prelude to the further investigation in the subsequent workshop (Denscombe, 2014). The fourth workshop extends the participatory action research to co-collaborators from professional practice enhancing opportunities for change; a positive, paradigmatic shift (Kuhn, 1996); away from adversarial relationships between the AECO disciplines in practice and education, and for an evaluation of the impact of the findings on inter-disciplinary practice.

BACKGROUND

Devising Architectural Technology Education Collaboratively

The concept that the project team in practice is composed of 'domain experts' each with well-defined and explicit fields of knowledge (Penn, 2008) is recognised in this research. Emmitt (2002) states that over the last fifty years successive government reports and much research have encouraged those in the building industry to work more collaboratively to repair the damage done by increasingly fragmentary and adversarial relationships. Egan (1998), building on Latham (1994), states that whilst the UK construction industry at its best is excellent, there is too much client dissatisfaction, low profitability and little investment in capital, research and development, and training. The Egan report is the work of a Task Force of industry specialists informed by their experience of radical change-to-improve in other industries. It recommends five key drivers of change; committed leadership, a focus on the customer (client or end-user), integrated processes and teams, a quality driven agenda, and commitment to people. The way of achieving reduced cost, construction time and defects is through radical changes to the processes by which projects are delivered: specifically, through the creation of a more integrated design and construction process (Egan, 1998).

On consideration of the three main phases of a construction project; conceptual design, detail design, and site assembly; there are two identifiable links in these three sequential activity areas where the transference of information is crucial to the faithful realisation of the building project from conception to completion. Architectural technologists are ideally placed to act as this constructive link (Society of Architectural and Associated Technicians, 1984) and the more effective and clear the communication is between the participants in the process, the better the completed building will meet the beneficiaries' needs (Emmitt, 2002). Technical knowledge and skill are not enough in practice; the participants in a building project must have the necessary social skills to work together effectively and efficiently (Emmitt, 2010). This social interaction might be face-to-face or, increasingly, by means of ICTs.

The more recent HM Government report, Construction 2025 (Department for Business, Innovation, and Skills, 2013) provides an update on the future aspirations of the construction industry. This has five visions for the future of the industry; broadly they envisage a diverse industry with rewarding and attractive career prospects, a world-leader in research and innovation which embraces ICTs and smart construction, sustainable through design, cost, supply and life-cycle efficiencies. The Confederation of British Industry (CBI, 2012) reports that businesses require graduates with work-related skills and the flexibility to help the organisation to evolve in the face of continuous and rapid economic and technological change. In the UK, the QAA benchmark statement for architectural technology (QAA, 2014) is revised every seven years but perhaps this period is too long: employer surveys have reported such a rapidly changing workplace that it is difficult to predict the skills required of graduates even in the next two years (Helyer & Lee, 2014). This future uncertainty cannot just be assumed but through collaborative research between academia, industry and professional bodies, the future integration of ICTs in the practice of architectural technology might become more predictable. A vocational course such as architectural technology (AT) can be devised with an evolving curriculum which reflects such changes in professional practice.

Research to Create Empathy Between Teacher and Learner

Research and learning both involve personal growth and development. Brew (1988, cited in Brew & Boud, 1995) states that research is learning. Thinking and critical reflection are required of the researcher as the learner. The learning process and concomitant acquisition of knowledge can be rationalized and predicted but so can allowing for learning which is unplanned and unexpected. Research assumes a strict scientific paradigm yet many academics who present their research know that it did not occur in this manner (Brew & Boud, 1995). The nature of research as a process of learning means a presumption of learning from mistakes and failures. Learning as 'coming to know' is not just about predictable, guaranteed knowledge acquisition in the learner via games and calculi with fixed rules.

In HEIs, research into learning requires clarification of the concepts of understanding, meaning and thinking (Wittgenstein, 1968). The methodology needs to be devised appropriately in accordance with a clarification of the epistemological structure of the type of learning under investigation. Learning is also about creating both individually and socially-constructed knowledge. The proposition here is that the epistemology of architectural technology is of socially constructed knowledge: all seemingly objective conclusions are ultimately founded upon the subjective conditioning/worldview of its researchers and participants (Ernest, 1991). Research is concerned with making meaning; making sense of chaos; and the translation and transference of this into normative, understandable explanations. It is contentious whether doing research is likely to enhance pedagogical skills, but it can increase the teachers' knowledge, interest and enthusiasm for their subject (Brew & Boud, 1995). If the researcher is focussed on the desire to teach more effectively, then the research needs to be centred on student learning: necessitating investigation of the factors which lead to student success in learning.

Research to Enhance Academic Professional Practice

Traditionally, research has been regarded as an esoteric pursuit, separate from teaching practice. Brew and Boud (2013) suggest that the policies for the professional development of academics need to focus not on traditional (and often separate) individual research but on learning which emerges from the social processes of practice. Academics should be offered opportunities to develop their own practice through participation in the exemplary practice of others (Boud & Brew, 2013). At VIA, the traditional method of teaching Architectural Technology Construction Management (ATCM) courses in accordance with the 'focused method' (i.e., in 'silos') had been abandoned in the late seventies in favour of the more multi-disciplinary, project-orientated pedagogical methods, and later problem-based learning (PBL). This was about the same time as PBL was introduced at Harvard University in the USA and other institutions in Europe, such as Limburguniversitetet in Holland and Hälsounviversitetet in Linköping, Sweden (Pettersen, 2001). VIA has had an international ATCM course comprising students from a multitude of countries working in multinational groups from the very outset of PBL in Denmark. These students work in groups with PBL projects throughout the whole duration of their undergraduate education. Therefore, VIA educators are confident that their students are well-equipped for the first tri-varsity collaboration in October 2015. A substantial part of the study in PBL is working in basic groups. The idea is that the group will function as a support network for the individual student, and is a safe, social platform for the learning process and the learning effort (Pettersen, 2001). Whilst SHU and WIT use PBL as the basis for their studio project briefs with inter-modular learning, there is limited collaborative, inter-disciplinary PBL between courses.

PBL as a learning method is based on the principle of using problem-solving as a vehicle for the creation, acquisition and integration of knowledge (Barrow & Tamblyn, 1980). On being presented with the problem, the learner must identify and search for the knowledge they will require to deal with, and perhaps solve, the problem (Ross, 1991). It is an active-learning, student-centred pedagogical approach. In professional education, the problems are often simulations of real-world scenarios: thus, legitimizing the problem by giving it relevance (Pettersen, 2001). The BIM Workshop is predicated on PBL so the students are only presented with a brief and given introductory lectures from keynote speakers in industry. They are usually given a basic 3D digital architectural/structural model and initial tutorials on the software protocols. The educators from the three institutions are always on hand over the two/three days for guidance and support. Prior to the workshop, the SHU educators introduced the students to Tuckman's (1994) four phases of teamwork; 'forming, storming, norming, and performing'; as a model for their reflection-on-action in their teams (Schön, 1983). An analogous model is perceived by the collaborative educators as they appraise and re-devise the workshop through its evolutionary stages. This includes Tuckman's fifth phase of 'adjourning' in the evaluation of each workshop as the prelude to the subsequent workshop.

