Teaching BIM in Schools of Architecture of South African Universities

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A Research Report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Bachelor of Science (Honours) in Quantity Surveying

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Declaration

We declare that this research report is our own work. It is being submitted in fulfilment of the requirements for the degree of Bachelor of Science (Honours) in Quantity Surveying, to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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Abstract

Purpose: This study aims to investigate the current BIM education status, the pedagogies used and the challenges faced when incorporating BIM into the curriculum, within the Schools of Architecture in South African Universities (Gauteng region) in order to achieve greater insights on the importance placed on Architecture students being adequately prepared to meet the expectations of the AEC industry.

Design/methodology/approach: This research design has been guided towards a Positivist philosophy. This study will be using Purposive Sampling whereby judgment is used to select cases that will best enable one to answer the research questions and achieve the research objectives.

Findings: All the interviewees understand BIM as a software tool rather than a process of generating virtual models that represent building facilities. BIM is taught as a standalone course and it is integrated with design related courses. Challenges encountered when incorporating and teaching BIM include costs and difficulty of grasping the software tool. Collaboration as a teaching method is not yet fully adopted. One of the respondent mentioned that they do collaborate with students from the engineering department but not in any BIM supporting process or software.

Practical implications: The significance of the research study is structured upon revealing the importance of BIM education to Architecture students in South Africa and how this can assist in preparing them to be graduates that meet the AEC industry’s expectations. It may also contribute by motivating Universities to include BIM within their curriculum and provide them with insight of effective approaches and methods that could be adopted within their teaching, in order to produce BIM competent graduates entering the AEC industry. Awareness of the challenges faced when integrating BIM into the curriculum may also be helpful towards Universities which are in an adoption phase of integrating BIM into their curriculum, as measures can be taken to address these challenges.

Keywords:
BIM, BIM Education, Pedagogy, Collaboration, Incorporation, BIM supporting software
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List of Figures

Figure 1: TPACK Framework (Koehler and Mishra, 2009)
Figure 2: The IMAC Framework (Macdonald, 2012)
Figure 3: Research Onion (Saunders, et al. 2011)
Figure 4: Flow Diagram of Methodological Choice and Strategy
Figure 5: “Lecture - Do” Method
Figure 6: Collaboration of Different Departments

List of Tables

Table 1: Schedule of Participants’ Information
Table 2: Key Responses

List of Acronyms

AEC Architecture, Engineering and Construction Industry
BIM Building Information Modelling
TPACK Technological pedagogical content knowledge
IMAC Illustration, Manipulation, Application and Collaboration framework
Table of Contents
1 Chapter 1: Introduction .................................................................................................................... 8
  1.1 Background to the Study .............................................................................................................. 8
  1.2 Problem Statement ....................................................................................................................... 8
  1.3 Consequences of the Problem .................................................................................................... 9
  1.4 Aim of the Study ......................................................................................................................... 9
  1.5 Research Objectives .................................................................................................................... 9
  1.6 Rationale for the Study .............................................................................................................. 9
  1.7 Contribution of the Study .......................................................................................................... 10
  1.8 Empirical and Body of Knowledge Substantiation ..................................................................... 10
  1.9 Primary Research Question ....................................................................................................... 11
  1.10 Research Sub-Questions .......................................................................................................... 11
  1.11 Scope of Study ......................................................................................................................... 11
  1.12 Delineations ............................................................................................................................ 11
  1.13 Limitations .................................................................................................................................. 11
  1.14 Assumptions ............................................................................................................................. 12
  1.15 Ethical Considerations ............................................................................................................. 12
  1.16 Hypothesis .................................................................................................................................. 12
2 Chapter 2: Literature Review .......................................................................................................... 12
  2.1 Introduction .................................................................................................................................. 12
  2.2 Methodology of Literature Review ............................................................................................ 14
  2.3 Research Methods Used in this Problem Area .......................................................................... 15
  2.4 Background Literature to Research Problem ............................................................................ 17
    2.4.1 Building Information Modelling in the AEC industry .......................................................... 17
    2.4.2 Status of BIM in South Africa .............................................................................................. 18
    2.4.3 Importance of BIM Education ............................................................................................... 20
    2.4.4 Courses that may incorporate BIM education ...................................................................... 20
    2.4.5 Approaches and methods used in teaching BIM ................................................................. 20
    2.4.6 Challenges faced when including BIM education into the curriculum .............................. 21
    2.4.7 Collaboration practices and pedagogies ............................................................................ 21
  2.5 Background to Empirical Objectives ......................................................................................... 23
    2.5.1 To identify Schools of Architecture courses that incorporate the education of BIM and related practices ......................................................................................................................... 23
    2.5.2 To examine the motivations behind including the education of BIM and related practices into the curriculum of these Architecture courses .............................................................. 23
2.5.3 To investigate the approaches and methods used in teaching BIM and related practices within these Architecture courses. ..........................................................23
2.5.4 To explore the problems that Schools of Architecture encounter when incorporating the education of BIM and related practices into the curriculum. ........23
2.6 Theoretical Framework ..................................................................................24
2.7 Synthesis and Conclusion of Literature Review ...........................................29

3 Chapter 3: Research Design ...........................................................................30
3.1 Introduction ......................................................................................................30
3.2 Research Philosophy and Approach ...............................................................30
3.3 Research Methodological Choice and Strategy ............................................31
3.4 Population and Sampling Plan ......................................................................33
3.5 Data Collection Plan ......................................................................................33
3.6 Reliability and Validity ..................................................................................37
3.7 Data Analysis Plan .........................................................................................37
3.8 Ethical Considerations ...................................................................................37

4 Chapter 4: Findings and Data Analysis ............................................................38
4.1 Introduction ......................................................................................................38
4.2 Challenges Encountered ...............................................................................39
4.3 Findings ...........................................................................................................39
4.4 Data Analysis ..................................................................................................48
  4.4.1 Understanding of BIM ..............................................................................48
  4.4.2 Incorporation of BIM ...............................................................................48
  4.4.3 Motivation to Incorporate BIM .................................................................48
  4.4.4 BIM Software ..........................................................................................48
  4.4.5 Teaching Methods ...................................................................................49
  4.4.6 Collaborative Practices ...........................................................................50
  4.4.7 Difficulties in Incorporation .................................................................50
  4.4.8 Difficulties in Teaching .........................................................................51

5 Chapter 5: Conclusions and Recommendations .............................................51
5.1 Evaluation of Empirical Questions .................................................................51
5.2 Key Findings ..................................................................................................51
5.3 Contribution to the Construction Industry ....................................................52
5.4 Recommendations for Future Research .......................................................53
5.5 Conclusion ......................................................................................................53

6 Reference List ..................................................................................................55
Annexures .................................................................................................................................. 60
Chapter 1: Introduction

1.1 Background to the Study
It is anticipated that Building Information Technology (BIM) will lead to changes in the performance of professionals in the Architecture, Engineering and Construction (AEC) industry. However, according to Goedert and Meadati (2008) full implementation of BIM in the construction industry has not yet been achieved, this is a problem as the industry does not have sufficient professionals that are BIM competent. The findings by Booyens et al. (2013) indicates it is quite clear that different companies recognize the necessity of keeping up to date with new technology and this is why they implement BIM technologies and processes in their companies and are requiring BIM competent employees.

According to Hjelseth (2015) the demand for Building Information Modelling expertise is increasing in the entire AECOO (Architects, Engineers, Construction, Owners and Operators) industry. Despite this clear demand, BIM remains understudied in the engineering curriculum at the undergraduate and graduate levels. The AEC industry needs a widespread education and training program if BIM is to achieve extensive adoption (Sacks and Barak, 2013). It is for these aforementioned statements that BIM education is essential.

