Computer Mediated Construction

Name: Ronan Gallagher

Student No.: D14124405

Module: Computer Mediated Construction

Lecturer: Asst. Prof. Matevž Dolenc, University of Ljubljana

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Abstract

The aim of this project is to investigate ways in which proficiency and knowledge in Information and Computer Technology (ICT) can be sustained after the initial training has been delivered. Building Information Modelling (BIM) software is an example of one such development in ICT that staff in the Department of Civil Engineering, the author's place of work, have recently been trained in. Building Information Modelling has of late received widespread acclaim and prominence in the built environment. As result, it inevitably is making its way onto curricula in both undergraduate and postgraduate architecture, engineering and construction (AEC) related courses.

One of the main motivating factors for investigating ways of maintaining and growing knowledge in concepts such as BIM is that every year a large knowledge base leaves the Department in the form of graduates. The graduates inevitably take with them a rich resource of tacit and explicit knowledge that will inevitably have to be re-learned by the next groups of advancing students. Learning new software can be daunting and extremely frustrating. Therefore, before the students graduate, it would be ideal if their experience and know-how could be garnered and digitally recorded in order to save subsequent students many hours of potential hardship. This scenario is not unique to academia. It also happens in the private sector when someone retires or leaves the organisation to develop their career.

Usally training is delivered to staff when a new technology is introduced or when major changes appear in software upgrades. The delivery of the training is usually provided by a certified third party provider for a limited period. The arrival and delivery of training is usually received with much anticipation which can subside quickly when the stark realisation of teaching commitments and research develops. Consequently, one of the most difficult aspects of staff training in new software and/or ICT is staff willingness to take on board what is essentially extra work.

This project sets out to explore the possibility of developing a knowledge community within the Institute among the staff and students of the Department of Civil Engineering. This knowledge community could take a blended approach in the form of a virtual presence and a social element in the form of regular face-to-face meetings. It is proposed that the knowledge community evolves and grows slowly, starting out with ad-hoc collaboration in the form of casual conversations, then moving on to a more structured setting in virtual space. It is proposed that the knowledge community take an open approach and allow all willing participants to join and contribute. Depending on participation, the concept could be rolled out to other areas.

The knowledge community will take time to construct and mature and it would provide information for staff that have let their initial training lapse and for students learning the software and concepts for the first time. The virtual environment would hold the bulk of the information, whilst the face-to-face meetings would allow the application of such knowledge. The computing environment will remain on the periphery to the development of the knowledge community. It will provide an asynchronous learning environment that will purely facilitate information exchanges. The virtual learning environment will also suit different learning styles – such as learning by doing, seeing and hearing.

1. ICT in the Construction Sector

1.1 General

The global Architecture, Engineering and Construction (AEC) sector along with Facilities Management (FM) have embraced ICT in the form of Building Information Modelling (BIM). Unlike the development of CAD, BIM is an influential market driver and not just a 'sustaining technology' (Forfás, 2013). According to the head of Wimpey construction, John Hollingworth, 'the construction industry is much a manager of information as it is of materials", (Sun and Howard, 2004). This fact is supported by the number of BIM articles being published in peer reviewed journals along with the increase in number of international events such as Autodesk University and Revit Technology Conferences. Pike Research (2012) predict the global Building Information Modelling market to be worth $6.5 billion by 2020. According to the Irish building Magazine (2014), BIM is gathering momentum in Ireland and they carried a multi-page article entitled "An Education in BIM" in their September 2014 publication which details all the providers of BIM related training in the Republic of Ireland.

Given the widespread adoption of BIM by the AEC industry it is paramount that educational institutes weave BIM into their syllabi and produce graduates that are essentially road ready. According to Horne and Thompson (2008) technology is having more influence on education today than it has ever done. There is little point in producing graduates trained in the use of two-dimensional draughting software whilst the construction section has moved on to intelligent fully three-dimensional building information models. In the author's opinion, remaining stationary translates to being left behind. However, therein lies the difficultly insofar as it is increasingly difficult to keep abreast of ICT and BIM developments and the speed of development shows no signs of abating (Klinc *et al.*, 2009).

The construction industry is very fragmented as is illustrated in Figure 1. A large percentage of firms have less than ten employees. As a result, there are a lot of specialist sub-contractors to communicate with in a typical project.

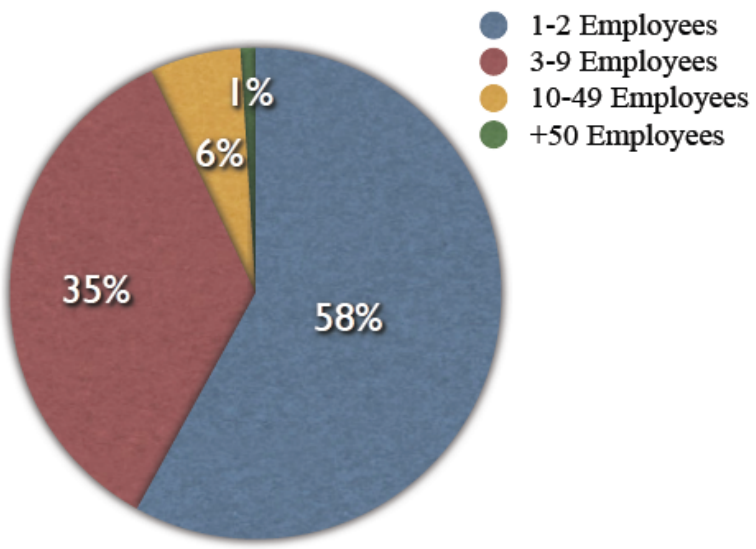

Figure 1: Breakdown of European construction firms (Dolenc, 2013)