At the end of each cycle of the workshop, every student participant is required to present their solution to the problem in their tri-varsity, inter-disciplinary groups. In contrast to the, arguably progressive, collaborative educational model at VIA, the "focused method" is used at SHU and WIT as the basis for their AT courses. The latter courses have a specialist disciplinary focus for their curriculum and sit within a department with other related, yet distinct, AECO disciplines (with tentative collaboration across the disciplines). The ATCM course at VIA teaches a combination of disciplines comprising architecture, construction, structural design, installations and project management: the students become generalists in all these fields of construction. The Tri-varsity BIM Workshop, interestingly, affords the mixing of specialists from a focused-method pedagogy with generalists from the PBL pedagogical method. During and at the end of each stage of the workshop development, reflection on practice and learning, by both students and educators, is part of the participatory action research.

A Need for Change in ICT and CAD Management Education

Harty's (2012) thesis investigates the emerging role of the architectural technologist as the professional who can manage the integration of the fragmented areas of specialization in the design and construction process by the use of building information modelling/management (BIM). Waterhouse (2014) states, in the 2014 NBS National BIM Report, that it is the information contained in the representational BIM model that is really valuable in the design, construction and building life-cycle phases. Harty concludes that there is a skills' shortage in BIModelling/Management which needs to be addressed by education. The high-quality information contained in the digital model can reduce risk, saving the client time and money. The consequence of more project certainty for clients and contractors by using BIM will drive its adoption in the industry according to Harty (2012). He specifically investigates the impact of digitalization on the management role of the architectural technologist in practice: proposing that the discipline of architectural technology might cross the boundaries of differing professions.

New technologies and approaches to production are creating new areas of expertise. This digitalization evolution warrants research into its impact on practice in the AECO sector, and the alignment of the associated education in HEIs in order to prepare the future workforce. The current procurement methods need to be understood and are central to future practice: collaborative (relational) contracts and Integrated Project Delivery (IPD) approaches can foster an equitable, creative environment and value for money for the client (Emmitt & Ruikar, 2013). Indeed, Emmitt and Ruikar (2013) contend that traditional procurement perpetuates adversarial behaviour unlike project partnering and strategic alliances.

However, any electronic information system is operated by human beings and whilst this is a challenge it is also, arguably, an advantage: people are yet to be eclipsed by artificial intelligence (Dreyfus, 1992). Emmitt (1999) believes that information management, not design, is crucial to competitive service provision. Information is transferred, codified and disseminated and this varies according to the project type, duration and procurement method. Its optimization is dependent on the efficacy of the social network and the appropriate application of ICTs. Firms that can plan their communication strategies intelligently will ensure competitive advantage in an information-driven industry (Emmitt, 1999). This resonates with Egan (1998) who advocates that radical changes to the processes by which projects are delivered would create a more integrated design and construction process and eventual Integrated Project Delivery (IPD) or Integrated Project Information (IPI). It is obvious to the authors that associated changes in professional education are needed. They set themselves up as international educational 'change agents' and sought liked-minded 'change role models' from industry (Schein, 1972). The workshops' goal was to enable participants to gain experience of how CAD Management and ICTs can optimize and connect teams working across disciplines during a key phase of a simulated architectural design project.

In managing this evolutionary change process, the ultimate goals are continuously re-examined: it is a dynamic and cyclical process reinforced by the change agents finding appropriate collaborators along the way. Any 'thought leaders' in the evolution of digital technologies in the AECO industry are believed to be apt ideological change role models. This is a symbiotic relationship between academia, practitioners and software testers and developers, involved in planned change. The learners, as consumers of education and future users of software, are a crucial group in the change agent collective: their feedback is pivotal to the success of the venture. The workshop collaborators from industry/practice (architectural, structural, environmental and MEP), professional education (AT academics and students), and software design and development (Autodesk) contribute collectively to the evaluation of findings from each workshop.

Managing the Planned Change Process

Ultimately, Schein (1972) warns that influencing a change process cannot be presumed. Rather, it is often the case that disciplinary analysis and the associated proposed change process have little impact due to the conservative nature of professional practice and education. Resistance to change should be anticipated and used to reformulate the ultimate goals along the way. The planned change process might vary in impact within each institution involved due to the peculiarities of professional accreditation and the educational culture in each country.

Crucially, the participants might be loath to relinquish the traditional ways of thinking and learning and, therefore, might resist learning new concepts and ideas, new attitudes and values, and new patterns of behaviour and skills (Schein, 1972). However, in the authors' experience, anything related to ICT innovation is usually readily embraced by students. The educational social system integrates educators and learners, both of whom are learning and have a part to play in the transformation of said system. The essence of a planned change process is the 'unlearning' of present ways of doing things (Schein, 1972) and this presents the greatest challenge to the planned change. The proceeding observation and appraisal of each workshop is conceptually based on the three sequential stages of Schein's dynamic and cyclical model of planned change; that is, Stage 1: 'Unfreezing' ('unlearning'), Stage 2: 'Changing' and Stage 3: 'Refreezing' (Schein, 1972). In so doing, it is borne in mind that no change will occur unless the participants are operating in a context of 'psychological safety' (Schein, 1972): that is, they feel that it is safe to give up old ways of doing things and to learn something new (Ratcliffe, 2008). Working with innovators in the industry adds credibility to the social system of change. However, for change to be sustained it needs to fit in with the educational culture of each institution so the 'refreezing' will vary and might be done through the creation of sub-cultures within each organization. At each sequential stage of the workshop evolution, the collective reviews systematically the driving and restraining forces. In identifying key barriers to change and what forces are acting on these barriers; be they social, operational, logistical or cultural; a future change programme which overcomes the barriers is created and informs the next workshop in the sequence. The workshop is hosted by each of the three institutions in turn and it is agreed that the hosting nation should decide the theme for each workshop. This is in itself a potential barrier to maintaining the focus of the planned change process.

Action Research Methodology: The Cyclical Process of Development

In researching the future of architectural technology education, the professions concerned must be open to a more informed, structured and imaginative approach (Ratcliffe, 2008). All collaborators in this research have a common belief that the BIM 'revolution' will create a paradigm shift (Kuhn, 1996) in the epistemology of the AT discipline. Thus, arguably, future predictions premised on the dominant tradition in Built Environment research of empiricist and retrospective data collection are flawed. A quantitative analysis methodology creates knowledge about the past whilst one needs to make decisions about the future. Instead, a special approach is required: this series of collaborative workshops is premised on a 'scenario learning' technique, based on a prospective methodological approach (Ratcliffe, 2008). This is action research: the active and interested participation by the researchers in the issue and processes being investigated so that they can identify, appraise and conjecture potential solutions. The proposition here is that the epistemology of architectural technology is of socially constructed knowledge: all seemingly objective conclusions are ultimately founded upon the subjective conditioning/worldview of its researchers and participants. The intention of action research is to effect a change: knowledge gained through reflection-on-action is used to instigate an evolutionary change and also, crucially, to; create knowledge about the process of change, the consequences of this change, and about the nature of the change itself (Fellows & Liu, 2008). Action research is complex and as such is appropriate for the study of collaborative practice in the AECO sector to inform education and practice. The educators are effecting educational change within their institutions and the staff, students and practitioner participants are contributing to industry software development and adoption of 21st century ways of working. The workshop collective is beginning to engage in dissemination and formal research in order to enhance and systematize their reflection-on-action (Denscombe, 2014).