Students that are not BIM competent by the end of their studies are put at a disadvantage. It is therefore essential for the emerging professionals to take cognisance of and understand BIM technologies and related practices while undertaking studies at an academic institution (Santos, 2010). Teaching BIM to students entering the AEC industry at a tertiary level will help ensure that they are sufficiently equipped to address the problems that the South African AEC industry is currently facing. This study aims to investigate the current BIM education status, the pedagogies used and the challenges faced when incorporating BIM into the curriculum, within the Schools of Architecture in South African Universities (Gauteng region).

1.2 Problem Statement
Emerging professionals within the South African Architecture, Engineering and Construction (AEC) industry lack the skills necessary to utilise BIM to its full potential, this results in companies spending more money and time on their Continuing Professional Development (CPD) programmes, whereas these BIM technologies and related practices could be taught at a tertiary level.
1.3 Consequences of the Problem
Poor usage of BIM throughout the entire project’s life cycle is one of the biggest consequences of the problem. As a result, projects are not being completed on time, within budget and scope. Another consequence is that graduates within the AEC industry who are not BIM competent are disadvantaged as companies require them to have these skills. This leads to the consequence of companies incurring unnecessary training costs by spending more money and time on their Continuing Professional Development (CPD) programmes.

1.4 Aim of the Study
This study aims to investigate the current BIM education status, the pedagogies used and the challenges faced when incorporating BIM into the curriculum, within the Schools of Architecture in South African Universities (Gauteng region) in order to achieve greater insights on the importance placed on Architecture students being adequately prepared to meet the expectations of the AEC industry.

1.5 Research Objectives
- To identify Schools of Architecture courses that incorporate the education of BIM and related practices.
- To examine the motivations behind including the education of BIM and related practices into the curriculum of these Architecture courses.
- To investigate the approaches and methods used in teaching BIM and related practices within these Architecture courses.
- To explore the problems that Schools of Architecture encounter when incorporating the education of BIM and related practices into the curriculum.

1.6 Rationale for the Study
From the literature review that was conducted on BIM, it is a concept that is working efficiently internationally. Currently in South Africa, BIM has not been grasped fully and as a result it is not being used to its full potential. In the report from the NATSPECS compiled by Rooney (2015) the findings with regards to the current status of BIM, that is the awareness and or uptake in South Africa is that BIM is hardly used in South Africa and when used it is usually for larger and more complex projects. Most projects are using 2D CAD as a standard software tool (Rooney, 2015).

According to Kiprotich (2014), Autodesk BIM and Tekla software packages have made a great impact in the construction of South Africa’s 2010 world cup stadiums and the Medupi
power stations. BIM was however not utilised to its maximum potential during the construction of these projects, if these projects were constructed within the full potential, lower costs could have been incurred and the projects could have been delivered at a higher standard of quality. Based on the literature being reviewed it is noted that if BIM is used to its maximum potential in the construction industry, mostly in the South African construction industry, it will enable the project teams to deliver the projects on time, within budget and more efficiently.

The construction industry is evolving due to clients demanding more complex projects, it is therefore necessary to develop technology that will help the construction professionals meet this demand. BIM is the appropriate technology that the industry needs to meet this demand and to mitigate issues such as unnecessary cost overruns, lack of communication between various parties involved in the projects, poor project delivery and management throughout the entire project’s life cycle from cradle to grave. Therefore it is essential for students to learn the skills surrounding BIM at a tertiary level in order for them to be more competent and to meet the expectations of the AEC industry.

1.7 Contribution of the Study
The significance of the research study is structured upon revealing the importance of BIM education to Architecture students in South Africa and how this can assist in preparing them to be graduates that meet the AEC industry’s expectations. It may also contribute by motivating Universities to include BIM within their curriculum and provide them with insight of effective approaches and methods that could be adopted within their teaching, in order to produce BIM competent graduates entering the AEC industry. Awareness of the challenges faced when integrating BIM into the curriculum may also be helpful towards Universities which are in an adoption phase of integrating BIM into their curriculum, as measures can be taken to address these challenges.

1.8 Empirical and Body of Knowledge Substantiation
The empirical data that will be used in supporting this study is mostly qualitative. It includes the analysis of academic journal articles, conference papers, Universities’ curriculum, and interviews with programme/course co-ordinators in Schools of Architecture of various Universities.
1.9 Primary Research Question
Do Schools of Architecture of South African Universities provide their students with the necessary skill sets of using BIM in order to meet the Architecture, Engineering and Construction (AEC) industry’s expectations?

1.10 Research Sub-Questions
1. Which courses within Schools of Architecture incorporate BIM education and related practices?
2. What are the motivations behind including BIM education and related practices into the curriculum of these Architecture courses?
3. What approaches and methods are used in teaching BIM and related practices within these Architecture courses?
4. What problems do Schools of Architecture encounter when incorporating BIM education and related practices into the curriculum?

1.11 Scope of Study
This study investigates the current BIM education status, the pedagogies used (i.e. how is it taught in the different years of study, details of the content taught, teaching time allocation and modes of assessing the course), and the challenges faced when incorporating BIM into the curriculum, within the Schools of Architecture in South African Universities. The study is limited to Universities within the Gauteng region and the criteria for selecting those varsities was based on the fact that they are close by and thus it would be easy to collect data through interviews, also bearing in mind the time constraints. Choosing these Universities however do hold the relevant significance and validity in our research as they are within the top 10 Universities in South Africa, according to Tucker (2015).

1.12 Delineations
The study does not cover other professions within the AEC industry but rather focuses only on Architects. That is the study will be conducted only on Schools of Architecture and not to Schools of Engineering and Construction.

1.13 Limitations
Since the study is conducted on Universities in the Gauteng region, the findings will be limited in that the status of BIM education in South Africa as a whole cannot be generalised. However, since the Universities that have been chosen are within the top 10 Universities in
South Africa, according to Tucker (2015), and thus the findings of this research can be said to hold the relevant significance and validity in the research.

1.14 Assumptions
It is assumed that the findings of this study reflect what the status of BIM education is like in most of the South African Universities that were not covered in the study.

1.15 Ethical Considerations
It has been noted that researchers need to protect their research participants, develop a trust, promote research integrity, guard against misconduct that may reflect on their institutions and cope with new challenging problems. First and foremost informed consent will be obtained from the participants after explaining exactly what the research is all about and what it entails.

During the data collection process, the participants’ values, dignity and needs should be respected as well as the sites used for research. Precautions must be taken so as to avoid insulting the programme/course co-ordinators that will be interviewed. Therefore interview questions should be well thought of and should not question the authority of the participants nor the level of education being offered at these Universities.

There may be cases where participants may or may not want their identity to remain confidential, the risks that come with this need to be covered. Authority must be acquired prior to data collection and it is best to have both the researcher as well as the participant benefit from the study. Anticipating the possibility of intimate information being disclosed during the process of data collection is important, if this may arise the participant’s privacy needs to be protected.

1.16 Hypothesis
Schools of Architecture of South African Universities are working towards meeting the AEC industries’ expectations regarding BIM education.

Chapter 2: Literature Review

2.1 Introduction
The research is based on the fact that the construction industry needs more professionals that are BIM competent. This is based on a global context, more specifically in developed countries. Higher learning institutes in the following countries have started incorporating
BIM in their curriculum: United states of America, England, Hong Kong, Germany and Russia (Wong et al, 2010), research shows that these countries have realised the need to have this program incorporated within their industry.