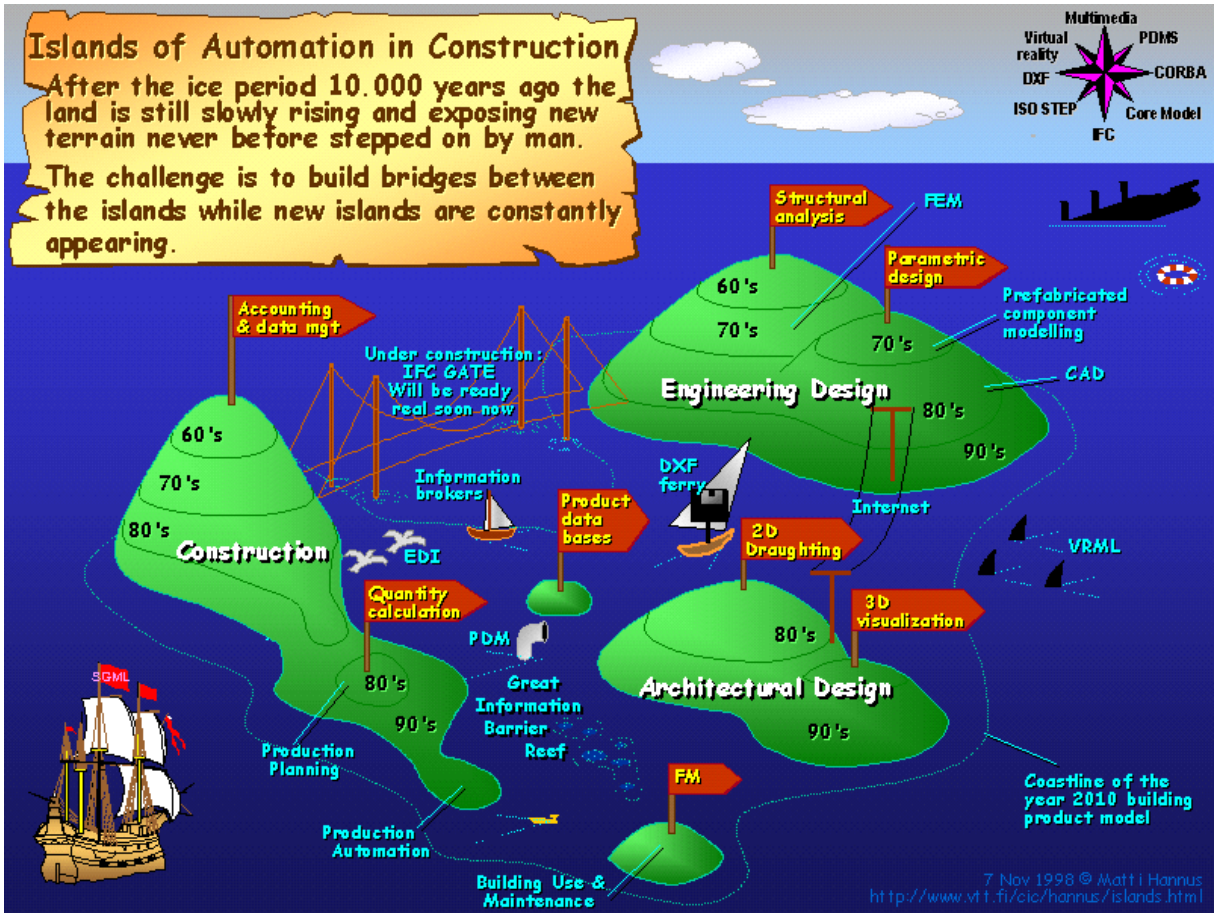

Figure 2: Islands of automation (Hannus, 1998)

This fragmentation of the construction industry is perhaps best illustrated by the 'islands of automation' concept by Seren and Hannus which was first published in 1987 and is shown in Figure 2 (Hannus, 1998). Each firm is only interested in improving its own productivity and this is one of the reasons why current IT applications are directed at a single activity (Sun and Howard, 2004). The Construction Industry Computing Association (CICA) software directory lists over 1650 programs from over 500 software developers for use in the design, construction and facility management of buildings (Sun and Howard, 2004). In general, large organisations tend to invest more resources in ICT that their smaller peers. However, there is a prevailing attitude towards IT within the construction industry to wait and see, until others have tried and tested it (Sun and Howard, 2004).

In the author's opinion, a typical Department in a third level education institute could also be illustrated using the 'islands of automation' concept. Each staff member being fully consumed with their own duties, interests and activities and only cooperating with other parties when necessary. Staff are really independent operators working on a discrete element of the overall product, that being the production and development of a graduate in a particular discipline.

1.2 Rationale and Objectives

As outlined earlier the main objective of this concept behind this project is to consolidate and grow the understanding of BIM concepts and software knowledge within the Department. A large knowledge base leaves the Institute on an annual basis and number of staff within the Department have let the initial training they received lapse. This project explores the possibility and options available to create a knowledge repository and community within the Department to make it easier to learn and/or relearn BIM related material. The knowledge repository will permit and encourage knowledge transfer and the easy retrieval of information.

All of the information contained in the repository will be sanctioned by a moderator. In the author's opinion, it is extremely important that the BIM repository only contains succinct and filtered information. The idea being that only a small (one or two) number of suggestions will be returned for each search. This is in contrast to general internet browser searches. For example, searching how to 'create a wall' in Revit will yield many thousands of results, as shown in Figure 3. Refining the search parameters could substantially reduce the number of answers offered, but it would be so much better if someone learning Revit could begin their search in a repository where the content has already been vetted and the material and terminology is appropriate for beginners.

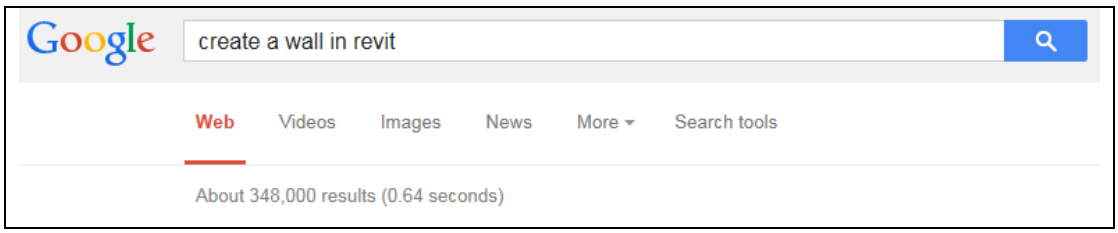

Figure 3: Internet search results for Revit wall creation

1.3 Potential Problems

As already mentioned, the construction of a knowledge repository and community is proposed to bolster efforts to become proficient with Building Information Modelling concepts and processes. There a number of potential problems that may hinder the development of the repository. These include the fact that BIM is rapidly developing and it will be difficult to keep up-to-date with any advances. Managing the knowledge and filtering the information within the repository will be very onerous and time consuming. Finally and perhaps the greatest problem that may be encountered is the willingness of staff and students to use and contribute to the repository. The academic year in the Institute comprises two thirteen week semesters. Therefore, there may be a general reluctance to contribute to the collaborative digital environment because of demands from other modules within a relatively short semester.

1.4 Educators Role

Succar (2009) lists educational institutions among the key players in what the author refers to as the "BIM policy field" and that they play a pivotal preparatory role in the design, construction and operation process. A summary matrix of BIM framework deliverables relating to educational institutes and industry, ranging from macroscopic to microscopic is shown in Figure 4.

Deliverables	Macroscopic: industry level	Mesoscopic: project level	Microscopic organisation level
	Multiple disciplines	Multiple organisations	Individuals and teams
Educational deliverables	Generating BIM Literacy Guidelines, producing learning tools and collating case studies — through publication of a BIM textbook	Identifying BIM Educational Deliverables according to organisational types and delivery modes — example: identifying vocational, tertiary, industry and industry associations' BIM educational deliverables	Classifying and embedding BIM Educational Deliverables into different curricula and the generation of BIM educational tools — example: developing course outlines and learning plans for an undergraduate course
Industry deliverables	Setting an industry-centric BIM Knowledge Store catering for organisations and individuals — through the publication of industry papers and setting up a BIM-focused wiki and a weblog	Generating BIM Implementation Guidelines in modular format detailing BIM Maturity Steps within and across industry disciplines — examples: BIM leadership, risk management and HR development modules	Generating a BIM Implementation Handbook in modular format including implementation templates and change tools — example: a BIM Skill/ Knowledge Competency Matrix for staff or a BIM Software Selection Matrix

Figure 4: Summary matrix of BIM deliverables (Succar, 2009)

In the author's opinion, educators have a critical role in addressing the skills gap between education and industry. Educators have to prepare graduates for future

job opportunities that have not been defined yet in a rapidly changing AEC industry. Some of the essential skills required for future graduates are shown in Figure 5. As can be seen in Figure 5, overarching all of the personal development skills for learners is the need for technical and ICT skills.

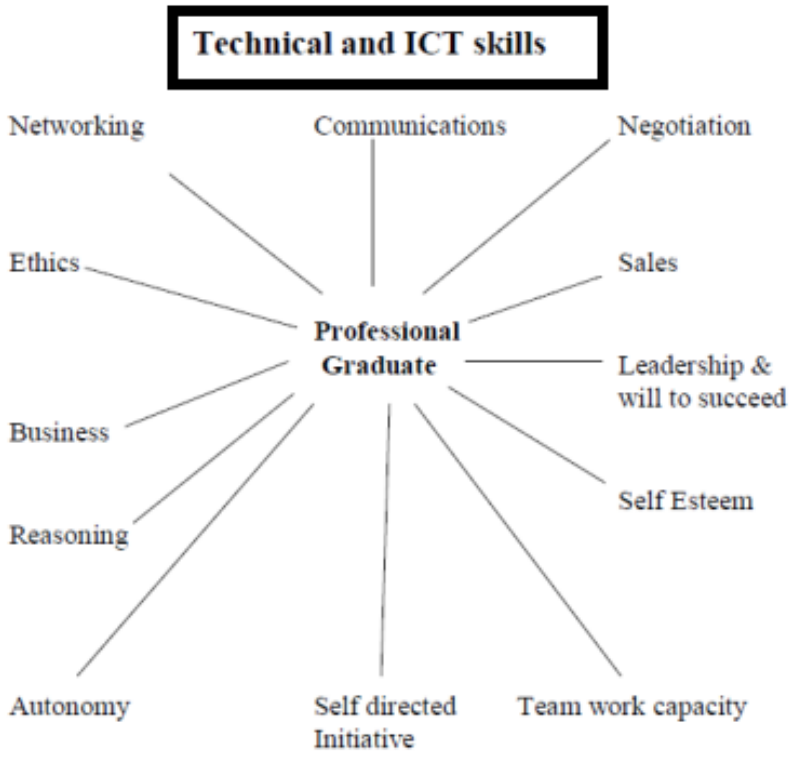

Figure 5: Personal development skills for learners (McGarthy and Kennedy, 2013)

Building Information Modelling is a classic disruption technology and is affecting the entire AEC industry and facilities management (FM) industries (Tobin, 2012). The onset of BIM is forcing many seasoned AEC professionals to adapt and retrain. As a result, there has been a surge in the number of mature students re-entering third level education institutes.