THE WORKSHOP EVOLUTION: PATHWAYS FOR FUTURE LEARNING

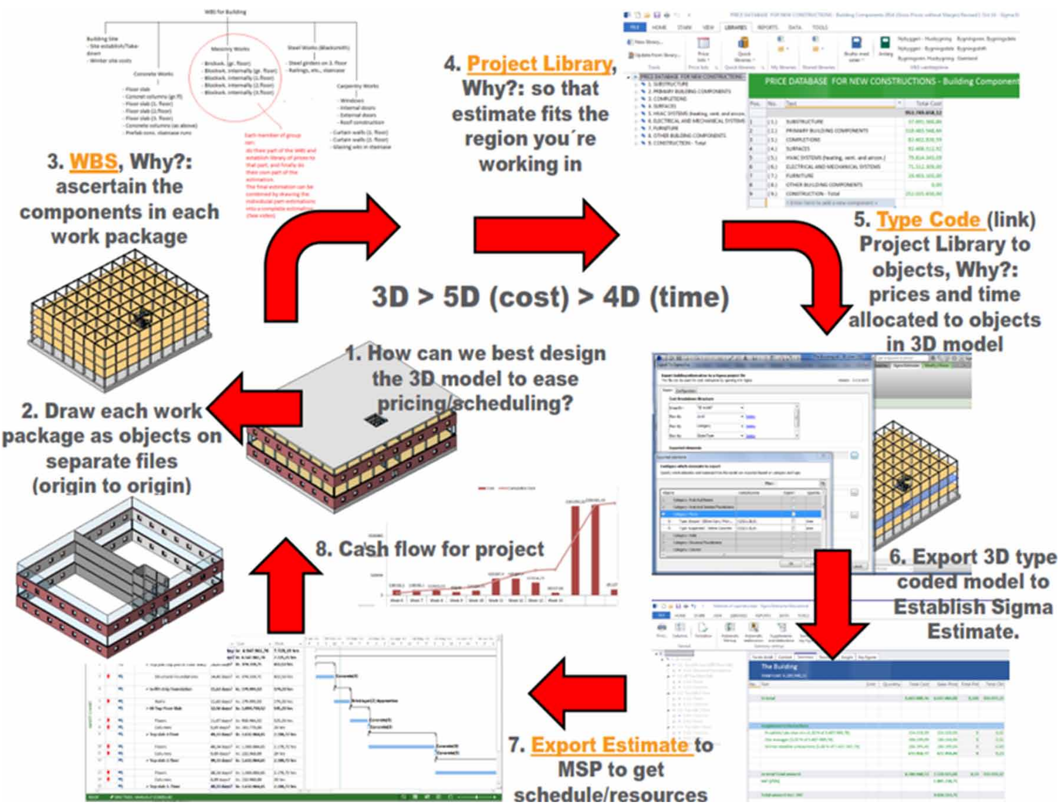
The action research strategy focusses on the authors' research aim: to change to improve the adoption of ICTs in the optimization of collaborative working within inter-disciplinary education and practice in the AECO sector. The strategy is to gain first an understanding of the problems in setting up and using the software and hardware in order to work collaboratively (Workshops 1 and 2). The authors evaluate each workshop through a survey of the student participants to confirm that their knowledge and understanding of BIM software/protocols and inter-disciplinary collaboration has been enhanced. The authors collectively evaluate each workshop during and at the end of each session. The later workshops involve industry collaborators, including Autodesk as providers of the cloud-based, collaborative software. The workshop host uses this evaluation to create the brief for the next workshop. This is then appraised in consultation with multidisciplinary practitioners and software providers as established members of the collective. In addition, as researchers and/or practitioners, the authors investigate separately and collectively their own practice, both in the academic and real-world contexts, with a view to altering these in pursuit of the research aim. In so doing, the authors employ formal and informal research techniques to begin to enhance and systematize that reflection. The following is an outline of each sequential workshop and its reflective evaluation as an action research prelude to the subsequent workshop.

March 2015: Workshop 1 – Geoff Olner, Frances Robertson (SHU)

One of the authors from SHU had visited VIA in order to set up the Erasmus exchange. This relationship was developed in devising the first workshop via email and Skype conversations between all three partner institutions. The workshop took place over two days hosted by SHU, launched with some keynotes speakers from Autodesk and architectural (technology) practice (Figures 1 and 2). Student participants (some after industrial placement) were from two of the tri-varsity collective and from

Figure 1. Workshop 1 poster

Figure 2. Workshop 1 brief



the universities of Derby, Huddersfield and Sheffield. The participants worked on a given simple Revit model and worked in their teams to divide the model into work sets. The author from VIA gave an introduction to the construction management software, Sigma, on the second day. He attended the workshop as a scoping exercise. The workshop did not link to any module but was set up as a symposium for interested educators and students.

Reflection, Appraisal, Proposed Changes

There were varying degrees of success amongst the groups in using both Revit and the costing and programming software. The feedback from student participants, gained via a survey, conveyed that both their knowledge and use of BIModelling/Management software had increased during the workshop. All participants enjoyed the cultural exchange. Educators surmised that the workshop should be longer, more structured and there should be more lectures and tutorial help with the implementation of the software. The collective gained experience related to; teaching collaborative PBL, technical requirements for setting up the hardware and the software for the workshop, simulating cross-disciplinary working, and ideas for creating assessment instruments within modules from the workshop.

October 2015: Workshop 2 – Ernest Müller, Per Christiansen (VIA), Liane Duxbury (SHU)

VIA teaching staff set the assignment for the workshop in collaboration with SHU and WIT. The workshop began with a keynote speaker from an environmental design consultancy outlining a case study. A 3D BIM-model, comprising a column-beam, load-bearing structure and the empty shell of a building was given to the groups. Each group was asked to come-up with an architectural layout proposal for an office building or shopping mall within the confines of the said 3D model. During the workshop, the groups were also required to conduct a Revit day-lighting analysis (Figure 3) of the building (required by SHU), a cost estimate, and the scheduling of the implementation of the project (including the cash flow for costs). Software such as Revit (3D design), Sefaira Architecture and Revit plugin for daylight analysis, Sigma (cost estimation), and MS-Project (scheduling) were used as tools to achieve the desired result. The proposal was delivered as 3D, 4D and 5D. This was a multi-disciplinary task, which required the involvement of several disciplines and, because VIA already used it, PBL was used as the pedagogical method for the workshop. Teaching staff gave introductory lectures in connection with the assignment and an introduction to new software. Educators from academia and practice were on hand during the workshop.

