BIM Implementation Strategies in Higher Education (Case Study Coventry University)

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Abstract

Nowadays, with the evolvement of construction, project managers are facing more complex tactics to manage project and their cost, information, schedule, maintenance and more. The UK government have provided a new strategy to undertake project management; this strategy was set to become a mandate as of March 2016. 'Building Information Modeling' or also known as 'BIM' is a new strategy used to enhance collaboration between multi disciplines in the architecture, engineering, and construction sector with the use of technology. BIM level 2 was modified to suit the British standards and a publicly available specifications was set to provide a 'common language' to all disciplines in construction, and as of March 2016 58% of the construction companies in the UK have embedded BIM and 97% are planning on implementing BIM in the next 5 years (NBS, 2016). The UK government have set another goal to reach a new mandate of implementing BIM level 3 in construction. Since BIM is a new idea and the industry is providing training to implement it, it should be implemented in education to reach BIM level 3 target. Also, since BIM is a new idea, there is a large uncertainty of how to implement BIM in higher education and to identify the different teaching and learning strategies of BIM in education.

This paper provide an overview of the idea of BIM and will explain what BIM is and the platforms used to apply different levels and dimensions of BIM in the industry. Then, the literature about BIM in education will be provided to show the different collaboration methods and teaching/learning strategies that could be adopted.

The data obtained to formulate a strategy that would commend the methods used by Coventry University will be case studies of BIM implementation in education from researchers, academics and practitioners in the architecture, engineering, construction, owner and operator industry.

1. Introduction

‘Building Information Modelling’ or ‘BIM’ is a new method used in construction to provide a more effective technique of collaboration while undergoing design, management, and maintenance. The attention towards Building Information Modelling (BIM) has been rapidly increasing over the years especially after the UK Government published in 2011 a Government Construction Strategy that involves the implementation of BIM in construction projects. In 2016 the UK Government published a new Government Construction Strategy where it was quoted in that report “The majority of departments have already met the requirements for BIM Level 2 and the remaining departments are on target to meet the 2016 mandate” (gov.uk, 2016).

1.1 Aim and Objectives

In order to understand the importance of BIM, what BIM truly is, and if it could be implemented in higher education. The following aims could be achieved by trailing the following objectives:

1. Provide a thorough explanation of what BIM is.
2. Know the UK government requirements.
3. Pinpoint any BIM collaboration types in education.
4. Show different types of implementation strategies
5. Provide previous strategies of implementing BIM in education

2. Definitions of BIM

Autodesk (2016) defined BIM as “a process that involves creating and using an intelligent 3D model to inform and communicate project decisions. Design, visualization, simulation and collaboration enabled by Autodesk BIM solutions provide greater clarity for all stakeholders across the project lifecycle.” BIM is the acronym of Building Information Modelling and portrays a collaborative process to design, build, and manage a building using one coherent platform that provides a 3D model where all the participants of the project can access and modify the model and the model’s information throughout the project’s lifecycle. BIM is not just a 3D platform and does not only help designers with the modeling of the project, but also helps all the participants with communication problems, cost defining, choosing materials, time management, energy performance, maintenance management. WSP Parsons Brinckrhoof (2013) explained BIM to be a ‘Sociotechnical system’ where BIM is the combination of man-made technology and social norms, behaviors and cultural institutions. BIM is considered to be ‘sociotechnical’ because the technical aspect is based on the influence of the social behavior. Figure 1 explains the different sociotechnical layers of BIM.