According to Kiprotich (2014), BIM is the solution to the crisis that the construction industry is facing. The construction industry suffers on a global perspective from poor quality delivery of projects, productivity during the construction phases and cost overruns during construction. (Panuwatwanich et al., 2013) The South African construction industry is no exception to these statistics, as they too are suffering.

Full implementation of BIM in the construction industry has not yet been established according to Goedert and Meadati (2008), this is a problem as the industry does not have sufficient professions that are BIM competent. BIM is the solution in resolving problems that the Architecture, Engineering and Construction (AEC) Industry is facing however this tool is not valuable if people are not using it to its full potential.

Teaching BIM to students entering the AEC industry at a tertiary level will help ensure that they are sufficiently equipped to address the problems that the South African construction industry is currently facing. It is firstly important to identify the competencies that need to be taught at educational institutions or trained on the job. Not all higher education institutes in South Africa have incorporated BIM education into their curriculum; this research paper aims to find out why South African higher learning institutes are lagging behind in teaching BIM to their students.

There is currently very little research that has been published on BIM education in South Africa, this paper aims to provide awareness on the importance of teaching BIM to students. Research has shown that the AEC industry has seen the importance of adopting BIM into the industry however awareness on how important it is to teach it at a tertiary level is missing.

The education of BIM in higher learning institutes is becoming significant to students themselves according to research done by Maghiar (2015). Students are realising that the AEC industry needs professionals that are BIM competent. Students that are not BIM competent by the end of their studies are put at a disadvantage. When companies are hiring, they will prefer to hire students that are BIM educated. The willingness of students to learn BIM in the AEC faculties shows the hunger that the future generation of the AEC industry professionals. The future generation that is willing to embrace BIM knowledge will definitely be a force to reckon with.
Challenges arise within higher learning institutes when incorporating BIM education into the curriculum (Wong et al., 2015), this paper will discuss the challenges that they are facing. As well as how higher learning institutes can resolve these challenges, these recommendations on how to resolve these challenges are based on how other institutes internationally have dealt with these matters.

2.2 Methodology of Literature Review
The literature review that we have conducted essentially forms a strong base of the research. It enables the development of knowledge necessary to better understand the focus of the research. One learns to appreciate the research that has been conducted and published with regards to surrounding topics of the ones that are to be covered within one’s own research.

Information was first gathered that would provide a greater understanding of BIM itself. This allows for a clearer view of precisely what BIM is and what it entails within the AEC industry. While in the process, it was presumed that South Africa falls behind in the utilisation of BIM in an international comparison. This leads one into wondering why this is so. It was reckoned that in recent years a great amount of companies in the South African AEC industry do in fact use BIM, where the lack is involved actually exists in the level of BIM that they are running at, as they are not using it to its full potential.

Next was to find literature that would aid in the understanding of why this lack is present in the South African AEC industry. It was then realised that there are not many articles that discuss BIM within South Africa. This created a minor speed bump in the research but may actually have proven to be a positive aspect, as one themselves will be discovering this problem that the South African AEC industry is facing.

It then dwelled upon, that employees within companies in the AEC industry may lack the skills themselves to utilise BIM to its full potential. This leads to the consideration that if these employees had learnt these skills at a tertiary level, it could have a tremendous impact on the utilisation of BIM within the AEC industry.

The focus throughout the entire literature review seemed to constantly change or rather guide one to a more concentrated problem that is occurring in the South African AEC industry. It leads to the working of a literature review that is focused mainly on the BIM education that is recently being included within the curriculum of some courses regarding the AEC industry.
2.3 Research Methods Used in this Problem Area

The articles that have been used within this literature study, have used the following methods in their research surrounding the implementation of BIM education within the Architecture, Engineering and Construction (AEC) courses of higher education institutes.

Content Analysis Method

This is a technique for systematically describing written, spoken or visual communication. It provides a quantitative description. Content analysis is also used to analyse new material recorded by the researchers, and to classify open-ended responses to interview or survey questions. (University of California, 2015).

Barison and Santos (2016) conducted a review and analysis of current strategies for planning a BIM curriculum, where they used the content analysis process to examine a set of papers and syllabuses that document experiences in schools, mainly those that today are identified as leaders in BIM education. The analysis was initially organized through a process of disintegration of the texts in analysis units. These units were defined by the criteria that must be considered when planning a course: prerequisites, goals and objectives, contents, teaching methodologies and evaluation. During the analysis, other three criteria were added: activities, BIM models and teaching resources. (Barison and Santos, 2016).

Survey Method

This method represents one of the most common types of quantitative, social science research. In survey research, the researcher selects a sample of respondents from a population and administers a standardized questionnaire to them. The questionnaire, or survey, can be a written document, an online questionnaire, a face-to-face interview, or a telephone interview that is completed by the person being surveyed. Surveys allow for the collection of data from large or small populations. (Colorado State University, 2016)

In the article titled Building Information Modelling for tertiary construction education in Hong Kong by Wong and Nadeem (2011), questionnaire surveys were conducted with students at undergraduate and graduate levels who studied BIM related courses at the Department of Building and Real Estate (BRE). Which sought to obtain the opinions of the respondents about the strengths, weaknesses and professional opportunities that may arise as a result of learning BIM in tertiary education. (Wong and Nadeem, 2011).
In the article titled The Integration of BIM in the Undergraduate Curriculum: an analysis of undergraduate courses, by Sabongi (2009), the colleges and universities which are members of the Associated Schools of Construction (ASC) were surveyed for their study. The questionnaire which was developed for this study requested quantitative and qualitative information from the respondents. The first section asked for demographic information about the institution. The second section concerned the curriculum at each institution. The third section asked questions about the usefulness of existing technology courses and about obstacles to changing curricula and developing new courses. The final portion of the questionnaire concerned accreditation. (Sabongi, 2009).

In the article titled Integrating Building Information Modelling (BIM) into Engineering Education: An Exploratory Study of Industry Perceptions using Social Network Data, by Panuwatwanich et al. (2013), a different approach of surveying was conducted. An exploratory analysis was conducted by using a qualitative analysis of the data obtained from a popular online social network platform for professionals – LinkedIn. Data in the form of discussion posts and comments associated with BIM in education were captured from a BIM-specific discussion group using NVivo 10 software. Discussion posts and comments were coded to identify important themes emerging from the data, which were then examined, interpreted and discussed. (Panuwatwanich et al, 2013)

**Case Study Method**

Basically, a case study is an in depth study of a particular situation rather than a sweeping statistical survey. It is a method used to narrow down a very broad field of research into one easily researchable topic. Whilst it will not answer a question completely, it will give some indications and allow further elaboration and hypothesis creation on a subject. (Shuttleworth, 2008).

In the article titled Integration of BIM in Higher Education: case study of the adoption of BIM into Coventry University’s Department of Civil Engineering, Architecture and Building, by McGough et al. (2013), a critical evaluation of the content of undergraduate courses within the CAB department in Coventry University as a case study for integration of BIM into Higher education. Critical review of current knowledge in the areas of government policy, application of BIM in the construction industry and the integration of BIM into higher education courses. Project Based Learning (PBL) to encourage group work between students,
therefore having the opportunity to practice aspects of collaborative working practices expected in the construction industry. (McGough et al, 2013).

2.4 Background Literature to Research Problem

2.4.1 Building Information Modelling in the AEC industry

The AEC industry has long been associated with the lack of efficiency, disputes and constantly lower productivity levels as expected or required by the industry due to its largely scrappy or fragmented supply chain. Due to the above mentioned problems, the construction industry has made an effort to come up with techniques that can help improve the quality, enhance productivity and reduce the cost of construction projects (Panuwatwanich et al., 2013).