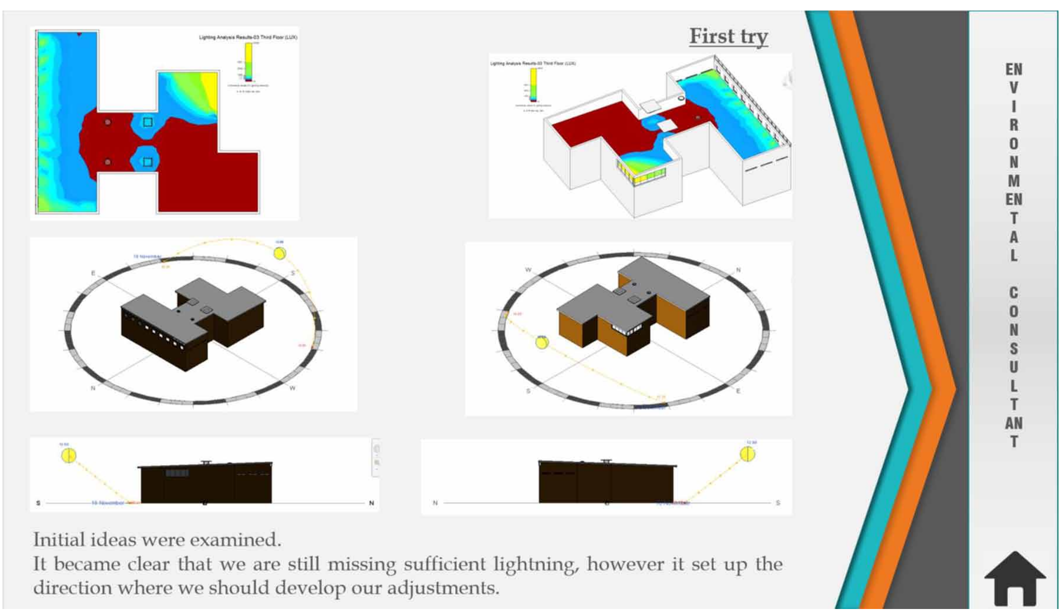
Presentations of group proposals, and how they arrived at them, took place at the end of the three-day workshop, and all group members participated in the presentation. Students were awarded marks as part of their respective modules within each institution for their final presentations.

Reflection, Appraisal, Proposed Changes

An author from SHU had delivered a presentation at the beginning of the workshop on aspects of collaboration in the SHU, AT curriculum. VIA had taken SHU and WIT educators to meet final year ATCM students who had shown them their project portfolios. At the debrief session, the educators agreed that the next workshop should continue to allow this highly valued educational/cultural learning and exchange. The students had experienced the rigours of a Danish education timetable: an early start and long days. The prospect of the incorporation of students from more disciplines was mooted by WIT and welcomed by the collective. The pedagogy at VIA is premised uniquely on group working and the partner institutions felt they could continue to learn a lot from this collaborative educational model.

However, the mixing of students of the two pedagogical methods at the tri-varsity workshop presents challenges in the creation of a new structure for student-based learning. It could be argued that the students from VIA who are used to PBL would find it easier to work in the collaborative workshop

Figure 3. Workshop 2 daylight analysis



environment and get benefit from it than the students from SHU and WIT who were not used to PBL (Godden & Baddeley, 1975). One of the first challenges in ordinary PBL-learning is to establish a common culture, conducive to cooperation between group members (in this case, between specialists and generalists) whilst simultaneously establishing an environment for teaching staff, whose role it is to motivate the learning process, to empower the students, to give direction and, occasionally, answer questions. It is counter-productive if teaching staff revert to teaching in accordance with traditional methods. The PBL environment particularly has pronounced challenges because of the requirement for process skills like project management, communication and collaboration: the cultural diversity in the PBL groups necessitate these skills from both students and educators in addition to developing their technical abilities (Kolmos, Du, Holgaard, & Jensen, 2008). The action research reflection-on-action recognises this acquisition of social and management skills as the potential subject of future systematic and rigorous enquiry.

November 2016: Workshop 3 – Gordon Chisholm, Brian Dempsey, Robin Stubbs (WIT)

WIT hosted the third workshop and invited other WIT, AECO programmes to take part (SEE4 and QS4). This allowed the development of a brief that covered design, structure, solar, energy and wind and cost analysis. The brief was to redevelop Waterford North Quays; recently designated a Strategic Development Zone in January 2016; with eight towers, each approximately 10,000m^2 and a minimum of thirty storeys tall with a 50/50 mix between office and residential accommodation. The BIM collaborative process for WIT AT students built upon the previous academia-industry partnership project, completed in May 2013, in which a commercial project at the tender stage was shadowed by WIT Architectural Technology, Quantity Surveying and Construction Management students, who had then presented to the practice design team. The outcomes from this identified the benefits of real-world, problem solving in the students' education along with enhanced engagement/participation. Although each discipline worked well in their respective areas (silos) collaboration was limited due to the allocated project time on each programme. This project was presented as a paper at the 2013 Construction IT Alliance(CitA) BIM Gathering (Thomas, 2013).

In the BIM Workshop there were eight teams of nine students mixed evenly between HEIs and disciplines. A fundamental element to the established work process was the formation of a ninth team comprising of one person from each team who would develop and coordinate a master plan for the overall site and feed this back to their respective teams. The North Quays Project devisal built upon the earlier feedback and expanded the role of the WIT, Architectural & BIM Technology, Year 3 students. A full module (Architectural Communication & BIM 5) was dedicated to the workshop. In preparation, the students set up and managed a common data environment (CDE) using Autodesk BIM 360, inviting team members to join, developed a BIM execution plan (BEP) including Gantt charts, prepared project Revit files with shared co-ordinates and set up file management and naming conventions as per BS 1192 2007+A2 2016. This all served to break the ice within the student teams as they all contributed and agreed their roles and responsibilities on meeting during the first morning. Prior to this there was a cultural trip in Kilkenny with a keynote talk by an international expert, Chris Bakkala, in tower structural engineering. His presentation was exceptionally informative for the students and staff and informed the basic tower design and analysis, in particular, core design and "hiding from the wind". The key outcome to the prelude was to establish a clear project management structure for the delivery of a coordinated team to design, analyse and cost an (at least) 30-storey mixed-use building as part of the redevelopment of Waterford's North Quay, all with efficient time-management. Throughout the workshop, the students collaborated within their own teams, across teams via the master planning team, and inside their respective disciplines to deliver a complex building design, master planned and costed within effectively a two-day workshop.The energy and enthusiasm that each student, team and HEI has brought to the workshops was again clearly evident in the final presentations (Figures 4-10): the North Quays Project was pivotal in cementing the on-going