> "The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn and relearn"
>
> Alvin Toffler

According to McGarthy and Kennedy (2013), the skills of critical thinking, self-directed learning, interpersonal ability, self -awareness and self-confidence are skills that help inspire and sustain life-long learning. These skills will be needed and honed in a flipped classroom scenario where the focus is student centred learning, such as that proposed in the knowledge repository. These skills are resources that the student will fall back on again and again throughout a lifetime of challenge and ongoing personal and professional development (McGarthy and Kennedy, 2013). Murphy and Scott (2009) and Mathews (2013) highlight the higher degree of importance on what students know, understand, and can do as a result of their educational experiences. Skills such as those outlined already are critical in forming AEC knowledge workers of the future. Using web 2.0 ideology, Klinc *et al.* (2009) state that a typical AEC knowledge worker of the future will operate and control their own blog, social bookmarking site, intranet tags and wiki entries. A knowledge worker such as this will be very motivated and will become key member of their own company being viewed as an expert in their field by their peers.

1.5 BIM Implementation

According to a survey carried out by the Society of Chartered Surveyors of Ireland (2014), many countries have been quick to embrace BIM with varying degrees of success and others are posturing until such time as the performance of the package can be accurately measured. From January 1st 2016, the UK is following in the footsteps of Finland, Denmark, Norway, US by mandating the use of BIM in public contracts (Forfás, 2013). The implementation of BIM in relation to contractors is highlighted in a worldwide survey of construction firms carried out by McGraw Hill Construction (2014). All of the 727 contractors surveyed reported a positive return of investment in relation to BIM, as can be seen in Figure 6.

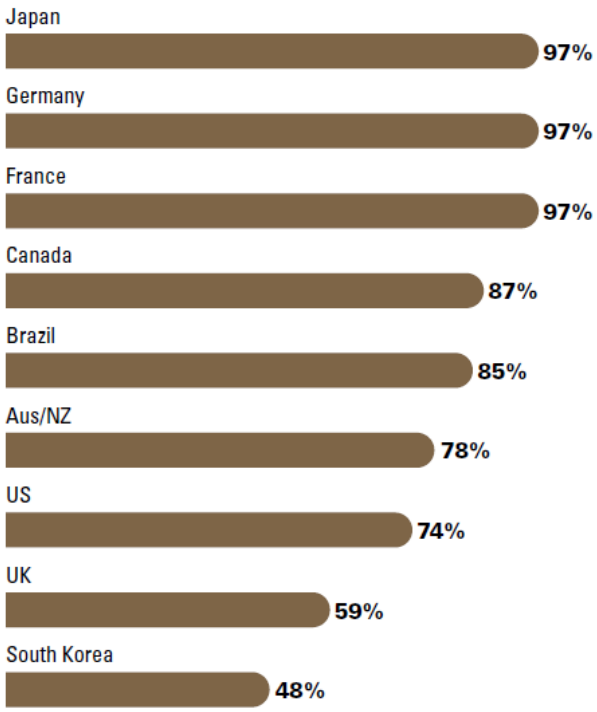

Figure 6: Contractors return on investment for BIM (McGraw Hill Construction, 2014)

In 2011, the Royal Institute of Architects of Ireland (RIAI) in conjunction the Construction and Information technology Alliance (CITA) performed an analysis of the penetration of BIM in the construction sector in Ireland. The results of the survey can be seen in Figure 7. The BIM adoption for Ireland is quite low, but it has grown substantially since the survey was carried out in 2011.

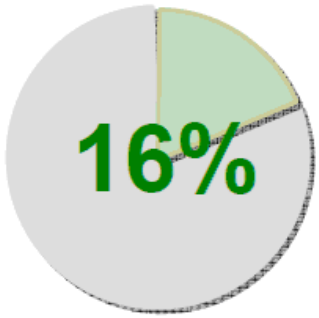

Figure 7: BIM adoption survey in Ireland (CITA, 2013)

1.5.1 UK Response

In 2011, the UK Government in prepared a white paper that called for the mandatory inclusion of fully collaborative 3D BIM in all public contracts with a value greater than £5 million stg. The deadline for the introduction BIM was set as January 1st 2016. This instrument has had a massive knock on affect and has given engineering and architecture firms the impetus to up-skill and re-train. In a global context, the UK is joining a growing number of countries that stipulate the mandatory use of public procurement contracts. Norway, Denmark, Finland and the US were among the first countries to introduce BIM for public contracts (Forfás, 2013). Following on from their mandate to include BIM in public procurements, the UK Government has highlighted the importance of Building Information Modelling in education by creating a BIM Academic Forum (BAF) (BIM Academic Forum, 2013). The BAF was formed in 2011 and has over 55 members from 30 teaching centres across the UK and includes representation from the Republic of Ireland (BIM Academic Forum, 2013). The representatives from the UK include a large number of universities and the representatives from Ireland are Dublin Institute of Technology and Galway Mayo Institute of Technology. Interestingly, none of the Irish universities are represented on the forum.

According to their literature, the vision of the BAF is to 'to foster integrated collaborative working on projects over the lifecycle of the asset through academic involvement and enhancement of BIM' (BIM Academic Forum, 2013). The purpose of the BAF is to propose a roadmap of incorporating BIM in discipline specific undergraduate and postgraduate education. As part of their endeavours, they have produced a BIM teaching impact matrix to assist in embedding the BIM into the curriculum. The BIM Academic Forum BIM teaching matrix is shown in Figure 8. The BAF stresses that each Higher Education Institute will need to consider its own approach and the BIM teaching impact matrix is to be used as an aid to determining the optimum requirements.

	BIM Level:			
	Absent	**Aware**	**Infused**	**Embedded**
BIM descriptor	BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.	BIM is a nice research area but should not affect how we teach. Our students should be aware of BIM and how it might impact their future.	Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.	BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should enabled by the BIM model.
Curriculum	No change	Key modules are identified and BIM knowledge incorporated.	Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.	Full curriculum review to allow every module to identify changes required for delivery through a BIM model.
Structure	No change	No change	Structural review needed but impact on current structure likely to be minimal.	A complete review of structure to enable the BIM model to be the driver/vehicle for learning.
Staff	No change	Staff in the key modules will need an understanding of BIM and how it impacts of industry.	All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.	All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.
Infrastructure	No change	No change	Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.	Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.
Curriculum - Research gap	Can be large	No change	Has to be small in some areas but with some flexibility.	Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/delivery.

Figure 8: BIM teaching impact matrix (Williams and Lees (2009) as cited in BIM Academic Forum, 2013)

1.5.2 Irish Response

The Irish Government has not yet set out their position on the mandatory inclusion of BIM in either public contracts or indeed education. It would be natural to presume that this is only a matter of time and one could expect that the Irish Government will follow the lead of the UK Government in this regard. The Society of Chartered Surveyors state "it is vitally important that we learn from other countries of the errors or shortcomings that have been experienced in the implementation of BIM" (SCSI, 2014). If the Irish government followed the UK and mandated BIM for public contracts, then there would be no alternative and a BIM model would become just another part of the process that must be complied, just like design standards. In the UK, the main driver for BIM implementation is value for money and in lean economic times one would expect that the Irish government would recognise the potential of BIM for cost savings (Irish Building Magazine, 2014).