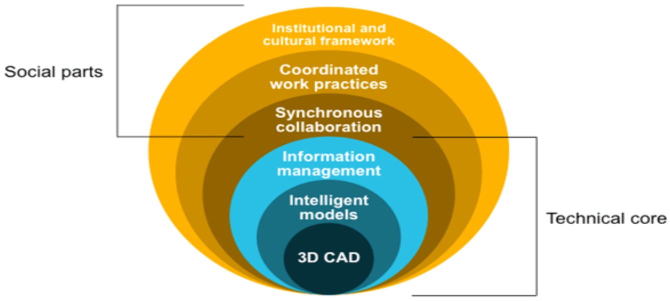

Figure 1: Sociotechnical layers (Parsons Brinckrhoof, 2013)

2.1 First principles of BIM

Although BIM is considered to be a new methodology, it has been present in construction in some form or another for a long time. Truly, BIM has been developing for almost 40 years. In 1975, Chuck Eastman a researcher wrote the paper “The use of computers instead of drawings in building design” and explained a working prototype called “Building Description System” or “BDS”, which comprise a parametric design and a single database for graphical aid and quantitative exploration (Codebim.com, 2016). In the decade between 1970 and 1980, growth on the idea was continuously developing in the world where in the USA it was called “Building Description System” and in Europe it was termed as “Product Information Model” or “PIM”. In 1986, a British Professor called Dr. Robert Aish, who is now part of the Autodesk research, first titled “Building Modeling” (Hetnationaalbimplatform.nl, 2016). Afterward, in 1992, the term “Building Information Modelling” appeared in the first paper written by Nederveen and Toleman from the Netherlands (van Nederveen, G.A. Tolman, F,1992). Nowadays, The UK government has provided a mandate for all construction companies in the UK to normalize. The mandate required is a level 2 BIM, which should come in effect by March 2016 (gov.uk, 2015).

2.2 BIM Levels

To understand the effectiveness of the different levels of BIM, Richards and Bew (Mordue. S, October 2015) provide a diagram describing the maturity levels of BIM (figure 2)

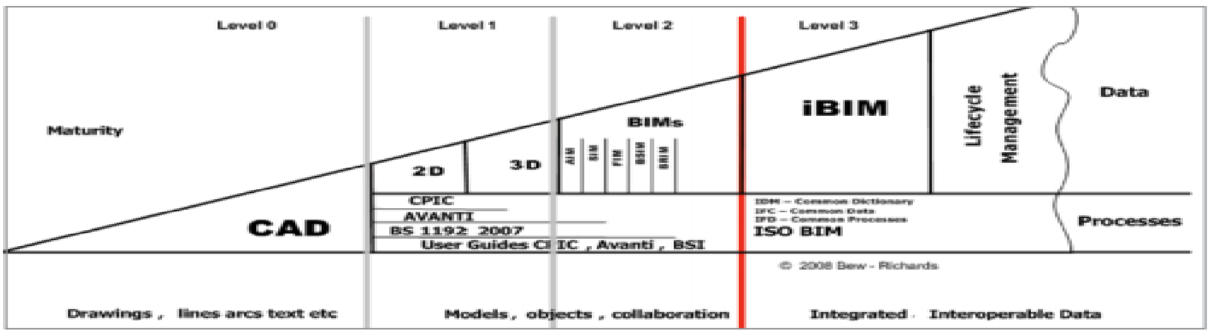

Figure 2.Richards and Bew Maturity Diagram (Mordue. S, October 2015)

- ➢ In level 0 BIM, no technology is used and all the information is in the form of hardcopies.

- In Level 1 BIM, the information is provided using technology where they are in the form of softcopies but no cloud collaboration is used.
- In level 2 BIM, all the information is in the form of softcopies and the information is transferred using an online library for all participants to access.
- In level 3 BIM, the participants of the project work on one model that contains 3D, 4D, 5D, and 6D information.

2.3 BIM Dimensions

BIM level 3 dimensions, 3D, 4D, 5D, and 6D are defined to be as follow:

- 3D is the the model of the project which is in 3 dimensions and shows all the information of materials and structures. This dimension has a walkthrough feature where you can access any part of the model and select every component of the project.
- 4D is the construction planning and organization. This dimension shows the sequence used to undertake the construction, the benefits of this dimension is to minimize any on-site health and safety risks.
- 5D is the cost information of the project where in the model, all the materials and components used have their costs included in the BIM model, after finishing the model, the cost can be regenerated using the BIM model itself
- 6D is the project lifecycle management information where after producing a 3D model, the model used during the construction phase the information used in the model can be used to produce a lifecycle management process.