Figure 4. Workshop 3 sketch designs

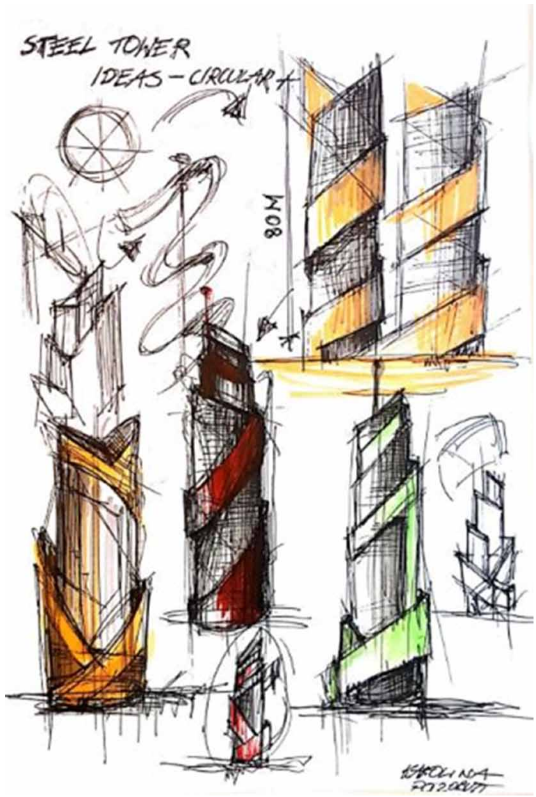


Figure 5. Workshop 3 sketch designs

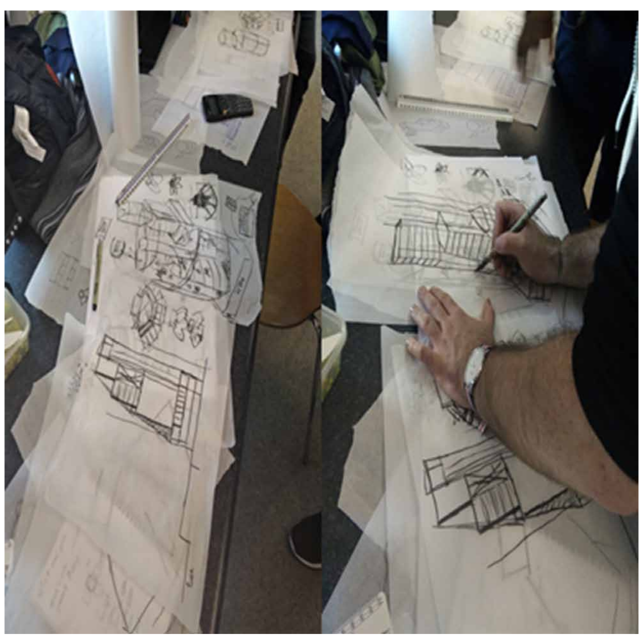
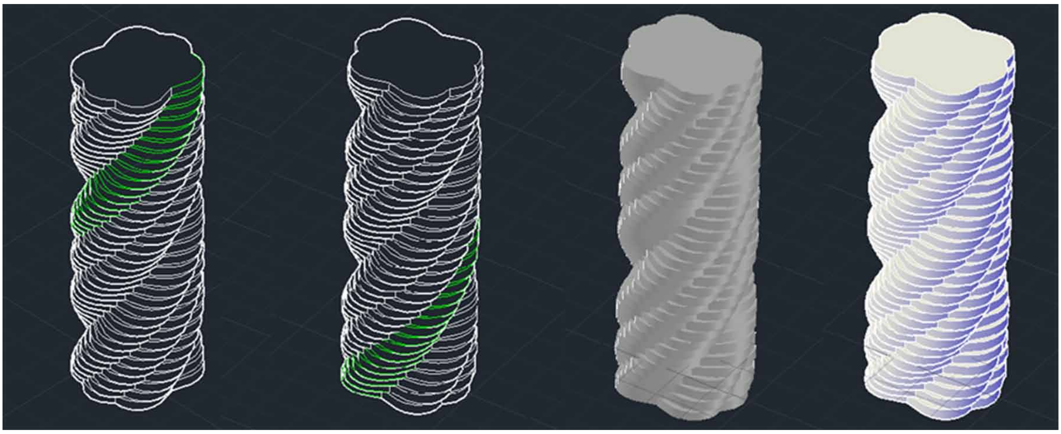


Figure 6. Workshop 3 design development



and evolving collaboration between the three institutions and consolidated embedding BIModelling/ Management within their respective programmes. At SHU, a new Level 6 'Inter-disciplinary Practice' module was devised: reflection-on-learning in the workshop and the psychology of group working are incorporated into the content and assessment of this module. The challenge of this assignment is the stipulation of an individual submission from a collaborative activity. One of the authors was funded through an Erasmus Exchange grant.

Reflection, Appraisal, Proposed Changes

Reflecting on the Waterford workshop proposed that future projects might be set around the delivery of a tall building. This suits all three HEIs as tall building design is not covered anywhere else on their