According to Dermirdoven (2015), one of the most prominent examples is the introduction of BIM, which is defined by the US National BIM Standards Committee (NBIMS) as “The digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.” BIM is not simply a software package, but a human activity that ultimately involves broad process changes in the AEC industry.

Building Information Modelling is a transformative methodology to designing, constructing and operating the built environment. BIM contains a wide range of concepts, tools and workflows which need to be learned and applied by industry stakeholders including learners too (BIM Industry Working Group, 2014). BIM requires the development and use of a computer-aided or made model to simulate all the entire stages of a project (Eadie et al., 2013).

With the implementation of BIM to its full potential, the entire construction process can be better organized to improve or rather enhance efficiency within projects, alter and develop productivity, performance and documentation in the AEC industry, by decreasing inefficiencies, increasing productivity, and increasing group effort and communication (Goedert and Meadati, 2008) as cited by Panuwatwanich et al., (2013). Given these benefits, it is vital that higher institutes of learning start integrating BIM into their existing curriculum to produce future practitioners who will perform better and more efficiently in construction teams (Indraprahasta, 2015).
Despite the acknowledged benefits of BIM and a number of BIM capable tools made available on the market for many years, the diffusion of BIM within the AEC industry has been slow, and its adoption has not been to its full potential (Becerik-Gerber and Rice, 2010; Linderoth, 2010).

According to the WSP Group (2016), these are some of the advantages of using BIM:

- Sharing of information is better which increases productivity.
- The quality of the product increased.
- Designs from architects are of better quality.
- The costs of life cycle are better controlled.
- Most importantly is the improvement in the efficiency during the construction phase.

2.4.2 Status of BIM in South Africa

According to a report from the NATSPECS compiled by Rooney (2015) the findings with regards to the current status of BIM, that is the awareness and or uptake in South Africa is that BIM is hardly used in South Africa and when used it is usually for larger and more complex projects. Most projects are using 2D CAD as a standard software tool (Rooney, 2015).

The findings by Booyens et al. (2013) indicates it is quite clear that different companies recognize the necessity of keeping up to date with new technology and this is why they implement BIM software. However they do not understand the full extent of what BIM is exactly and how it should be implemented. The coordination and communication between the project team needs work. Standard BIM systems needs to be created for example: creating a BIM server for each project. All the participants who are BIM competent will be able to have access to the server resulting in the whole team using the correct and most up to date drawings. The clients need to understand the extra cost will be saved by implementing BIM which will aid in avoiding clashes. They also get a virtual representation of their building once the project is finished. The authors also found that BIM knowledge is growing, but that is still far away from recognizing its full potential. The construction industry participants need BIM education to understand how BIM needs to be implemented. It does not stop by purchasing BIM software. That is only the beginning.

It is extensively anticipated that BIM will lead to changes in the performance of professionals in the Architecture, Engineering and Construction (AEC) industry. It is therefore essential for
the designer or user to take cognisance of or acknowledge and understand the concepts of BIM while undertaking studies at an academic institution (Santos, 2010).

To prepare current existing and future professionals in the AEC industry with the necessary knowledge, understanding and skills to participate in collaborative BIM workflows and joint project delivery, it is therefore essential to recognise the proficiencies that need to be taught in the higher learning institutes or trained on the job (Sacks and Barak, 2010). Succar et al. (2013) as cited by Dermirdoven (2015) describe the distinct BIM competencies as the personal qualities, professional knowledge and technical abilities required by the user to perform a BIM activity or deliver BIM related products.

This is supported by Dermirdoven (2015). For many, experience with BIM begins in academia. The challenges reside in the classic gap between academic focus on disciplinary principles and the industry needs for specific application proficiency. There is a need to establish and improve BIM knowledge, skills and experience of current engineering professionals.

The majority of BIM education available currently concentrates more on providing training in the use of particular BIM software packages (Rooney, 2015). Teaching for both graduates and professionals in open BIM concepts, BIM management and working in collaborative BIM environments appears to still be in its early stages (Rooney, 2015).

As the implementation of BIM increases, the demand for graduates within the Architecture Engineering and Construction industry will not only be disciplinary competencies but also some level of BIM knowledge and capability that will continue to increase. Also, students are becoming more aware of the significance of BIM as further improving their employability skills in an emerging construction and civil engineering market, along with accreditation, this is important in their choice of an appropriate curriculum (Maghiar, 2015). This is further supported by findings of (Fox and Hietanen, 2007) that proficiency is an essential component that can add to the inter-organizational use of BIM, while there are a small number of fundamental barriers. According to Young et al. (2008) lack of sufficient training of using and understanding BIM is the most major barrier to BIM adoption.

The AEC industry needs a widespread teaching and training program if BIM is to achieve extensive adoption. If BIM is not incorporated efficiently into the higher institutes of learning curricula, graduates will lack the skills required to meet the construction industry’s
expectations whereby three-dimensional models which are the foremost medium for expression and communication of design intent (Sacks and Barak, 2013).

2.4.3 Importance of BIM Education
BIM education is the process and or method of learning the conceptual and practical knowledge relating to BIM technologies, workflows and protocols. This learning process would equip all the users of BIM with the appropriate knowledge and understanding of the entire capability spectrum of BIM. It is an effort that ranges from expanding basic awareness about BIM risks and benefits to solidifying specialist BIM knowledge and skills (BIM Industry Working Group, 2012).

BIM education is the main method of communication to spread technology-enabled, process driven and policy-encouraged advances in design, construction and operation of facilities. It enables current and future generations within the AEC industry to mitigate the challenges that are associated with the industry (BIM Industry Working Group, 2012).

According to Hjelseth (2015) the demand for Building Information Modelling expertise is increasing in the entire AECOO (Architects, Engineers, Construction, Owners and Operators) industry. Despite this clear demand, BIM remains understudied in the engineering curriculum at the undergraduate and graduate levels. The AEC industry needs a widespread education and training program if BIM is to achieve extensive adoption (Sacks and Barak, 2013). It is for these aforementioned statements that BIM education is essential.

2.4.4 Courses that may incorporate BIM education
Higher learning institutes are introducing BIM in different courses of the curriculum and Barison and Santos (2010) categorised these courses into Digital Graphic Representation (DRG), Design Studios, BIM Course, Workshops, Construction Management, Construction or Building Technology, Thesis Projects, Workshops and Internships.

2.4.5 Approaches and methods used in teaching BIM
Stand-alone or Single Course Methodology – This method of teaching is basically where BIM is introduced as a BIM course where it does not collaborate with other courses within the curriculum of the institution. It basically teaches or rather covers the entire BIM capability spectrum, that is, the use of the BIM software, creation, development and analysis of BIM models etc. (Wong, et al., 2010).

Integrated or Interdisciplinary Approach Methodology – In this methodology BIM is taught by simulating a real life project whereby students from different courses for example
Construction Management and Architecture students collaborate together to undertake a project using BIM. This method helps to bridge the gap between theory and practice and promotes team work. This method, according to Wong et al (2010) works best for the industry because the industry is interested in students who are able to apply what they learn to practical problems within the field and also able to work or participate in a team.

Distance Collaboration Methodology – This teaching methodology is the same as the interdisciplinary method but only differs in that it involves a collaboration of students from distant or different schools (Wong, et al., 2010).