2.3.1 BIM Level 2 Mandate

The UK Cabinet Office stated in May 2011 a new continuing government strategy to improve the construction industry. The short term goals of the strategy is to reduce cost of construction by 15 to 20 percent and the long term goals are:

i. Reduce long-term working costs for construction projects
ii. Help meet the UK's carbon reduction target
iii. Increase competitiveness of the UK's design and construction market.

To help achieve these goals, many standards and specifications are generated to back up the strategy. Those standards and specifications include 8 main components that would permit project members to identify, follow, and understand BIM protocols and procedures. Autodesk (2016) identified the 8 main components to be:

1. **PAS 1192-2:2013**: PAS is the acronym for Publicly Available Specifications under the British Standards 1192 and is issued in 2013. PAS 1192-2 is the main part of BIM that identifies the collaboration process for engineering, architectural, and construction information and explains the use of Construction Operations Building Information Exchange (COBie). Where COBie is the exchange of information of new and existing facilities.
2. **PAS 1192-3:2014**: Similar to PAS 1192-2:2013 but created in 2014 and provide standards for the operational phase with respect to the delivery of the project. This specification portrays how Asset Information Model is created from the Project's information Model (PIM). Also, the PAS explains how the model is utilized and maintained until disposal.
3. **BS 1192-4:2014**: Similar to previous British Standards but created in 2014 and shows the expectancies of the exchange of nongraphic information of a project. The use of COBie for operating, commissioning, and maintaining in a neutral spreadsheet for decision making, asset management, and facility management.

4. **PAS 1192-5:2015**: similar to previous specifications but created in 2015 and focuses on technical security considerations for stakeholders and government owners in the UK
5. **BIM Protocol**: A legal appendix for designing and constructing contracts, which permits project members to share information within a contract. It explains responsibilities, restrictions, and liabilities of the project models.
6. **Government Soft Landings**: GSL is a government policy of graduated handover for projects done for the government. It involves the assistance of project teams to government clients to aid them on how to control their assets effectively. This policy also emphasizes on including operational workers during the design and construction phase to assess the impact of the operation.
7. **Classification**: This is a 'common language' between all parties involved in designing, managing, and constructing a government project. Having a specific classification allows electronic project data to be indexed and planned to be straightforwardly available and searchable.
8. **Digital Plan of Works**: A digital plan of works (dPoW) was appointed by the UK government to outline the information needed at a specific time of the project's lifecycle and the party accountable for creating and issuing that information.

2.4 The benefits of BIM

According to a National BIM report conducted by NBS in April 2016 (NBS, 2016), 56% of the industry has adopted BIM, which is 6% more than last year's survey. Also 86% plan to implement BIM by April 2017 and 97% are planning to adopt BIM in the next 5 years. One of the leading companies in the construction industry within the UK that has adopted BIM is Mott Macdonald. Mott Macdonald has been adopting and operating BS1192 compliant CDEs on some of the world's largest projects for almost 7 years (NBS, 2016). Mott Macdonald has identified the benefits of BIM to be:

- **Better Collaboration Outcomes**: Using a single model where all project members such as design disciplines, customers, contractors, suppliers and specialists cultivate collaborative working relationships. This will help members focus on project delivery and better outcomes.
- **Superior performance**: By using BIM, a detailed comparison between different designs, options, and facilities can lead to a more efficient, cost-effective and sustainable solution.
- **Improved Solutions**: BIM provides enhanced generative modelling technologies that can provide improved cost-effective solutions against agreed parameters.
- **Better Certainty**: Benefits of having a model, the project can be visualized from the early stages, which would help owners and operators generate awareness of the design content, thus permitting them to amend the design to achieve the results needed. Before undergoing construction BIM helps the team members to 'build' the project in a virtual model, prepare certain procedures, enhance the outcome of temporary works and better plan materials, equipment and labor.
- **Faster Project Delivery**: Due to ease of visualization, up to 50% of planning time can be saved by agreeing on early designs and facilities. Also, many design problems and clashes can be identified at early stages of planning by running simulations on different BIM platforms.