Figure 7. Workshop 3 wind analysis

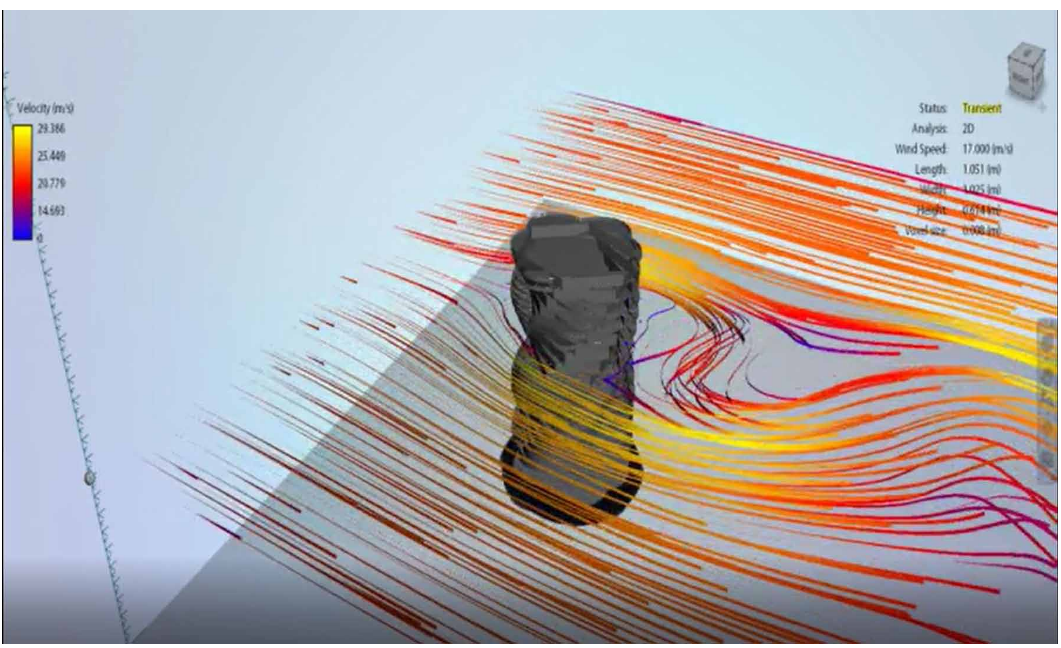


Figure 8. Workshop 3 daylight analysis

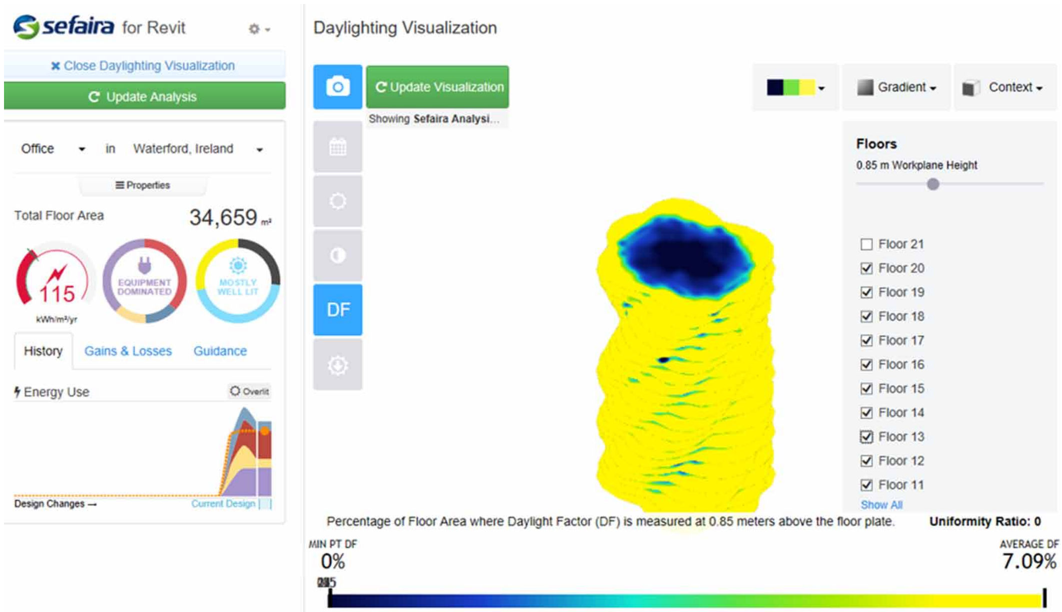
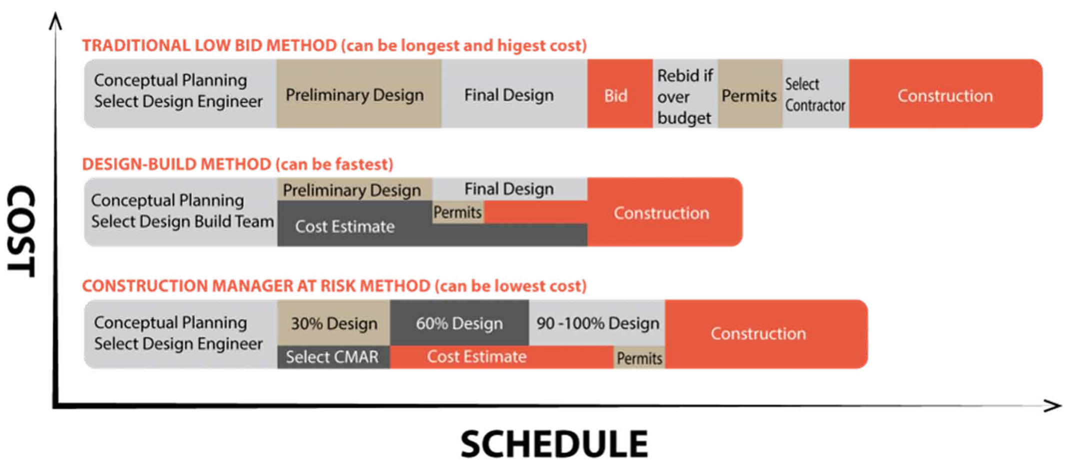


Figure 9. Cost analysis: Procurement



programmes. It was also proposed to maintain the prelude set up and develop real-time collaboration during the workshop. The WIT, SEE and QS programmes will attend future workshops and SHU educators intend inviting other SHU disciplines to take part thus consolidating the *'refreezing'* of the planned change through intra-departmental osmosis of the BIM Workshop collective sub-culture.

However, a challenge arises in connection with extending the groups with new disciplines, from workshop to workshop. As the groups get bigger and bigger (for organisational and logistical reasons), the more unmanageable the group work becomes, and the less and less the disciplines on the periphery of the group feel a part of the social network of the group. Learning is a social and interpersonal process and happens by virtue of relationships within the groups (Pettersen, 2001). Participation, dialogue and reflection are key to the understanding of group life, group processes and

Figure 10. Final renders of group towers

interactions within the group. All members must be engaged, to some extent, in active cooperation to be able to call it a collaborative group. It is about interaction in face-to-face relationships involving close physical and social contact. The idea is that the group must function as a supportive and safe social platform to facilitate the individual´s learning, and this is the catalyst for the individual´s and group´s learning process.

An example with regard to the tri-varsity group work, especially where the “focused method” students are concerned, is that it is difficult for some specialist disciplines (e.g., the Quantity Surveyors) to take ownership of, for example, the architectural proposal and be part of the social fabric of the group, as they might not be active in the initial design process and are usually waiting to participate until the very end of the assignment. However, in some instances QS4 students prepared initial design costings and amended these as the design developed, playing a leading role in the teams. These students had just returned from industrial placement and offered a lot to the groups.

The ideal size for groups in a PBL setting is from three to nine persons (Pettersen, 2001). Because of the many disciplines involved, the BIM Workshop groups are on the verge of the ideal. Student-centered learning emphasizes the hands-on approach to solving the assignment and it is important that the students communicate with one another and the teachers (Kolmos et al., 2008). It is also difficult to determine students´ participation level in large groups, and ways must be found to engage everyone in the group in discussions on all issues. The question, therefore, for the planning of future workshops is whether the students from the specialist pedagogical educational model should be expected to participate and take ownership of the whole project. A discussion of this leads to the question of whether the the ontology of the architectural technolgist is as a specialist or a generalist, or a mix (and in what proportions) of both. This presents new research opportunities into the collaborative education of mixed-pedagogical method groups, and into the disciplinary identity and education of the architectural technologist in the digitalization of the AECO sector.

November 2017 Workshop 4 – Frances Robertson, Geoff Olner (SHU), Tiberius Gruia, Lee Mullin, Philipp Müeller (Autodesk)

The fourth workshop in November 2017, hosted by SHU, aimed to enable integration between student, educator and practice participants. The theme was a fictitious redevelopment of an existing disused tower block in Sheffield. In devising the workshop, one of the authors from SHU created a simultaneous parallel workshop for industry disciplinary professionals from architectural, structural and building services specialisations. Thus, it was anticipated, extending the workshop to practitoner participants and creating opportunities to learn from industry professionals, extending the action research collective. Contacts made through a local BIM collective, ‘Steel City BIM’, were consulted on the scope and relevance of the workshop for local small to medium enterprise practitoners. Sheffield Innovation Project (SIP) funding was secured for the venture and included an industry networking dinner at the end of the workshop to promote and celebrate the collective effort, allowing the scoping of future interested parties to join the collective. Two of the authors were funded through an Erasmus Exchange grant.

This workshop built on an existing incorporation of the products and services offered by Autodesk in their AECO portfolio of solutions. Specifically, through collaboration between the educators and Autodesk, the workshop was developed to introduce the students (and practitioner participants) to the benefits of collaborating in the 'cloud' using Autodesk Revit, A360 Collaboration for Revit, A360 Team and A360 Glue. Through Autodesk, the licenses for the software were arranged well in advance of the workshop starting, enabling the students to communicate and form their groups remotely in the weeks prior to to coming together physically during the three-day workshop. The WIT students created a BIM Execution Plan (BEP) for all groups to follow. The student and practice participants were required to create an architectural 3D model from a given 3D structural model. They were then given a schematic 3D MEP model on the second day of the workshop and used clash detection software to identify and design out the unacceptable clashes collaboratively, between their created disciplinary groups within their project teams. The final group presentations, including the practitioner groups, were less focused on the quality of the design but more on; the process of the creation of the groups, reflection on efficiencies of working, and the intricacies of information creation, flow and management during the clash detection and resolution process between the disciplinary representatives.