Workshops – This is more of an approach to incorporating BIM rather than a methodology of teaching it. In this approach BIM is taught in short duration courses (Wong, et al., 2010).

2.4.6 Challenges faced when including BIM education into the curriculum
According to Hjelseth (2015) the demand for BIM expertise is increasing in the entire AECOO (Architects, Engineers, Construction, Owners and Operators) industry. Despite this clear demand, BIM remains understudied in the engineering curriculum at the undergraduate and graduate levels. Succar (2012) as cited by Hjelseth (2015) argues that introducing and integrating BIM education to academia is a difficult process of change and like any other major change process it is probably going to encounter resistance. Some of the reported difficulties include:

- “The complexity of introducing or incorporating new topics into an already crowded existing curriculum.
- Unfamiliarity of lecturers with BIM or lack of sufficient knowledge and understanding of other fast-paced technologies and workflows.
- Unwillingness of some lecturers to alter traditional teaching methods coupled with unwillingness by some to rehabilitate in new topics.
- Inability to bridge the traditional educational mentality of certain departments not wanting to share information with others within the AEC industry and to deliver collaborative courses and programs.”

2.4.7 Collaboration practices and pedagogies
BIM education is best done in a collaborative manner according to Macdonald (2012) who was involved in a project that aimed to find methods of refining collaborative design education of students within the AEC industry. This method of education in BIM will eliminate the fragmentation culture that is currently present in the AEC industry.
According to Smith and MacGregor (1992) as cited by (Becerik-Gerber, A.M.ASCE, Ku and Jazizadeh, 2012) the term collaborative learning refers to a method whereby students work together in small teams towards a common objective. It can be seen as incorporating all team-based pedagogical methods. Collaboration is a behavioral choice (also referred to as paradigm or culture shift within the BIM context), as well as a cognitive capability (Mathews, 2015) (Mathews, postgrad) When properly implemented it can be said that collaborative learning can improve both hard and soft skills and improves higher-level skills (Becerik-Gerber, A.M.ASCE, Ku and Jazizadeh, 2012). Integrative thinking is often addressed as a consequence of BIM rather than a condition of BIM i.e. varsities tend to teach software before teaching the skills of collaboration and thus high-quality multidisciplinary thinking is unlikely to develop. (Manson, 2013)

BIM Technologies and related practices are gradually growing in the AEC industry. The number of undergraduate courses offering BIM-oriented courses is also on the rise (Mathews, 2015). The demand for students who are BIM competent is increasing, i.e. the demand for students who possess digital modelling skillsets and skills related to collaborative practices is increasing (Mathews, 2015). Implementing BIM into the curriculum will enable an interdisciplinary approach that combines effort and results in better student outcomes and facilitates knowledge transfer (Mathews, 2013).

BIM is a tool that requires all professionals to be involved at the initial stages of the project; for the design model to have enough detail it is vital for the construction team to provide all the necessary information at the inception stage of the project (Barison and Santos, 2016).

The main purpose of implementing BIM in the AEC industry is to reach a collaborative project delivery process by uniting individuals, process, and technology (Mathews, 2015). Professionals within the AEC industry must take complete advantage of the technologies, and the integrated collaborative process it promotes (Mathews, 2015). However, too often BIM is seen in AEC education as a technology rather than an integrative practice tool dependent upon collaboration. As it has been implemented, BIM instruction “falls under current definitions of technology, thereby overlooking its potential for more radical conceptual shifts affecting the nature of design expertise or collaboration” (Manson, 2013)

There are two types of collaboration methods, that is, conceptual collaborations and technical collaborations. Technical collaboration tries to or rather solve the problems that are identified through conceptual collaborations (Mathews, 2015). According to Manson (2013) there are
three highest ranked collaboration pedagogies for student learning, that is, group discussions, practice by doing and teaching from and by peers.

According to Bishop, et al. (2009), collaborative practices has the following commonly cited advantages:

- Higher level of integration and communication between the various parties.
- Early involvement of Contractors and some Sub-Contractors in construction projects.
- Increases the capacity to develop trust between various stakeholders in projects.
- Facilitates inter-organisational, knowledge transfer and collective learning.

2.5 Background to Empirical Objectives

2.5.1 To identify Schools of Architecture courses that incorporate the education of BIM and related practices.
This will aid in our understanding of the courses that BIM relate to and to determine the relevance of integrating it into the course. It will also enable us to determine whether the content covered in theory can be applied in practice.

2.5.2 To examine the motivations behind including the education of BIM and related practices into the curriculum of these Architecture courses.
The aspects that have inspired the master plan of teaching BIM at a tertiary level needs to be discovered. This will aid in understanding the aspects that have brought about this great step for the AEC industry. This information will be gathered through the survey of the heads and lecturers within these courses as they will have a better grasp on understanding the need for graduates to have BIM knowledge and skills when entering the AEC industry, as well as the motivations behind this requirement.

2.5.3 To investigate the approaches and methods used in teaching BIM and related practices within these Architecture courses.
This will enable us to discover how BIM is being taught i.e. how is the spread across the years of study, details of the content taught, teaching time allocation and modes of assessing the course. It will also help us determine whether or not these approaches and methods are appropriate in comparison to literature findings.

2.5.4 To explore the problems that Schools of Architecture encounter when incorporating the education of BIM and related practices into the curriculum.
A few issues that arise when incorporating BIM education within curriculums have been discovered through literature, which we found in case studies regarding higher education
institutes in other countries. However problems seem to differ from institute to institute, therefore it will be of great help within this research if a few South African Universities are surveyed so that some problems faced locally are discovered.

2.6 **Theoretical Framework**

For the purpose of our research we will adopt two theoretical frameworks which were tried and tested in research areas that are similar to ours. These two theoretical frameworks are the TPACK (Technology, Pedagogy, and Content Knowledge) framework and the IMAC (Illustration, Manipulation, Application and Collaboration) framework. The former focuses on how to teach with technology and latter focuses more on teaching BIM but however we will consider both of them.

**Technology, Pedagogy, and Content Knowledge framework (TPACK)**

The TPACK framework is basically formed from an interaction of content, pedagogy, and technology knowledge components and how these components relate to the teacher’s understanding of learning technologies. TPACK is the basis of educating effectively with technology, requiring an understanding of the representation of concepts using technologies, educational methods that make use of technologies to teach contents, understanding of what makes concepts hard or easy to learn and how technology can help mitigate some of the difficulties that students face, knowledge of students’ previous knowledge and understanding and theories of epistemology, and understanding of how technologies can be utilised and or applied to build on existing knowledge to develop new epistemologies or to reinforce the old ones (Koehler and Mishra, 2009).

The model below shows the formation of the entire TPACK Framework through the interaction of the aforementioned components.
Interactions of the Components within the TPACK Framework

1. **Content Knowledge (CK)** – This is concerned with the educator’s knowledge and understanding of the theme or subject to be learned or taught for example knowledge of concepts and approaches of developing such understanding and knowledge (Shulman, 1986) as cited by Koehler and Mishra (2009). Thus it is very essential for teachers to understand the knowledge of content as failure to do such might lead to incorrect information to students and development of misconceptions about the content or subject matter (National Research Council, 2000; Pfundt, & Duit, 2000) as cited by Koehler and Mishra (2009).

2. **Pedagogical Knowledge (PK)** – This concerns the educator’s in depth knowledge and understanding of the processes/methodologies of teaching and learning (Koehler and Mishra, 2009). These include general educational purposes, values, and aims. An educator with in depth pedagogical knowledge and understanding is able to recognise how students conceptualise knowledge and obtain skills and how they develop habits of mind and positive attitude towards learning (Koehler and Mishra, 2009).