The principal advocacy group for BIM in Ireland is the Construction Information Technology Alliance (CITA) (CITA, 2013). CITA have a number of regional BIM hubs located throughout the country as shown in Figure 9. CITA acts as a conduit for local engagement in national discussions and it provides linkage with regional representative groups such the Society of Chartered Surveyors of Ireland, Royal Institute of Architects of Ireland, Engineers Ireland, Chartered Institute of Building and the Association of Consulting Engineers of Ireland (CITA, 2013). The position of CITA and all the relevant stakeholders within the AEC landscape of Ireland is shown graphically in Figure 10. As can be seen from the figure, CITA have a central role to play in the implementation of information and communication technology in the construction sector in Ireland.

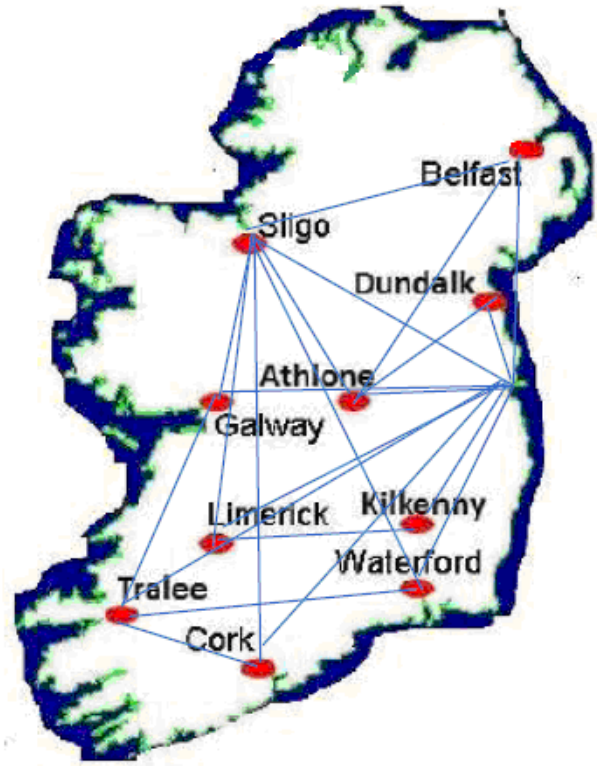

Figure 9: BIM regional hubs (CITA, 2013)

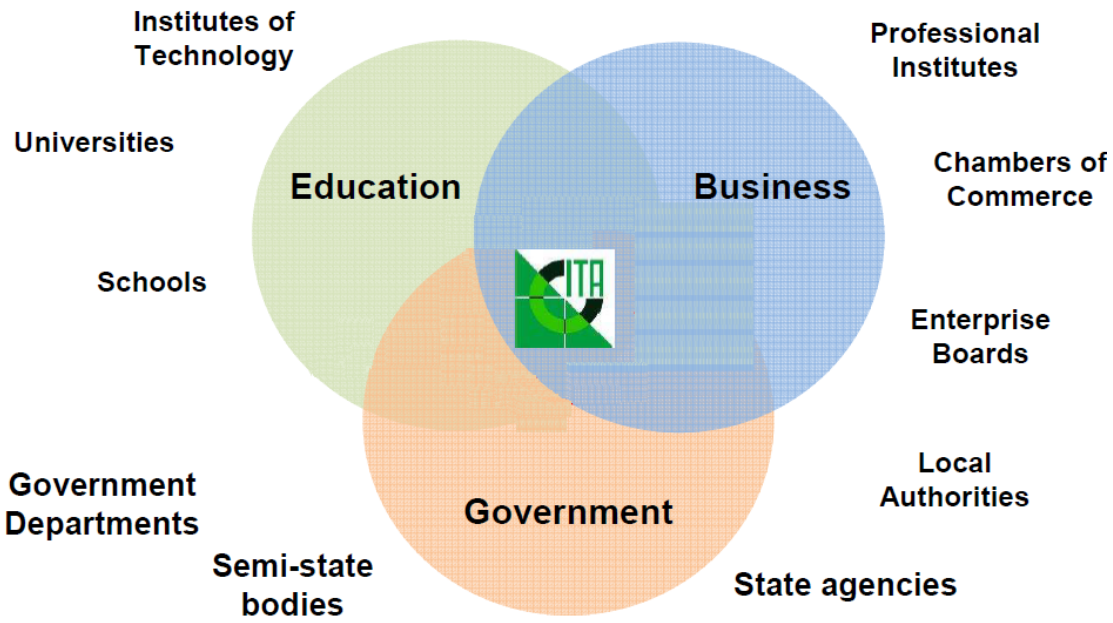

Figure 10: CITA's role in the Irish AEC industry (CITA, 2013)

1.6 Where does BIM belong?

The question may be asked, 'where exactly does BIM belong?', In undergraduate education, post graduate education or solely in professional practice? The education sector is quite unique in that it is sheltered from the onerous work schedules and deadlines for large construction products as experienced by practising professionals on a daily basis. Furthermore, a lot of lecturers have held their position since before the widespread application of BIM, therefore, a lot of them may not be fully aware of the intricacies and processes involved with BIM as they have not encountered it on a 'live' project. As a result, there is potential for BIM guidelines and protocols to be interpreted incorrectly.

Despite this however, Arnett (2012) and Andersson (2013) argue unequivocally that BIM concepts and processes firmly belong in undergraduate education. In their view, BIM has to be embedded across whole courses. Arnett (2012) states that a high percentage of civil engineering graduates do not progress past their primary undergraduate or bachelor degree. Therefore, if BIM was only to be delivered in post graduate curricula then a large percentage of the AEC workforce would not be familiar with the processes when they enter the working environment. This scenario is changing in Ireland as Engineers Ireland have recently mandated that masters degree is now required for progression to chartered status (Engineers Ireland, 2012)

2. Literature Review

2.1 General

It is important to note that computers cannot improve the knowledge acquisition and that learning is an active process and has to be done by the learners themselves (Ebner *et al.*, 2006). There are many acronyms and phrases that essentially label computer assisted leaning. Some of these labels include learning network, domain oriented design environments, virtual learning environment, collaborative digital environment and information technology based design and construction integration (ITDCI). According to Mokbel (2009) an ITDCI is a collaborative knowledge-based activity in which each participant continuously contributes and shares their knowledge to realize a specific goal. Furthermore, these contributions are bonded by a unified and cohesive culture with the use of the supportive IT-tools (Mokbel, 2009). In a knowledge network such as the one proposed, members are capable of being both learners and teachers and it is hoped to emulate some of the more well know knowledge repositories such as; MERLOT, the Penn State BIM wiki and the Open IFC Model repository.

<u>MERLOT Open Education Resource</u>

MERLOT is an example of a very well-known open education resource (OER) and stands for Multimedia Education Resource for Learning and Online Teaching (Merlot, 2014). It carries information on a range of subjects from Arts, Business, Education, Mathematics and social sciences (Merlot, 2014).

<u>Penn State BIM wiki</u>

The Pennsylvania State BIM wiki carries information on all things BIM related including software, protocols, workflows, 3D modelling and student projects.

<u>Open IFC Model Repository</u>

The Open Industry Foundation Class repository is maintained by the University of Auckland and contains information on open industry foundation class files structure and exchange (University of auckland, 2012). It also contains a portfolio of sample IFC models that are free to download.

2.2 E-learning 2.0

The internet is currently undergoing regeneration and its second phase has been termed Web 2.0 (Dolenc, 2013). The internet and its capabilities have been transformed during this regeneration from web 1.0 to web 2.0 and with it a host of new tools have emerged, as shown in Figure 11.