- **Reduced Health and safety risks**: By using the 3D model, asset managers and operation managers can enhance public safety and optimize operations on site. Also, contractors can use complex details from the model to review any safety risks before going on site.
- **More Precise**: When all members collaborate on a single model, everyone will be able to identify issues and resolve them before construction and thus eliminating impacts of redesign on cost and time. Also, using BIM allows the integration of existing facilities with new facilities.
- **Fewer Waste Generated**: Using some BIM platforms, there is an option to order the exact quantity where materials are not over-ordered. Also, due of precise program scheduling, materials and equipment are delivered in time which would enable more space on site and lower potential of damage to materials.
- **Constant Improvement**: All members included in the BIM project can leave feedback regarding the information and the performance of the members and the process, which would then drive for improvement on following projects.
- **Whole Life Asset Management**: Projects executed using BIM not only contain information about construction and sequences but also contain component information that aids with ordering, operating and maintaining

Nevertheless, from the survey conducted by NBS (2016) for the national BIM report, many of the respondents believe the advantages of embedding BIM in construction are:

- 63% of the respondents believe that BIM adoption will cause 33% decrease in the total life cost and of initial cost of construction.
- 57% of the respondents believe that BIM will cause a 50% decrease in time from the start date to completion date for new-build and refurbished projects.
- 39% of the respondents believe that BIM will cause a 50% reduction in the emission of greenhouse gases within the construction industry.
- Almost 30% believe that BIM will help reduce the trade gap between exports and imports for construction materials.

2.5 The Challenges of BIM

Although BIM is considered to be a better and more efficient strategy in construction, being a relatively new approach, BIM has created many challenges in the construction industry. The top 5 challenges cited by institutes that haven't done the move to the level 2 mandate have been identified by the NBS national BIM report of 2014(NBS, 2014) to be:

1. **No client demand**: 73% of the organizations that consist of five staff or fewer have cited that there was no client demand.
2. **Not always relevant**: 71% of the organizations that consist of five staff or fewer consider that BIM is not always relevant, applicable, or appropriate to their workload.
3. **Cost**: Ever since the recession, organizations have been cautious and they consider BIM to be a liability rather than a helpful. This is true since the move will require spending on software, providing training and time. Although the cost could be weighed against the benefit of BIM but some organizations are not willing to take the risk just yet.
4. **Projects considered too small**: Although BIM can be used on all sized projects, some companies believe that some projects are too small to use BIM.

5. **Lack of expertise**: 62% of the organizations that consist of five staff members or less and 77% of the organizations of six staff members or more have reported the lack of expertise and skills in BIM. With the development of the industry, it is ideal for companies to increase recruitment now to uplift the lack of expertise in the BIM sector instead of facing training costs.