3. **Pedagogical Content Knowledge (PCK)** – This includes the main business of educating, learning, curriculum, assessment and reporting, such as the conditions that promote learning and the links among main curriculum, assessment, and pedagogy (Koehler and Mishra, 2009).
4. Technology Knowledge (TK) – Technology is always changing as compared to the other two components within the TPACK framework and thus defining it is very difficult (Koehler and Mishra, 2009). This conceptualisation of Technological Knowledge does not conceive a single permanent definition of technology but rather perceives it developmentally, as evolving over a lifetime (Koehler and Mishra, 2009).

5. Technological Pedagogical Knowledge (TPK) – This is an understanding of how education can transform or be affected when certain technologies are used in particular ways. This includes knowing the pedagogical affordances and constraints of a variety of technological tools as they collaborate with suitable pedagogical designs and strategies (Koehler and Mishra, 2009).

The Illustration, Manipulation, Application and Collaboration framework (IMAC)

The IMAC framework’s objective is to support for the development of both technical skills which are commonly known as hard skills (Marando, 2012) and interpersonal skills which are commonly known as soft skills (Marando, 2012) and include collaboration and teamwork (Macdonald, 2012). This framework caters for all AEC industry students irrespective of their year of study (Macdonald, 2012) and it also considers appropriate teaching methodologies at each stage and aims at achieving in depth levels of student development and learning as students advance through their education (Macdonald, 2012). Koltich and Dean (1999) as cited by Macdonald (2012) defines two standards of teaching that is, the transmission model and the engaged critical model which emphasises the need for students to collaborate and gain in depth knowledge and understanding of the concept they are learning and encourages the use of problem based learning as teaching methodologies (Macdonald, 2012).

![IMAC Framework](image)

*Figure 2: The IMAC Framework (Macdonald, 2012)*
The Four Stages of the IMAC Framework

1. Illustration Stage (Knowledge/Comprehension and Receiving/Responding) – This is the preliminary stage in the framework whereby students are taught the key concepts of BIM in their separate area of study (Macdonald, 2012). At this stage the BIM Models will have adequate details to enable lecturers to highlight different components and interconnections to show how buildings are designed (Macdonald, 2012).

2. Manipulation Stage (Comprehension/Application and Responding/Valuing) – At this stage, students start to work together and operate existing models by themselves and will be required to make some alterations within the models to suite or rather incorporate these models in relation to their specific area of study (Macdonald, 2012). Students are also expected to develop their technical and interpersonal skills in this stage (Macdonald, 2012).

3. Application Stage (Application/Analysis and Valuing/Organising) – At this stage, students are assumed to have learned and acquired basic theoretical knowledge about the BIM models and are expected to start applying them in their area of studies to solve simulated real life problems (Macdonald, 2012). Architecture students are expected to start developing and inventing the BIM models from the very beginning and learn how to set these models up for effective collaborative learning (Macdonald, 2012). Engineering students are expected to utilise the BIM software tools to analyse the models using exports from the BIM models (Macdonald, 2012). Construction management students are expected to develop 4D and 5D schedules, and plan logistics and materials ordering using models from the aforementioned fields of study (Macdonald, 2012). Students will be introduced to the roles played by other professionals within the project team, and how the models are used in assisting information and data exchange within the project team, and will also be taught how BIM models can assist in sustainable design and value engineering (Macdonald, 2012).

4. Collaboration Stage (Synthesis/Evaluation and Characterising) – This is the final stage and students across the Architecture, Engineering and Construction (AEC) disciplines collaborate together to work on joint projects (Macdonald, 2012). To enable students to engage and understand what is expected from them, they will
be given slightly finished models to start with, and then be asked to make some amendments to the models as new information is added or arises as the project progresses. The students will also be introduced to the types of standard form of contracts that facilitate BIM and collaborative working, and are expected to improve both their technical and interpersonal skills (Macdonald, 2012).

Currently there is little research on BIM education in South Africa, this research paper will be the frontline to upcoming research on BIM education in South Africa. The significance of BIM in the construction industry has been discussed and the industry is realising the importance of implementing BIM. Since the necessity of BIM in the industry has been established this paper aims to establish the need of knowledge in BIM in South Africa.

The latter framework is directly linked to Barison and Santos (2016) article in that they suggested that the key to teaching BIM is the art of collaboration between the students within the design field (engineering and architecture). This is further supported by Wong et al. (2010) whereby he suggested that this method works best for the industry because the industry is interested in students who are able to apply what they learn to practical problems within the field. This research will also look at how students within the Architecture Engineering and Construction (AEC) fields collaborate with each other in using and sharing BIM model information and how this methodology is taught.

Higher learning institutes that have already introduced BIM into their curriculum are currently facing the following issues according to Barison and Santos (2016):

- The struggle for students in trying to learn and understand the software.
- Difficulty of trying to understand how the process of BIM works.
- The kind of learning environment the institutes will provide for the students.

Understanding the problems that higher learning institutes are currently facing is critical for this research paper. Once there is an understanding of what problems that the higher learning institutes are facing, recommendations can be made to help institutes overcome these problems.

The research will be a replication of the methodology of (Barison and Santos, 2016) to compare results, but this paper will be more focused on a South African context. Barison and Santos, 2016 bring good methods on how BIM can be taught in higher learning institutes, their paper will be a suitable guideline on how this research will be conducted. This research
will be incorporating both frameworks that were described above, in order to define our research objectives.

2.7 Synthesis and Conclusion of Literature Review

The construction industry worldwide is moving towards collaborative practices supported by the use of BIM tools and processes (Macdonald, 2012). And as it has been suggested in most articles that BIM is the solution in resolving problems that the AEC industry is currently facing but this tool is not valuable if people are not using it to its full potential (Becerik-Gerber and Rice, 2010; Linderoth, 2010). Full implementation of BIM in the construction industry has not yet been established according to Goedert and Meadati (2008), this is however a problem as the industry does not have sufficient professionals that are BIM competent. Notwithstanding this, it is essential that higher learning institutes start integrating BIM into their existing curriculum to produce future practitioners who will perform better and more efficiently in construction teams (Indraprahasta, 2015). However, the current shortage of building design professionals trained in BIM remains a barrier to universal adoption of collaborative working practices in the industry. Collaborative working using BIM requires not only the learning of new technologies, but also the learning of a new way of working. Various studies suggest that universities are lagging behind the construction industry in terms of adopting BIM technologies and improved collaborative working practices (Macdonald, 2012). Current building design education practice rarely involves collaboration between students training in the AEC industry professions (Macdonald, 2012).

Based on the findings by Rooney (2015), it is clear that BIM is hardly used in most of the projects in South Africa and if used it is usually for larger and more complex projects. However this is a problem as BIM is being adopted and used by a lot of countries in the world, and since South Africa is a developing country it is very essential for it to extensively adopt BIM in order to develop further pertaining to the construction industry, which is one of the most contributing sectors in the GDP of the country and thus growth and development in this sector will result in the increase in the country’s GDP and thus the entire economy of the country. It is for these aforementioned facts that it was decided to conduct research on BIM education methodologies, looking at all the factors that affect it and focusing on how higher learning institutes use collaboration as a method of teaching BIM technology. This led to the adaptation of the TPACK (Technology, Pedagogy, and Content Knowledge) framework which focuses on how educators teach using technology and the IMAC (Illustration, Manipulation, Application and Collaboration) framework which focuses on how to teach or
rather include collaboration in teaching BIM to students. These two frameworks will form basis of conducting the entire research.