Web 1.0 →	Web 2.0
Read only	Read/Write/Collaborate
Web as reading platform	Web as publishing platform
Developer authorship	Public authorship
Individual intelligence	Collective intelligence
Software applications	Web as software platform
Commercial/proprietary	Open source/shared
Static	Dynamic
Impersonal	It knows you & your needs
Restricted collaboration	Collaborative
Short tail	Long tail
Official releases	Constantly versioning
Text-based	Multimodal
HD as storage platform	Web as storage platform
Lecture	Conversation

Figure 11: Web transition (Weisberger and Butler, 2011)

The advent of new tools has shocked traditional eLearning, according to Ebner *et al*. (2007). They suggest that the arrival of tools such as Blogs, Wikis, Podcasts and RSS will be the future of learning. In a study carried out by Vasiu and Andone (2011) students used blogs, wikis and other open source tools as part of their academic assessments with positive results. Many of the students in the study believed that integrating some web 2.0 technologies in the academic activities facilitated innovative explorations, experimentation and profound thinking and analysis from students (Vasiu and Andone, 2011). According to Sun and Howard (2004), previous revolutions such as the industrial revolution have taken a long time, to spread out from their original sources, but the 'Information Society' emerged all around the world and within a single generation. A typical personal learning network of a modern day knowledge worker is shown in Figure 12. As stated already, an employee like this will be highly motivated, well connected and will be viewed as an expert in their field by their peers. In summary, leveraging web 2.0 tools for educational purposes offers great potential and perhaps greater challenges (Berger and Krousgrill, 2010). A survey by Cosgrave *et al*. (2011) shows there is an increasing trend of VLE use in higher education in Ireland.

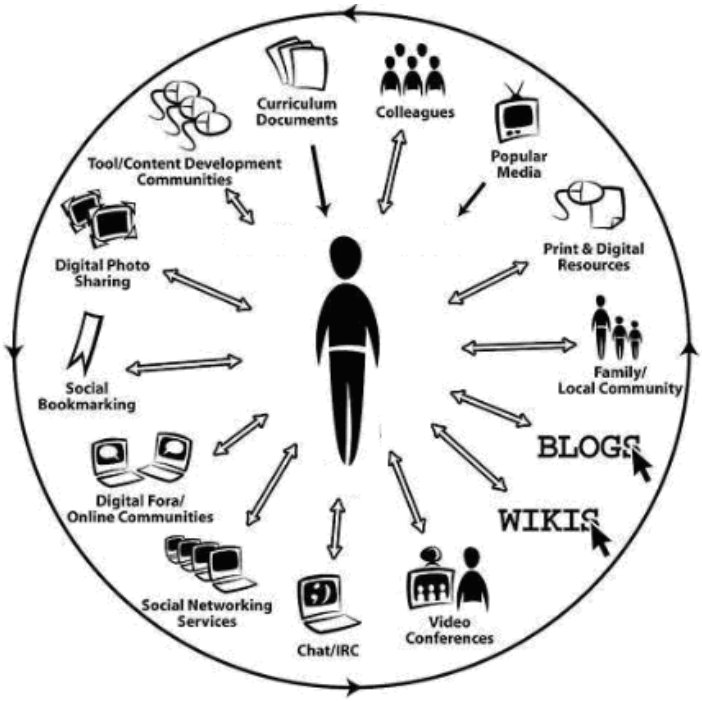

Figure 12: Personal learning network (Bray, 2013)

2.3 BIM Pedagogy

According to Meadati and Irizarry (2010) and Arnett (2012), BIM is an excellent learning and teaching tool. Its accessibility and visualization are the key characteristics that help BIM to serve as a better learning and teaching tool. Arnett (2012) argues that undergraduate curricula should be built around BIM and that all modules should be delivered with a BIM ethos. According to Meadati and Irizarry (2010) the development of a BIM knowledge repository should include 3D modelling along with any necessary additional information, such as structural design. This concept is shown in Figure 13.

Figure 13: BIM knowledge repository development methodology (Meadati and Irizarry, 2010)

Students have very different learning styles. In the Department of Civil Engineering in the author's place of work there are a very high percentage of mature students. These mature students typically come from a building trade background such as carpentry, plumbing and electrical. Based on their learning style, students can be identified as auditory, visual, and kinesthetic learners. Auditory, visual, and kinesthetic learners learn through hearing, seeing, and doing respectively (Meadati and Irizarry, 2010). Arnett (2012) states that the inclusion of BIM at undergraduate level education provides further benefits, when considered with respect to learning theories. BIM software produces excellent quality 3D graphical representation for problems which in turn can be used to assist learners in developing visualisation skills.

2.4 Knowledge and Knowledge Management

There are two forms of knowledge, tacit and explicit. According to Sun and Howard (2004), explicit knowledge can be captured and stored and can be used with out reference to others. Tacit knowledge is the cumulative store of experiences, mental maps, insights, acumen, expertise know-how, trade secrets, skill sets, understanding and learning that an organisation has (Sun and Howard, 2004). Tacit knowledge is unarticulated and relates to the senses, intuition or implicit rules of thumb (Nonaka and von Krogh, 2009).

Tacit knowledge is fundamental to the creation or organisational knowledge such as the proposed BIM knowledge repository. Organizational knowledge creation is the process of crystallizing, making available and amplifying knowledge created by individuals to an organization's knowledge system (Sun and Howard, 2004). Knowledge management is critical to the success of the proposed knowledge repository. The tacit knowledge held by the staff members within the Department should be the scaffold for the BIM champion to contextualise their experiences and transform their tacit understanding and experience of BIM into learning objects on the BIM knowledge repository. In order for the tacit knowledge to be crystallised it will have to be transformed into explicit knowledge.

The concept of knowledge conversion explains how tacit and explicit knowledge interact along a continuum (Nonaka and von Krogh, 2009). The process involved in the conversion of knowledge is shown in Figure 14.

		To	
		Tacit	**Explicit**
From	**Tacit**	Socialisation	Externalisation
	Explicit	Internalisation	Combination

Figure 14: Knowledge conversion process (Sun and Howard, 2004)

The knowledge conversion processes outlined in Figure 14 are crucial to the success of the proposed BIM knowledge repository. For example, from Figure 14, in order for tacit knowledge to be converted to explicit knowledge it must externalised in the form of a report, blog or drawing. This explicit knowledge will then be stored and made available to all of the repository members.

As stated earlier, knowledge management will prove to be crucial to the success of the Department's knowledge repository. Knowledge management is relatively new to the construction industry and it indicates recognition of the intellectual property rights of an organisation (Sun and Howard, 2004). The strategy used to crystallise the tacit knowledge held by individuals will be critical. In the case study carried out by Arayici *et al.* (2012) at an architectural practice in Liverpool, the knowledge management strategy involved actively managing knowledge in the firm. In the case study, employees of the architectural practice strove to explicitly encode their knowledge into a shared knowledge repository and retrieved knowledge needed, which was lodged in the repository by others. It was found that merging the architectural practice databases into an integrated knowledge base helped support the competitive intelligence and organisational memory of the firm (Arayici *et al.,* 2012). According to Fischer and Scharf (1998) knowledge management and knowledge conversion is a very delicate operation. It can be to

be very difficult to de-contextualize and re-contextualize knowledge because if the chunk is too big it won't be view or used and if it's too small then it will not really be a reusable learning object on its own.

2.5 Professional Bodies

The education sector is rather unique insofar as, higher education institutes in Ireland seeking accreditation for their courses do so in a five year cycle. As yet, professional bodies such as the Society of Chartered Surveyors (SCS), Engineers Ireland (EI), Chartered Institute of Building (CIOB) or the Royal Institute of Architects of Ireland (RIAI) have not mandated the inclusion of BIM in undergraduate courses that have been presented to them for review. If this outlook were to change, then 3rd level educational institutes would have to include BIM and develop their competence in this area. There are principally two ways in which the author envisages this could happen. Firstly the inclusion of BIM in all public works could be mandated by EU member states or it could come as a directive from the European parliament. Secondly, professional engineering bodies internationally could mandate BIM in courses seeking their accreditation. This in turn, would put pressure on professional bodies, such as EI, CIOB, RIAI and the SCS to pursue a similar agenda from the courses under their remit. This would come about as a result of international agreements such as the Sydney and Washington Accords which are international agreements on educational qualifications. They essentially are international passports for graduates of accredited courses to travel and work internationally. A summary of the international education qualification agreements is included in Appendix A (Engineers Ireland, 2014).