Reflection, Appraisal, Proposed Changes

In devising the workshop for industry participants, it was realised that this introduced a significant challenge to create an exercise that was relevant to commercial practice. In many ways this was similar to the challenge of understanding the differences between the learning of the students from mixed-method pedagogical educational models: socially constructed knowledge is believed to dependent on the context of the creation of that knowledge and is, therefore, subjective. Research within academia can produce unfathomable, self-referential, findings irrelevant to practice; research into practice can be an unchallenging reaffirmation of the status quo, often driven by commercial interests and stifling to academia. The practitioners would need a workshop which is commercially relevant to justify the time taken out of the office to participate. The cloud-enabled collaboration did, however, cater for remote participation.

Related to this, there was a negative reaction to participation from architectural practices that use different 3D modelling software: the concomitant barriers to information exchange across platforms has, antithetically, inhibited their inclusion in the workshop exercise. Resolving this is an on-going task and another potential focus of the research-informed evolution of the tri-varisty and industry collaboration. Positively, the involvement of practitioners and educators in symbiotic knowledge-creation is being used to inform practice through education and vice versa. In disseminating this research as part of an on-going process, the authors are aiming to contribute to the application of theory into practice for the AT professionals of the future. The analysis of qualitative data via a survey of all participants is a possible method for translating the workshop findings into an action plan to feedback the research directly into practice.

CONCLUSION

The ultimate collective goal is to align AT education to practice. Student feedback confirms that they gained more experience and understanding of how ICTs can optimize and connect teams working across disciplines. The fourth workshop allows a focused simulation of using clash detection software, building on the earlier introduction to BIM workflows. Student reflection attests that this has several benefits but they criticize the communicator in the software, preferring face-to-face communication where possible but a more immediate simulation of this when working remotely. The relevance of the workshop is guaranteed through the involvement of change agents and role models from software companies and practice, some of whom are current students or alumni. The members of the tri-varsity collective believe the inter-disciplinary collaboration between their courses is being enhanced, opting to continue to develop the tri-varsity workshop. However, within their organizations there is still work to be done to find opportunities for intra-departmental educational collaboration. Future workshops need to be carefully devised along a strategic line of development which following previous success; perhaps, continuing to focus on the intricacies of information management within the use of ICTs in the AECO sector. In conclusion, Table 1 identifies and summarizes the implementation and findings of the action research strategy in each sequential workshop.

Action research by definition does not reach a conclusion per se: it is not an end in itself but an on-going means to discovering and revealing new research questions. In this particular instance, the change agent collective is growing and affirming the adoption of the simulation of collaborative practice using ICTs in AT education and practice through dissemination of their findings. They are searching for evidence to reinforce that professional architectural technologists are ideally placed to take on emerging roles associated with BIM adoption in the industry. This will necessitate an appraisal of the acquisition of social and technical skills in the application of collaborative ICTs. The collective have presented their work-in-progress at the Construction IT Alliance (CitA) conference in Dublin, in November 2017. They applied to present at Autodesk University in London in June 2018. The potential for related and tangential research to the BIM workshop has been alluded to in the preceding discussion. Through engaging in normative research projects, which the wider subject

Table 1. Summary of each workshop

Workshop	Reason for Workshop	Workshop Methodology	Workshop Focus	Main Workshop Findings	Impact on Change
1 (Mar. 2015)	• Scoping exercise • BIM Symposium	• Survey participants • Participatory action research	• Keynotes on collaborative BIM software development applied to practice • ICT inter-disciplinary workflows using Revit, Sigma and MS Project	• Students learned about digital tools to enable collaborative working • Educators informed about logistics and hardware requirements • Consolidation of BIM collective	• Aim to integrate workshop into curriculum • Prelude to next workshop
2 (Oct. 2015)	• Collaborative digital design, analysis and delivery; 3D, 4D & 5D	• Survey participants • Participatory action research	• Keynote on sustainable design analysis (SDA); workshop experience of SDA at concept design phase • ICT inter-disciplinary workflows using Revit, Revit Daylight, Sefaira, Sigma and MS Project	• Students learned about digital tools to enable collaborative working and design analysis • Educators informed about logistics and hardware requirements • Challenges of PBL and group learning in the curriculum	• Prelude to next workshop; confident to seek to include more intra-departmental disciplines • Workshop being incorporated into the curriculum
3 (Nov. 2016)	• Collaborative digital design, solar, wind, energy and cost analysis	• Survey participants • Participatory action research	• Collaborative tower design after keynote from international expert • Students from QS, SEE, ATCM &AT	• Creation of CDE using ABIM 360, production of BEP, file management and naming conventions as per BS1192 2007 & A2 2016	• Workshop predicated on industry-academia research project • Aim to focus on information management
4 (Nov. 2017)	• Collaborative digital design, and clash detection and resolution	• Survey participants • Participatory action research	• Cloud-enabled collaboration; architectural, structural and MEP • Parallel workshop for practitioners	• Focus on information management and industry standard protocols • Real-time model synchronization	• Real opportunity to extend the workshop integration with practice

community can understand, the creation of a successful systematic change programme in collaborative working can be evaluated. There has been tentative achievement of the collective aim as reflection on its own is not enough in action research (Denscombe, 2014). Importantly, through future systematic and rigorous research projects, alluded to within this paper, the collective may add to the resources which can be used to achieve improvement in academic and professional practice.

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REFERENCES

Barrow, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer.

Boud, D., & Brew, A. (2013). Reconceptualising academic work as professional practice: Implications for academic development. *The International Journal for Academic Development*, *18*(3), 208–221. doi:10.1080/1360144X.2012.671771

Brew, A. (1988). Research as learning.

Brew, A., & Boud, D. (1995). Teaching and research: Establishing the vital link with learning. *Higher Education*, *29*(3), 261–273. doi:10.1007/BF01384493

Ceranic, B. (2013). Sustainable design analysis and BIM integration. In S. Emmitt (Ed.), *Architectural technology research and practice* (pp. 89–120). John Wiley & Sons Ltd. doi:10.1002/9781118292365.ch3

Confederation of British Industry (CBI). (2012). Boosting employability skills. Retrieved from http://www.cbi.org.uk/business-issues/education-and-skills/in-focus/employability/

Denscombe, M. (2014). The good research guide for small scale research projects (Fifth edition. ed.) Open University Press.

Department for Business. Innovation and Skills. (2013). Construction 2025: Industrial strategy for construction - government and industry in partnership. ().HM Government.

Dreyfus, H. L. (1992). *What computers still can't do: A critique of artificial reason*. Cambridge, Massachusetts: The MIT Press.

Egan, J. (1998). *Rethinking construction*. London: Department of the Environment, Transport and the Regions.

Emmitt, S. (1999). *Architectural management in practice: A competitive approach*. Harlow: Longman.

Emmitt, S. (2002). *Architectural technology*. Oxford: Blackwell Science.