Chapter 3: Research Design

3.1 Introduction
This chapter covers the research design that follows the research onion developed by Saunders, et al (2011). The layers from the outer ring to the inner ring are as follows: Philosophy, Approach, Methodological Choice, Strategy, Time Horizon, Techniques and Procedures. The chapter then closes with Ethical Considerations, which are significantly important for every researcher to adhere to. These are the expected behaviour, standards and values that must be held up, in order to protect the identity and sensitive information of the participants that take part in the study.

3.2 Research Philosophy and Approach
The philosophy of this research design follows the research onion developed by Saunders, et al (2011). There are four research philosophies, namely Pragmatism, Interpretivism, Realism and Positivism. This research design has been guided towards a Positivism philosophy which is associated with qualitative research in that an existing theoretical perspective is going to be tested. However one can argue that Positivism is normally associated with quantitative research and Interpretivism is the one that is general associated with qualitative research. But according to (Saunders, et al., 2011) some qualitative research strategies start with a deductive approach to test an existing theoretical perspective which basically refers to positivism.

There are three types of research approaches, namely Deduction, Induction and Abduction. This research design follows an inductive approach. An inductive inference, known premises are used to generate untested conclusions (Saunders, et al. 2011). Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework (Saunders, et al. 2011). The aim of this inductive approach is to gain a better feel and understanding of the nature of the problem. In this research, the problem being that employees within the South African AEC industry lack adequate BIM knowledge in order fully utilise the process. Going further this may be due to higher learning institutes not incorporating BIM education into the curriculum. Another reason for following an inductive
approach is that it concerns the context in which such events take place, thus the study covering a small sample of subjects is more appropriate than a large one.

![Research Onion](Saunders, et al. 2011)

**Figure 3: Research Onion (Saunders, et al. 2011)**

### 3.3 Research Methodological Choice and Strategy

Qualitative and quantitative approaches should not be seen as polar opposites, rather representing different ends of a continuum (Newman & Benz, 1998). However, a study may tend to lean more towards qualitative than quantitative, much like this one. This is displayed through the open-ended questions that link to interview questions, in comparison to having close-ended questions that depict quantitative hypothesis as well as the use of numbers. Much of the data collecting process is through qualitatively observing a setting. Qualitative research aims to explore and understand social/human problems in regards to the significance of them to individuals or groups. This research process involves emerging procedures and questions, data typically collected in the participants setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data (Creswell, 2009).

A case study strategy of data collection was chosen in order to achieve our research objectives. It explores a research topic or phenomenon within its context or within a multiple real life contexts (Saunders, et al., 2011). The relevance of the use of a case study is that this research aims to gain a rich understanding of the context of the research and the processes being enacted (Eisenhardt & Graebner, 2007). It also enables researchers to answer questions such as why, what and how. This is the reason why this strategy is often utilised in exploratory and explanatory research. There are multiple research methods to collect data that fall under the case study strategy, such as observations, interviews, questionnaires and
documentary analysis. The methods that will be most focused on in this research are interviews and literature reviews. The literature reviews will be based on articles surrounding the teaching methods of BIM within AEC related courses in universities worldwide. The interviews will be conducted towards programme/course co-ordinators in the Schools of Architecture of South African Universities within the Gauteng region.

Figure 4: Flow Diagram of Methodological Choice and Strategy
3.4 Population and Sampling Plan
The population of this research study are South African Universities, while the sample focuses on Schools of Architecture of Universities in the Gauteng region. The sample size is rather small, however, this will suffice as these Universities rank within the top ten Universities within South Africa.

According to Saunders, et al. (2011), sampling techniques may be divided into two types, either Probability Sampling or Non-Probability Sampling. The sample that we are dealing with has been chosen specifically due to the fact that these Universities are conveniently accessible in a geographical perspective, therefore it falls under Non-Probability Sampling, which we will go into more detail.

There are four types of Non-Probability Sampling, namely, Quota Sampling, Purposive Sampling, Volunteer Sampling and Haphazard Sampling. This study will be using Purposive Sampling whereby judgment is used to select cases that will best enable one to answer the research questions and achieve the objectives, therefore it is also referred to as Judgemental Sampling. It is often used when working with very small samples and when researchers wish to select cases that are particularly informative. However cannot be considered to be statistically representative of the entire population (Saunders, et al. 2011).

Purposive Sampling diverges into Extreme Case Sampling, Heterogeneous Sampling, Homogenous Sampling, Critical Case Sampling, Typical Case Sampling and Theoretical Sampling. This study uses Homogenous Sampling which focuses on one particular subgroup in which all the sample members are similar, such as a particular occupation or level in an organisation’s hierarchy. This sampling plan is often chosen when the research question that is being addressed is specific to the selected participants who have similar characteristics which allows exploration of greater depth and minor differences to be apparent. In this study, the participants are programme/course co-ordinators of Schools of Architecture of specific South African Universities.

3.5 Data Collection Plan
There are a multitude of data collection methods available, this study makes use of Semi-Structured Interviews conducted to AEC related programme/course co-ordinators within the chosen Universities. Semi-Structured Interviews are non-standardised and are referred to as Qualitative Research Interviews. A list of themes and key questions are to be covered however the use of them may differ in each interview. Meaning that some questions may be
omitted in particular interviews, given a specific organisational context that is encountered in relation to the research topic. The order that the questions are asked may also vary depending on the flow of the conversation. An addition of questions may be necessary in order to properly cover the research question and objectives.

Due to the nature of the questions and the answers provided within the discussion, an audio recording as well as note taking is used to ensure that the data is properly captured. It has been acknowledged that the interviewee’s consent to make use of audio recording is a necessity. Making notes not only serves as a back-up if the recording does not work, but also helps in maintaining concentration, allows for the jotting down of thoughts that will not be present on the recording, and shows the interviewee that their responses are of high importance to the researcher. The interview schedule may consist of comments in the opening of the discussion, a possible list of prompts to encourage further discussion, as well as some comments to close it (Saunders, et al., 2011). It is best if the interviews are conducted face to face, as it has its communicational benefits and therefore a high standard of data is collected. However telephonic interviews may be possible if it is the interviewee’s preference.

In order to begin the data collection process, a letter had to be received from the School of Construction, Economics and Management of the University of Witwatersrand, to enable the researchers to go out and conduct the interviews. Once this was received, communication was made with the different Universities in which research needed to be conducted on. Multiple phone calls and emails were sent out in order to set up interviews with the required participants. This was a rather repetitive and tedious process, however the staff members involved provided great assistance, so as to direct the group to specific people that would have the knowledge that this study seeks, luckily enough, three interviews were set up with amazingly helpful and qualified people. Below is the background and data collection process that was undergone for each of the three successfully covered Universities.

The entire group was able to meet with the participants associated with each of the three Universities, to conduct the meeting together. In order to convenience the participants, the group travelled to each University in which the venue of the meeting was the participants’ designated office. All interviews followed a similar structure with the same designated group member reading out the questions, so as to keep to a standard throughout and avoid any bias. However the remaining two members would interact with the participant by asking probing
questions in order to gain a greater depth on certain topics as well as creating a comfortable environment through discussion.