2.7 Platforms used in implementing BIM

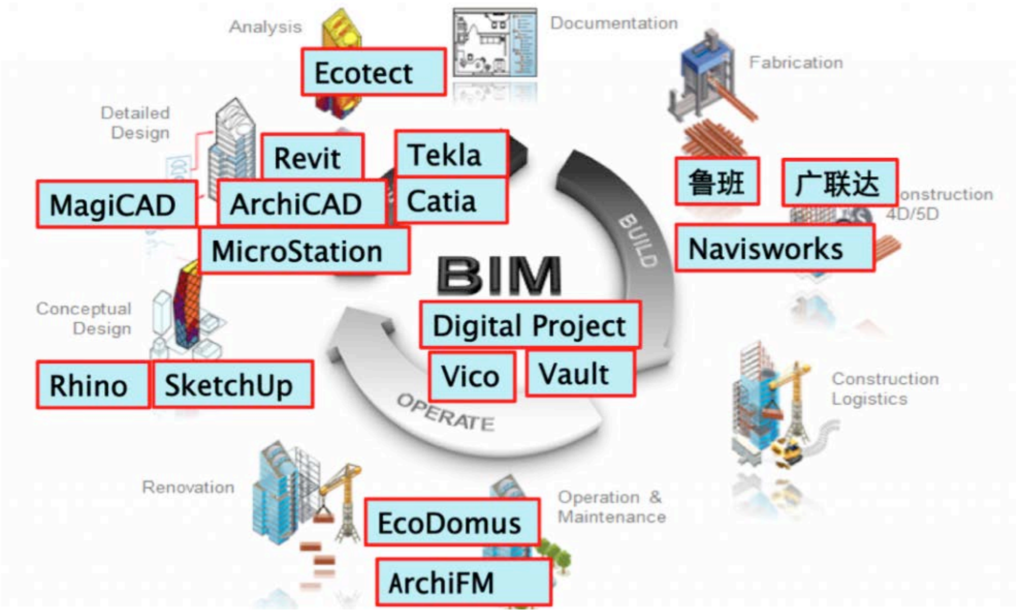

Figure 3: BIM Platforms (theBIMhub, 2015)

BIM is a strategy of many options. There are many platforms that contribute to the utilization of BIM. Figure (3) shows some of platforms used by different parties to contribute to the project. Table (1) shows the list of software used by each party.

3. Building Information Modelling in Higher Education

Importance of teaching BIM in higher education

BIM nowadays have dominated the construction industry. Members of the industry are undergoing training and buying BIM platforms to keep up to date especially after the UK government set a strategy to reach level 2 BIM mandate. The importance of teaching BIM in higher education is vital where students transitioning into the industry are aware of the process and aware of the platforms used in BIM. Professor David Philp (HEAcademy, 2013) explained that "At this point in the evolution of the UK BIM strategy it is of increasing importance that our teaching institutions are equally well informed of the progress that is being made across those Government departments which are spearheading implementation on projects and across its asset base." Education has always strived to follow the relevance of the need of the industry and currently Building Information Modelling is considered to be an attractive topic to continue the evolution of the construction industry.

3.1.1 Accredited universities that teach BIM in higher education in the UK

According to The Higher Education Academy (2013) there are 20 higher education institution noted in figure (5) that have embedded BIM within their curriculum. Some of these institutions use it as a complete course and others have embedded BIM within courses. According to the Chartered Institute of building (Bimplus, 2016), some institutes that use BIM as a higher education course:

1. University of Salford: MSc BIM and Integrated Design
2. Middlesex University: MSc Building Information Modelling Management
3. University of South Wales: MSc Building Information Modelling and Sustainability
4. University of the West of England: MSc Building Information Modelling (BIM) in Design Construction and Operations
5. University of Northumbria: MSc Building Design Management and Building Information Modelling (BIM)
6. University of Liverpool (in London): MSc Building Information Modelling
7. University of Derby: University Diploma in CAD and BIM (Architecture)
8. University of Wolverhampton: MSc Building Information Modelling
9. University of Westminster: MSc Building Information Management
10. Birmingham City University: MSc Integrated Design and Construction Management
11. The Construction IT Alliance (CITA): MSc in Construction Informatics
12. University of Reading: MSc Information Management for Design, Construction and Operation
13. RGU Robert Gordon University Aberdeen: MSc Visualisation in Architecture and the Built Environment
14. Dublin Institute of Technology: MSc in Applied Building Information Modelling and Management

Figure 4: Institutes that teach BIM in the UK (HEAcademy, 2013)

4. Research Design and Methodology

A research is usually conducted to explore an idea, investigate an issue, resolve a problem, or make an argument. In this research paper, a research is done to explore an idea and make an argument. This paper is made up of 2 different segments. The first segment of this paper explains the issues raised when undergoing a research methodology and the second segment clarifies why the particular method was chosen and how the method will be accomplished. This paper will explain the research aims and objectives, research design, research methods, research population, and key steps used to identify implementation strategies of BIM in higher education.