3. Building Information Modelling Knowledge Repository

3.1 Proposed Solution

It is proposed to build a BIM knowledge repository for all staff and students in the Department of Civil Engineering. It is possible to build a learning object repository from scratch by using standard metadata such as IEE or Dublin Core (Fischer and Scharf, 1998). However, it is intended to keep the proposed solution as simple as possible by using the Institute's virtual learning environment (VLE), Blackboard, as the portal to contain the proposed Building Information Modelling knowledge repository. There are a number of reasons for choosing to use the Blackboard environment, these include;

1. it is a simple solution
2. all staff and students are familiar with Blackboard as it is used across all the existing modules
3. the repository will be held solely for the staff and students of the Institute
4. the repository will be accessible to staff and students both on and off campus.

The idea of a private space on the Institutes Blackboard virtual learning environment is allow all levels of queries and questions. There are a lot of tools and resources already in existence concerning BIM and in the author's opinion, therein lays the problem. There is an information overload when it comes to carrying out a simple search on the internet, as illustrated earlier. Furthermore, the number of hits increases even more when the search query is difficult to express and perhaps the searcher doesn't know exactly what they should be looking for. In online moderated fora, in the event that a question is judged to be unsuitable, it can be down voted and potentially closed or deleted. This is will not occur in the proposed fora. The proposed BIM knowledge repository will be controlled by a moderator and will depend on the participation and contribution of its members. A schematic of a typical knowledge community is outlined in Figure 14. As can be seen in the figure, the ethos central to a successful knowledge community is that everyone thrives when the knowledge community thrives.

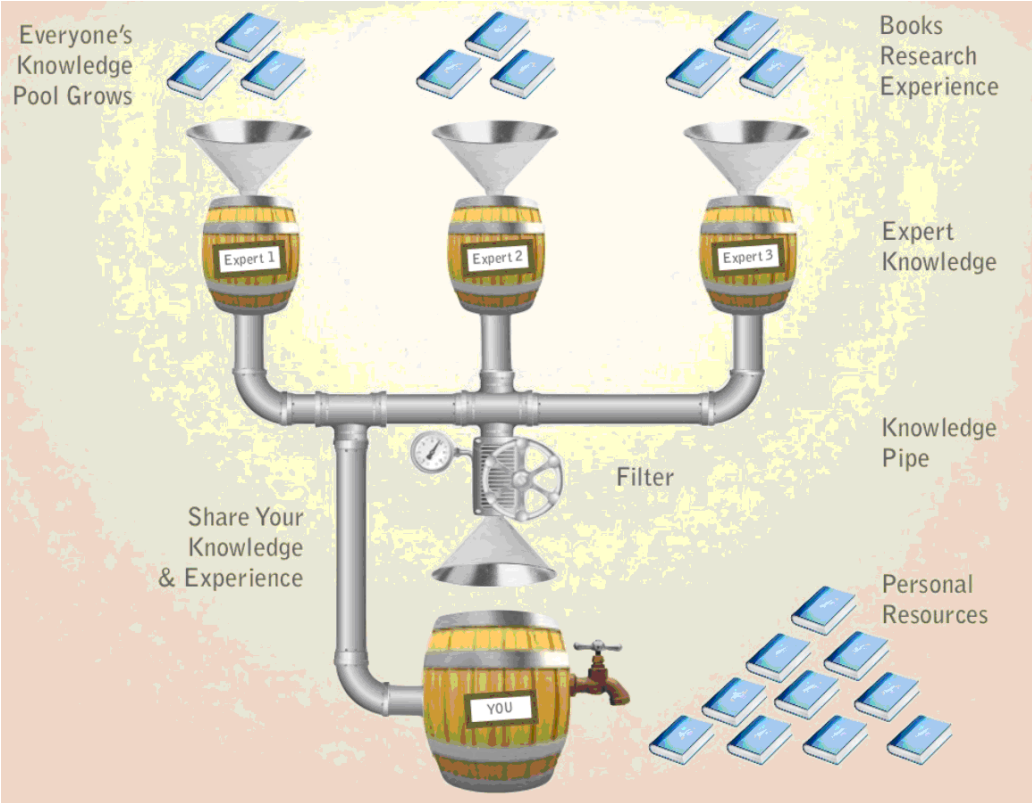

Figure 14: Knowledge community (Weisberger and Butler, 2011)

Ebner *et al*. (2006) sates that although learning is an active cognitive process on the part of the learner, it is also a social process and develops through conversation. Therefore, based on the assumption that interaction, participation and communication are crucial elements for viable learning communities a learning environment has to enforce the possibility of community building.

People generally do not like filling in surveys never mind repositories. According to Fischer and Scharf (1998) the only way to get people to fill in repositories is either is either pay someone or force everyone. The first option is not available for obvious reasons therefore the BIM knowledge community will have to flourish on people's goodwill and operate on the philosophy of 'give a penny, take a penny'. That is, to encourage all members to contribute in some way to the repository when they get some value out of it.

3.2 Blackboard Environment and Tools

A typical layout of the Blackboard environment is shown in Figure 15. The figure also highlights some of the in-house Blackboard tools that will be used in the repository. These include Announcements, Blogs, Discussion Board, Glossary and Wikis.

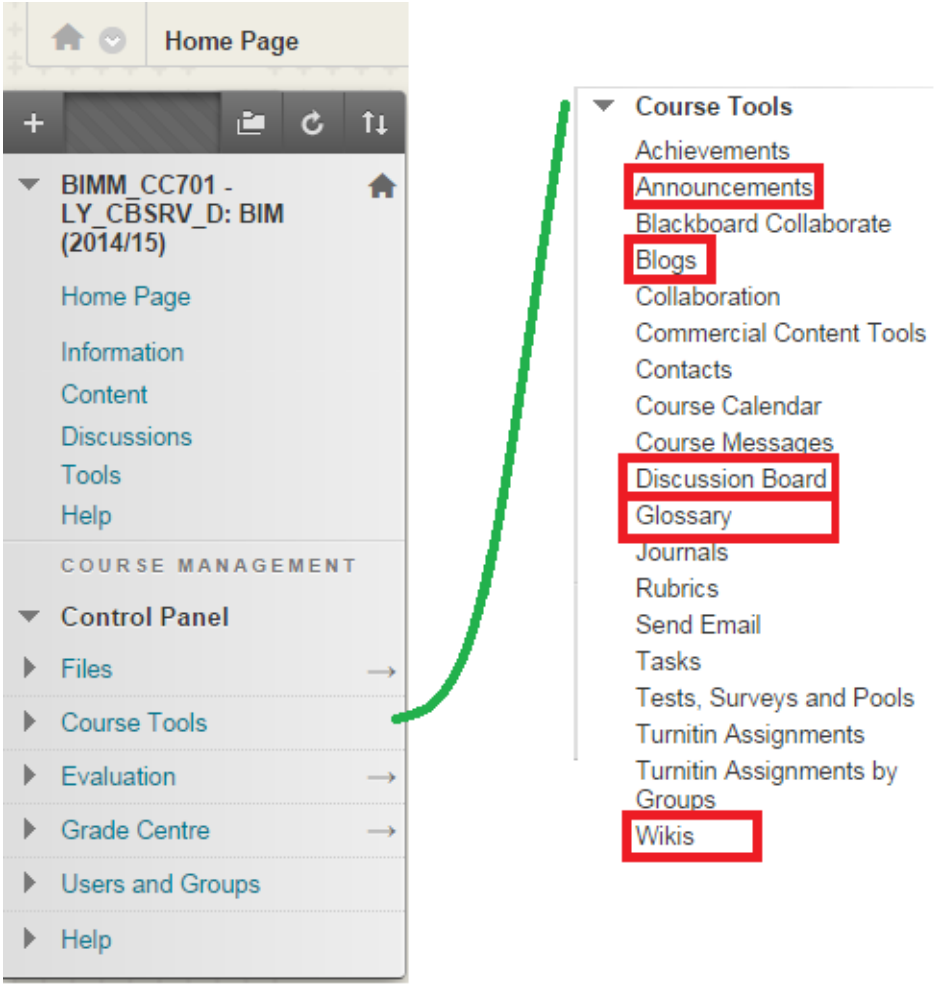

Figure 15: Proposed Blackboard virtual learning environment

The announcements tool will be used to notify the community members of any updates to the knowledge bank. The moderator of the VLE will be encouraged to create and maintain a blog discussing the various BIM related issues in the Department. The discussion board will be used by members to ask and respond to queries. The glossary tool will be used to catalogue and explain BIM terms and processes. The wiki will be used by all members in much the way as the Penn State wiki outlined earlier. All members will be encouraged to use and contribute to the repository via the wiki.