Emmitt, S. (2010). *Managing inter-disciplinary projects: A primer for architecture, engineering, and construction*. London: Spon. doi:10.4324/9780203885338

Emmitt, S., & Ruikar, K. (2013). *Collaborative design management*. London: Routledge. doi:10.4324/9780203819128

Ernest, P. (1991). The philosophy of mathematics education Falmer Press.

Fellows, R., & Liu, A. (2008). Research methods for construction (3rd ed. ed.). Chichester; Oxford: Wiley-Blackwell.

Godden, D., & Baddeley, A. D. (1975). Context-dependent memory in two natural environments: On land and under water. *British Journal of Psychology*.

Harty, J. (2012). The impact of digitalisation on the management role of architectural technology [PhD thesis].

Helyer, R., & Lee, D. (2014). The role of work experience in the future employability of higher education graduates. *Higher Education Quarterly*, *68*(3), 348–372. doi:10.1111/hequ.12055

Kolmos, A., Du, X., Holgaard, J. E., & Jensen, L. P. (2008). *Facilitation in a PBL environment*. Aalborg Universitet.

Kuhn, T. S. (1996). The structure of scientific revolutions vol. (3rd ed.) The University of Chicago Press. doi:10.7208/chicago/9780226458106.001.0001

Latham, M. (1994). *Constructing the team*. London: HMSO.

NBS. (2014). *NBS national BIM report*. RIBA Enterprises.

Penn, A. (2008). Chapter 2 - architectural research. In A. Knight, & L. Ruddock (Eds.), Advanced research methods in the built environment (1st ed., pp. 14-27) Wiley-Blackwell.

Pettersen, R. C. (2001). *Problembaseret laering PBL, for elever, studerende og laerere*. Oslo: Universitetsforlaget.

QAA. (2014). *Subject benchmark statement: Architectural technology*. Gloucester: The Quality Assurance Agency for Higher Education.

Quality and Qualifications Ireland (QQI). (2016). Awards standards architectural technology. Retrieved from http://www.qqi.ie/Publications/Publications/Architectural%20Technology%20Awards%20Standards.pdf#search=architectural%20technology%2A

Ratcliffe, J. (2008). Built environment futures research: The need for foresight and scenario learning. In A. Knight & L. Ruddock (Eds.), *Advanced research methods in the built environment* (1st ed., pp. 216–229). Wiley-Blackwell.

Schein, E. H. (1972). *Professional education: Some new directions*. New York: McGraw Hill.

Schön, D. A. (1983). The reflective practitioner: How professionals think in action BasicBooks.

Society of Architectural and Associated Technicians. (1984). *Architectural technology: The constructive link*. London: SAAT.

Thomas, K. (2013). (2013). Collaborative BIM learning via an academia-industry partnership. Paper presented at the *Construction IT Alliance BIM Gathering,* Dublin.

Tuckman, B. W. (1994). *Conducting educational research* (5th ed.).

Wittgenstein, L. (1968). *Philosophical investigations*. Blackwell.

Frances Robertson (ARB, MCIAT, Passivhaus Certified Designer (PHI)) qualified as a registered architect in 1990 having worked in large and small practices in London. She graduated from Strathclyde University in 1984 with a BSc (Hons) in Architecture: a course rooted in building science and cutting-edge CAD. She studied for her Diploma in Architecture at PCL (now the University of Westminster) and has a passion for architectural technology (AT). In 2001, she joined Sheffield Hallam University as an Associate Lecturer, becoming a full-time Senior Lecturer and the course leader of the BSc (Hons) AT degree in 2006. Her job focuses on ensuring the AT student is provided with a challenging curriculum and prepared for eventual MCIAT status. She became a professional Architectural Technologist (MCIAT) in 2015. She is currently studying for a PhD at the University of Bath; "The Future Practice of Architectural Technology: Informing Practice and Education"; under the supervision of Professor Stephen Emmitt. She has been an external examiner for Architectural Technology HEIs in the UK and Ireland.

Ernest Müller, MSc., is a Senior Lecturer at VIA University College in the Architectural Technology & Construction Management/Bygningskonstruktøruddannelsen Course (Profession Bachelor). Other teaching tasks include various management courses in network colleges in Europe, e.g., the University of Cantabria, Santander, Spain (Master in European Construction Engineering), and MSc for Northumbria University, UK. Also, she has taught short management courses at the Architectural School at Riga International School of Economics and Business Administration (RISEBA), Latvia. He has extensive experience with teaching management courses on a regular basis (1-2 times/year) at Tianjin Chengjian University, in Tianjin, and at the University of Chengdu, and Sichuan University (Architectural Faculty), Chengdu in China. These courses are design and project management courses, with special emphasis on the use of the BIM models for cost calculation and scheduling (3D,4D and 5D). He is one of the pioneers in establishing international educational programmes for 'Constructing Architects' at VIA University College.

Gordon Chisholm, Registered Architect, Technologist & Certified Passive House Designer is a principal member of the team that are integrating BIM within The School of Engineering at Waterford Institute of Technology. Key to this is, the ongoing industry-academia links fostered via The BIM Collective Research Group Est. 2013, who have developed BIM related projects with over 80 companies. Gordon has 25+ years' architectural experience in low energy design of domestic & commercial projects in Ireland and internationally as well as a leading role over the last 13 years teaching & developing the BSc (Hons) Architectural & BIM Technology programme in the Dept. of Architecture.

Geoff Olner is sole principal of Architectural Images, an independent Computer Aided Design Building Information Modelling consultancy service. The office specialises in bringing the benefits of CAD/BIM to Architectural Practice using a wide spectrum of tools and media. Architectural Images goal is to maximise the benefits of using technology and software as part of the design process. To provide methods of visualising and 'testing' the design during development and also communicating design ideas to other interested parties. Founded in 1994, Architectural Images was set up out of a desire to explore the full potential of computing in the architectural process. As a qualified architect, Geoff was well positioned to understand where computers can offer significant benefits, giving designers the opportunity to explore architectural vision, increased productivity/flexibility during drawing production whilst addressing interoperability between the design team, client and external consultants. Teaching and training other construction professionals has become part of the Architectural Images philosophy. As MSc Technical Architecture Course Leader and Senior Lecturer in Architectural Computer Aided Design and Building Information Modelling at Sheffield Hallam University Geoff has had the opportunity to develop CAD/BIM design development strategies that can be transferred from academia into professional practice.

Liane Sharon Duxbury is a Senior Lecturer in Architecture and Environmental Design in the Department of the Natural and Built Environment. Prior to joining Sheffield Hallam University, she held the position of Head of Domestic Technical Team at Stroma Certification, managing three strands of energy and sustainability assessment: Domestic Energy Assessment (DEA) On-construction Domestic Energy Assessment (SAP) and Code for Sustainable Homes. (CSH). During this time she was an influential member of the Communities and Local Government (CLG) advisory groups for SAP, Part L and the Code for Sustainable Homes acting as member of an expert group drawn from government, academics and certification providers to advise the UK Government on issues relating to the review and development of conventions within UK building regulations, in order to standardise the assessment process and align with the requirements of Part L and the transition towards the UK Governments zero carbon ambition.