4.1 Methodological choice

When undergoing a research, whether the research method is primary, secondary, or both, there are different types of methodological approaches. These approaches are dependent on the research aims and objectives and the data required. The main scopes to methodological choices are:

- Qualitative
- Quantitative
- Mixed Method (quantitative and qualitative combined)

4.1.1 Qualitative approach

According to Wyse (2011) a qualitative research is mainly an investigative method of research. Using a qualitative approach is mainly to understand prime ideas, reasons and motives. The cause of implementing a qualitative approach is to provide understandings of the problem or to aid in the development of ideas or theories for a quantitative research. Also, it is used to reveal beliefs and opinions trending which would then help uncover the problem more thoroughly. Methods used to collect data for a qualitative research may be unstructured or semi-structured. Some of the methods used to undergo such an approach may be typically small and the population required are selected to satisfy a specific quota. Some of the techniques used are:

- Focus groups (group discussions)
- Individual interviews
- Participation/observations

4.1.2 Quantitative Approach

Wyse (2011) explained that a quantitative approach is mainly used to measure the problem by producing two types of data; either numerical data or data that can be converted to exploitable measurements. Quantitative research is mainly used to generalize data from a larger number of participants than a qualitative approach to quantify ideas, performances, feelings, and other defined variables. When undergoing a quantitative research, measurable data should be utilized to convey specifics and learn patterns within research. When comparing quantitative and qualitative data collection methods, a quantitative method is considered to be more structured than a qualitative method. Some of the techniques used to implement a quantitative data collection methods include:

- Surveys (online surveys, paper surveys, mobile surveys and kiosk surveys)
- Face-to-face interviews
- Telephone interviews
- Longitudinal studies
- website interceptors
- Online polls
- Systematic observations.

4.1.3 Mixed method approach

Conducting a mixed method approach includes gathering, studying, and mixing quantitative and qualitative data in a single study or a longitudinal program of inquiry.

The purpose of using this type of approach to undergo a research is to implement both qualitative and quantitative research methods together to deliver a more enhanced understanding of the research problem. They explain that a mixed method of both quantitative and qualitative approaches may lead to 5 kinds of research designs:

1. Concurrent Mixed Method Design (Triangulation Design)
2. Embedded Design
3. Explanatory Design
4. Exploratory Design
5. Sequential Embedded design

4.2 Existing Strategies of Implementing BIM in Education

The National Institute of Building Sciences (2015) have held their 9th event on 7-8 of April 2015 to raise attention on BIM. For the event, NIBS have requested researchers, academics and practitioners in the architecture, engineering, construction, owner and operator industry to present a short paper about knowledges, experiences and challenges for implementing BIM in education or describe course contents or project practices. Some of the strategies used to implement BIM are highlighted below, and the full report from The National Institute of Building Sciences is attached as appendix A.

4.2.1 How should we teach BIM? A case study from the UK

The UK's perspective of BIM is that it has 4 significant levels:

- Level 0
- Level 1
- Level 2
- Level 3 (RIBA, 2012).

As the UK's government has implemented the use of BIM by the year 2016, the minimum required level of BIM implementation is level 2; the creation of models in BIM applications by specific disciplines before deployment in a shared workspace (BSI 2013; BSI 2007).