3.3 External Tools

The college's Blackboard subscription is limited; therefore some use will be made of externally provided web 2.0 tools, such as RSS and video websites such as Youtube and Vimeo. These tools will be linked and embedded within the content of the knowledge repository.

RSS stands for Really Simple Syndication and is provided by some websites to allow users to their website or blog more easily. Instead of bookmarking webpages and returning intermittently to check for updates, web reader services, such as 'feedy.com' allows the user to tag various websites and blogs they are following. The reader automatically notifies the user of any updates on the bookmarked sites. This means that user saves an awful lot of time surfing various websites to check for updates/new material. Youtube and Vimeo are very well established learning object repositories in their own right. Extensive use will also be made of these websites. Appendix C contains a brief list of internet based digital resources for BIM related material that will be followed in the BIM knowledge repository. Due to the high cost of training and conference fees all information, contacts and papers made during a conference attendance will be disseminated and made available to all members electronically.

3.4 Opportunity

A wide range of courses are delivered in the Department of Civil Engineering at the author's places of work. These include Quantity Surveying, Building Services Engineering, Fire Safety Engineering, Architectural Technology and Civil Engineering with the majority of them lasting three years. Almost every profession that would be involved in a building design is present the institute. Therefore, in the author's opinion there is a unique opportunity in-house for full multi-disciplinary collaboration. The students have the opportunity to use the many software packages within the Department, as listed in Appendix C, to build a collaborative federated model.

5. Execution Plan

4.1 General

This execution plan was formed based on discussions held with the author's peers within the Department of Civil Engineering. The idea of having a BIM knowledge repository was received with approval by all. The concept behind creating a knowledge bank or learning repository within the college Blackboard environment is to make it accessible to staff and students of the institute both on and off campus. There a number of things that can be done both in the Department and externally with society at large.

From an in-house view point, there are two key elements that must first be implemented in order for the knowledge bank to be successful. These initiatives include 'going digital' and embedding BIM within the curricula. In the first instance, students should be made submit all assignments and project work in hard and soft copy via Blackboard. Currently, students submit their efforts in either hard or soft copy. This initiative will entrench the Blackboard VLE in the student's everyday work. Secondly, all of the module curricula should be re-written around a central BIM tenet and use could be made of the BIM Academic Forum BIM teaching impact matrix (see Figure 8). Undergraduate courses and their curricula are periodically reviewed and updated. The next scheduled Programmatic Review is in the 2015-16 academic year.

From an external view point the Department could entertain and liaise with industry, former students, external examiners and professional bodies. All graduates could also be allowed guest membership of the BIM portal and they could give back something to their alma mater other than financial donations. External examiners could be chosen to review academic standards as well as inviting them to collaborate with the delivery of some of the modules, such as capstone projects. Professional bodies could be invited to give guest lectures to illustrate the role of BIM in the workplace. The Department has already recruited the expertise of an experienced Architectural Technologist

4.2 Implementation Road Map

The plan is to keep it simple at the start and to slowly gather momentum so that no one gets overwhelmed with information overload. In essence the information needs to be gathered and filtered properly. Listed below is a set of steps that the proposed BIM repository should follow;

1. As already stated, all continuous assessments and projects should be submitted both in hard copy format and electronically though Blackboard. Hence, after a period, submissions could be accepted only in electronic format. This will help to reduce printing costs and will appeal to all.
2. All projects, at least capstone projects initially, could be set as multi-disciplinary to foster collaboration between the different courses.
3. Students could be required in the course of a project, say, to document their learning process and detail 'what they learnt'. These learning journeys could take the form of a blog on the virtual learning environment.
4. At the next Programmatic Review in the 2015-16 academic year all courses could be re-written to include central BIM scaffold running through each semester from which all modules will be supported.
5. The Department has procured the services of an experienced Architectural Technologist who has operated as the BIM manager for a large London based construction firm. This person delivers a weekly four hour block of a Revit class to a group comprising part-time students and staff. Each commences with brief preamble to some BIM related topic, such as BIM protocols. The training has been received very well and it is expected that the training will continue into next semester as it gains momentum. The preamble to each class could be recorded and posted on the VLE.
6. Staff in the Department could be encouraged to gain competencies in BIM by completing accredited courses.
7. Members of the repository will be encouraged to meet face to face in a casual setting and perhaps deliver short presentations on their work.
8. The Department could seek to become a member of the BIM Academic Forum or a CITA hub.

4.3 Pros

There are many benefits that would arise from establishing and maintaining an internal bespoke knowledge repository. Some of these benefits will include;

- The graduates would be sought after as they would be ready to join the workforce and would not require any BIM specific training
- The graduates would be ready for work in a new technological construction landscape.
- Keep abreast of developments and emerging trends and software.
- It would be beneficial for any member of staff wishing to further their career in the private sector.
- It would be beneficial for anyone presenting themselves for chartership with a professional body such as Engineers Ireland, Society of Chartered Surveyors of Ireland or the Chartered Institute of Building Services Engineers.
- The social or face to face aspect will enable members to ask questions that may be difficult to articulate and are intimidated by the vastness of information available. This would help grow a community environment within the Department.

4.4 Cons

In tandem with the benefits outlined above there are also a number of concerns with the development of a knowledge repository for BIM related material. Some of these potential difficulties include;

- Perhaps the biggest problem that will be encountered will be staff willingness. The majority of staff within the department has no time and little or no incentive to devote time to the creation of a VLE. The question must be asked why would someone contribute to the knowledge repository? Revit learners have the propensity to stumble from one problem to another. They typically do not dwell on the solution for too long, they move on and they inevitably encounter another modelling issue at the next stage. If a

Revit learner were to dwell on a solution to a particular issue and document it in such a way that it could be followed by others, then completing course work would take much longer. Parallels may be drawn with those who answer queries on internet fora. If one were to devote a large amount of their working day to for a queries then their productivity would suffer. Some people answer online queries to be helpful and nice with the understanding being that they were once at the beginner's stage also, whilst other post answers to show off their superior knowledge.

- If students are presenting work in digital format, then this would lead to further difficulties. For example, there may be an additional tendency to plagiarise material from the internet by students. To resolve this, the students could be taught how to cite properly and they could be required to submit their work through anti-plagiarism software before they submit it.
- It will be difficult to maintain momentum and to constantly update the repository.
- It will be difficult to abreast of all emerging technologies and developments, particularly with normal course work to complete.
- There needs to be an appetite to assimilate new information and for immersing oneself in new technology.
- It may be difficult to find a volunteer willing to undertake the role of BIM champion and moderator of the portal. This role will undoubtedly be unpaid and will not command any benefits as there are simply no resources to finance it.
- Multi-disciplinary projects may be difficult to administer. For example, a particular group of students, for example, Quantity Surveying would have to wait and rely on the Architectural Technicians to produce the building model, meaning that their work would suffer. The reliance on other groups from other disciplines could be overcome by mixing the students fin each group. However, from experience, not all students in a group assignment will produce the same level of work.
- The educational sector is an artificial environment and it may be difficult to mimic a real life multi disciplinary construction project in relatively short thirteen week semesters in three year course programmes.

- The digital repository may appear intimidating.
- BIM can be very confusing. There is a lack of clarity about file formats such as Industry Foundation Class and there may be concerns about interoperability issues between different software packages.
- There fears over the ownership of the BIM model.
- There may be concerns whether or not BIM will succeed in its aims or be replaced by another emerging technology in a few years.

4.5 Discussion

According to Casey (2008) many graduates often report a lack of coherence in the information and communication technology tools used in their courses. Typically the software used in the early years of an undergraduate course are design specific such as AutoCAD or Sketch Up. Casey (2008) suggests that Building Information Modeling (BIM) may offer the opportunity to unify disparate technologies to provide a coherent IT skill set for engineering students.

The implementation road map outlined earlier is very much a proposal that requires a lot of consideration, planning and negotiation with staff and management in the Department. If each course were to be re-written with BIM embedded throughout then an evaluation strategy would have to be created to assess the progress being made. The education sector is in a difficult position as the roll out of BIM gathers momentum, educational institutes are required to produce graduates with skills for jobs that have not yet been considered or created.

According to Casey (2008), if BIM emerges as the lingua franca for the AEC industry, then the need for engineers to participate in the interdisciplinary design process using the common BIM skill set will be extremely important. In the author's opinion, fundamental to achieving success is complete immersion and reinforcement of BIM within the curricula. It is extremely important that the change process is gradual and continuous and not just one episodic change (Sackey *et al.*, 2013)

6. Discussion, Recommendations and Conclusions

5.1 Discussion

At the outset of the project the idea was to emulate the Penn State Wiki. However, from the Penn State website it can be seen that not all areas of the wiki are updated. Whilst the portfolio section is current with entries for the 2014-15 academic year, the most recent entry for BIM related material is 2011. Can one conclude from this that everyone at Penn State knows all they need to know about BIM or even that the wiki as it currently exists is best it can be? Or does it mean that the members of the wiki/students of the faculty have lost interest and/or migrated to another platform? Evidence of the use of another learning environment is not apparent from the Penn State website. Also, given the fact that some of the portal is up-to-date would lead one to believe that some of momentum and interest has been lost.

It would appear that momentum is the single greatest factor in defining the success of a knowledge repository. As described earlier, momentum could be maintained for the proposed BIM repository by mandating that students either maintain blogs or update the wiki to detail their learning path and assignment briefs could be tailored for inclusion in the repository. This effort would have to be included as part of the assessment mark. This activity will ensure that the repository is accessed frequently.

The next greatest difficulty is how to structure the repository in a coherent and logical manner. If someone turns to the repository for assistance then there is only a small opportunity to either convince them of its usefulness. Therefore, if the structure is inappropriate or difficult to navigate, then the user may be more disillusioned than they were at the outset.

5.2 Recommendations and Scope for Further Work

Sustaining training and maintaining a high level of knowledge in ICT/BIM is extremely difficult for a 3rd level education institution due to budget constraints and research and teaching demands. However, there are a number of suggestions that can be made and actions that can be taken with little or no extra cost. The Department could;

- Make use of free BIM software such as Tekla BIMsight, Autodesk Design Review, Navisworks Freedom, Bentley i-Model navigator, Graphisoft BIMx, Solibri Model Viewer or Nemetschek IFC Viewer
- Appoint a moderator and BIM champion. Essentially someone in the department who commands respect from their colleagues and can trouble shoot software issues. The BIM champion could maintain a blog or reflective journal on the repository.
- Allocate some resources and time to the role of moderator.
- To begin the process of the creation of a BIM repository, the department could decide to migrate to using BIM software in the existing modules as they are at the moment. This will have the effect of compelling staff members to develop their BIM training. This will inevitably spark BIM, software and interoperability conversations within the department and will encourage collaboration between staff members.
- Seek industry partners and liaise closely with them in the form of guest lectures and training.
- Secure industry experts to deliver crucial integrated BIM modules.
- Prepare accredited postgraduate courses that would necessitate staff to keep abreast of developments in Building Information Modelling.
- Set up a student society to promote Building Information Modelling
- Collaborate with another institute who are likely to have the same concerns and issues.
- Depending on the success of the BIM knowledge repository, the concept could be rolled out across other departments.

5.3 Conclusions

The arrival of new technology can be characterised by classic hype theory. Keeping any type of ICT training fresh and current is going to be an extremely difficult task and it may be an even impossible remit. This is due to many reasons, such as budgets, teaching commitments and the rapid pace of the developing technologies. All members of staff expressed their opinion that the proposal of a BIM knowledge repository was a good idea and they were also positive with regard to the idea of face to face meeting. However, concerns were raised over the notion of re-writing syllabi to embed Building Information Modelling processes.

If the Department of Civil Engineering were to implement the BIM knowledge repository as outlined in this report then in the true sense of BIM, instruction on a range of BIM software (Revit, Bentley AECOsim, ArchiCAD) should be given. This notion would complicate things further as regards interoperability, staff competence and the setting of student course work. In addition to this, the Department already has a large number software programmes to maintain. Appendix B details some of the licensed software held by the Department. Obviously, the easiest thing to do would be to adopt a BIM platform ecosystem, such as Autodesk products, which is in conflict with the true ethos of BIM and that being that BIM should be open and not software specific. If OpenBIM was adopted it would mean that lecturers within the Department would need to be proficient in multiple packages. This scenario is somewhat idealistic and contradicts what happens in engineering offices where typically, for one reason or another such as the cost of software subscription, a small number of software packages are procured and used. The idea being that expertise in a small number of engineering software packages is more beneficial to the company.

The greatest obstacle to sustaining and maintaining up to date skill sets and the creation of a BIM knowledge repository is the willingness of staff. In much the same way that the construction industry remains quite fragmented and private about their intellectual property, staff members within a typical Civil Engineering department are also likely to keep their tacit knowledge to themselves.

Perhaps the most surprising outcome of this project is that, whilst there is a need for an up to date digital repository that is constantly enriched with user experiences and knowledge there is still very much a requirement for social interaction. After all, technology is nothing without people. In conclusion, whilst computers will inevitably be used as the main communication tool, the importance of human social interaction should not be underestimated.

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Appendix A International Agreements on Educational Qualifications

The Washington Accord

Through the Washington Accord, all accredited engineering degree programmes, which we have accredited as satisfying the academic requirements for the Chartered Engineer title, are recognised by professional bodies in other signatory countries as equivalent to their own accredited engineering degree programmes.

The Sydney Accord

Through the Sydney Accord, approved Engineering Technology Programmes (National Diploma in Engineering, BEng Tech degree, BEng Degree, BTech degree) are accepted for membership purposes by the Accord signatories on the same basis as their own accredited Engineering Technology Degree and Diploma Programmes.

The Dublin Accord

Through the Dublin Accord, approved Engineering Technician Programmes (National, Higher or Technician Certificate in Engineering) are accepted for membership purposes by the Accord signatories on the same basis as their own accredited engineering technician certificate programmes.

FEANI - Fédération Européenne d'Associations Nationales d'Ingénieurs

Level 8 engineering degree programmes accredited by Engineers Ireland are eligible for inclusion in the FEANI Index of schools and courses are accepted for the Eur Ing title.

Appendix B Engineering Software

Autodesk Revit	BIM software
Autodesk AutoCAD (Civil 3D, Electrical)	Draughting software
MasterSeries	Structural design software
Mudshark	Quantity Surveying software
BuildSoft	Quantity Surveying software
Bentley Hevacomp	Building Services Design Software
Bentley AECOsim	BIM software
CFAST	Fire simulation software
STEPS	Evacuation software
Simulex	Evacuation software
PyroSim	Fire modelling software
FDS	Smoke modelling software

Appendix C Online BIM Resources, Blogs etc.

www.autodeskcurriculum.com

www.revitcity.com

www.bimafterdark.com

http://www.bimtaskgroup.org/

http://www.nationalbimlibrary.com/

http://beyonddesign.typepad.com/

http://revitoped.blogspot.ie/p/blog-listing-bim-and-misc.html

http://www.seandburke.com/