A study by Barison and Santos (2010a) has shown that out of 25 universities that incorporate BIM in their curriculum, 6 universities teach it at an introductory level, 12 universities teach BIM at an intermediate level and 7 universities teach BIM at an advanced level, where the introductory level requirements did not need any pre-requisites or any sort of high level computing skills and it therefore makes it suitable for students in their first year of studies.

Effective learning by students can be achieved by a combination of many methods, including lectures, self-study, lab tutorials, problem based projects / coursework and web based tutorials.

Video based (web) tutorials are able to offer a new vista to the learning experience that cannot be obtained from the traditional 'text' based handouts. Evidence in literature suggests that this method of learning aids in metacognition (Wouters et al, 2007); support problem based learning (Chan, et al. 2010) as well as increasing stimulation, retention and satisfaction of student learning experience (Choi and Johnson, 2007). By encouraging self-learning through video tutorials, students are able to acquire CAD/BIM skills with a knock on effect on computer lab sessions, which can then focus on coursework (problem solving). This is as opposed to current scenario, where substantial amount of time spent by students in lab sessions is dedicated to first, learning how (CAD) software work, leaving less time for applying the learning in their coursework. This should eventually speed up the Kolb Learning Cycle (Kolb, 1984).

In addition to customary texts on BIM which provide theories and conceptual backdrop, there are important documents that are crucial as learning materials and to the learning outcomes of BIM in

the UK. These include: regulatory guidelines like BS1192-2007 (BSI 2007), PAS 1192 (BSI, 2013) and the CIC BIM Protocol (BIM Task Group 2013b); industry standards such as Royal Institute of British Architects (RIBA) BIM overlay (RIBA, 2012), and Royal Institution of Chartered Surveyors' (RICS) new rules of measurement (NRM1) (Wu, et al. 2014). Other sources of BIM knowledge and understanding come from case studies by industry professionals who give presentations on how

BIM has been used in real-life projects. Depending on the program and its focus, acquisition of various practical skills is achieved through data generation from BIM authoring software, model coordination and auditing, and finally collaboration through shared workspaces.

Using Loughborough University as a case study, it has been found from research that as there are 4 undergraduate programs and 5 post graduate programs of different disciplines requiring BIM and therefore the co-location of these programs in one school has allowed for the optimization of multi-disciplinary modules where group work is often used to achieve learning outcomes.

4.2.2 Best Practices and Lessons Learned in BIM Project Execution Planning in Construction Education

Construction management and construction engineering students at Arizona State University are introduced to various in-depth applications of BIM during their 4th year Project Management Course.

The adoption of BIM is happening all throughout the Architecture, Engineering and Construction industries and the different disciplines within the AEC are utilizing BIM in different ways to suit their particular needs.

BIM is being introduced in education just as much as it is in industry. The Architectural discipline oversees the biggest portion of programs with BIM components offered (Beccerik-Gerber et al. 2011). Construction Management disciplines were late in adopting a BIM component within their education realm but they have increased their offerings and have realized the benefits (Beccerik-Gerber et al. 2011). Accreditation of each BIM course may be a constraint to the disciplines that may be offering the courses.

There are teaching strategies that combine the teaching of the technical skills of BIM platforms and the BIM management strategies.

Con 453 is a Project Management course at Arizona State University that has been revamped to address the managerial aspects of BIM while introducing the technical skills required to create BIM content. Con 453 was structured with lectures and lab sessions; the students attend a total of 75 minute lectures per week, and one 2-hour lab per week. The lectures present a typical theoretical approach to the course content; why is BIM used in the industry, and also why its use has been increased in recent years.

4.3 Limitation of the Study

When undergoing this research paper, there were 2 limitations faced. The first limitation was encountered when undergoing secondary data collection where the topic does not have much literature about implementing it in higher education. The only countries that have implemented BIM are developed countries and they have limited data about the subject.

The second limitation appeared when undergoing the methodology where the research philosophy was too vague to be explained as pragmatism, positivism, realism, or interpretivism.

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