Participant A is the co-ordinator of REVIT courses for the whole school of Architecture within their associated University and the interview took 32 minutes. Participant B is the Head of Art, Design and Architecture within their associated University and the interview took 30 minutes. Participant C is actually a combination of three people, an instructor for third year students, an instructor at honours level and a design studio master and coordinator of the third year design and construction theory courses, within their associated University and the interview took 40 minutes. Each interview was equally satisfying and informative, and seemed to intrigue the participants of the study. All the interviews were voice recorded to ensure quality data collection, which was then transcribed to a typed document in order to make data analysis an effective and efficient process.
Table 1: Schedule of Participants’ Information

<table>
<thead>
<tr>
<th>Position of participants</th>
<th>Case A</th>
<th>Case B</th>
<th>Case C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1 - Co-coordinator of REVIT courses for the whole school of architecture.</td>
<td>Participant 2 - Head of Art, Design and Architecture.</td>
<td>Participant 3- Instructor for third year students. Participant 4- Instructor at honours level. Participant 5- Design studio master and coordinator of the third year design and construction theory courses</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age range of participants</th>
<th>30 – 40 years</th>
<th>50 – 60 years</th>
<th>30 – 40 years 30 – 40 years 40 – 50 years</th>
</tr>
</thead>
</table>

<table>
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<tr>
<th>Sex of participants</th>
<th>Female</th>
<th>Male</th>
<th>Male Female Male</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Interview duration</th>
<th>32 minutes</th>
<th>30 minutes</th>
<th>40 minutes</th>
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<table>
<thead>
<tr>
<th>Interview type</th>
<th>Face to face</th>
<th>Face to face</th>
<th>Group face to face</th>
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<table>
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<tr>
<th>Venue</th>
<th>Designated office of participant’s within the University associated with.</th>
<th>Designated office of participant’s within the University associated with.</th>
<th>Designated office of participant’s within the University associated with.</th>
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<table>
<thead>
<tr>
<th>Courses that participants teach</th>
<th>Design building and construction processes.</th>
<th>Design.</th>
<th>Architecture interior design.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>BIM software used</th>
<th>AUTOCAD and REVIT are taught to students. However students may integrate SKETCHUP, LUMION, PHOTOSHOP, RHINO and GRASSHOPPER.</th>
<th>AUTOCAD and REVIT are taught to students. However students may integrate SKETCHUP, PHOTOSHOP, RHINO and GRASSHOPPER.</th>
<th>Focused on AUTOCAD and REVIT. However students dabble in other software that is integrated.</th>
</tr>
</thead>
</table>

<table>
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<tr>
<th>Level at which the courses are taught</th>
<th>Introduction to AUTOCAD in first year. Integrated into REVIT from there on, into post graduate level.</th>
<th>Introduce a computer course to improve student’s literacy. Then teach both AUTOCAD and REVIT through into post graduate level.</th>
<th>Start of teaching AUTOCAD and move onto REVIT. Which is used in all years from under graduate to post graduate level.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Funding of University</th>
<th>Public and Private</th>
<th>Public and Private</th>
<th>Public and Private</th>
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</table>
3.6 Reliability and Validity
Semi-Structured Interviews lack standardisation, therefore it may bring about reliability concerns. As this research is qualitative, there is also a concern of reliability regarding other researchers revealing similar information. The other reliability concern is the consideration of the three types of potential bias. Firstly, interviewer bias is where the interviewer’s tone, comments as well as non-verbal behaviour brings about bias regarding the interviewee’s response to the questions asked. It is also in regard to the way that the interviewer interprets the responses. Secondly, interviewee/response bias is caused by the perception that the interviewee has of the interviewer. The interviewee may be willing to participate, however may be sensitive to certain topics covered and may therefore hold back certain information that they do not wish or are not allowed to share. Thirdly, participation bias is caused by the nature of the interviewees. There may be a reduction of willingness of some people that we would like to interview, as it requires a lot of their valuable time.

Validity refers to the degree to which the interviewer has been able to acquire access to an interviewee’s knowledge and experience, and is able to infer meanings that the interviewee intends from the language used by that person (Saunders, et al., 2011). A high standard of validity may be attained using Semi-Structured Interviews if they are carefully conducted through the scope of clarifying questions, probing meanings, and the ability to explore the responses from different angles.

3.7 Data Analysis Plan
After gathering the data which was transcribed from the recordings of the interview, the raw data was then grouped according to the research questions asked. Thereafter, from the research questions and the responses, key subject ideas were identified in regards to the research questions and these were used as a basis of the analysis. During the process of analysis, the responses were grouped according to similarities and differences and it was found that a lot of responses were similar pertaining to the research questions which made the analysis to be less complex. A detailed interpretation of the responses was done and this was used to formulate the findings of the study.

3.8 Ethical Considerations
It has been noted that researchers need to protect their research participants, develop a trust, promote research integrity, guard against misconduct that may reflect on their institutions and cope with new challenging problems. First and foremost informed consent will be obtained from the participants after explaining exactly what the research is all about and what it
entails. During the data collection process, the participants’ values, dignity and needs should be respected as well as the sites used for research. Precautions must be taken so as to avoid insulting the programme/course co-ordinators that will be interviewed. Therefore interview questions should be well thought of and should not question the authority of the participants nor the level of education being offered at these Universities.

There may be cases where participants may or may not want their identity to remain confidential, the risks that come with this need to be covered. Authority must be acquired prior to data collection and it is best to have both the researcher as well as the participant benefit from the study. Anticipating the possibility of intimate information being disclosed during the process of data collection is important, if this may arise the participant’s privacy needs to be protected.

Chapter 4: Findings and Data Analysis

4.1 Introduction
In this chapter a presentation of the analysis and findings of the research study will be, and also a brief description of the research sample and the challenges encountered during the collection of data and how these challenges were addressed. The research findings will be obtained through a thorough and in depth analysis of the data collected which will form basis for the conclusion and recommendations of the study. A general content textual analysis of the transcribed interviews was used, in which we tabularised a summary of the responses of the participants representing each University that were collected in the interviews conducted. Data collection was done through interactive face to face interviews with course/programme co-ordinators within the Schools of Architecture of three Universities within the Gauteng region. The following, are the key subject ideas that will be used during the data analysis process.

- Understanding of BIM
- Incorporation of BIM
- Influences for the incorporation of BIM
- BIM Software
- Teaching Methods
- Collaborative Practices
- Difficulties in Incorporation
• Difficulties in Teaching

4.2 Challenges Encountered
During the process of collecting, a couple of challenges were encountered. The first one was the difficulty in setting up interviews with the participants as they are very busy people with very tight schedules. Another major challenge that was encountered was that one of the participants within the research sample could not be reached due to the fees must fall movement and this is then one of the limitations of the study. However these challenges did not have a huge impact on how the research study was carried out and how the data was collected but rather the latter challenge did reduce the degree of validity or weight of the research by a very small margin especially the conclusion reached, however this was deemed as a limitation and thus the findings and conclusion reached can be said to be valid.

4.3 Findings
The table below presents a summary of the responses of the participants representing each University that were collected in the interviews conducted.
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| Understanding of BIM    | • BIM is building information modelling and working in architecture firms that used BIM software, one can take it from a REVIT point of view.  
• REVIT model is intelligent and because of BIM you can do scheduling from that.  
• The communication of information can be transferred throughout all kinds of different fields and disciplines. | • BIM is an intelligent digital representation of a proposed or already built structure.  
• You can either draw visualise it digitally, or you can go and record an existing structure and represent it digitally for your own purposes which might be for ecstatic, building performance or climatic performance of a building.  
• It is also the pragmatic use of one type of software that cohesively generates and updates 2D and 3D drawings simultaneously. | • BIM modelling is the incorporation of 3D modelling with additional information to the model giving you additional 3D feedback essentially which they are trying to integrate now. |
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| Incorporation of BIM| • An external company comes in and teaches it to the students.  
• It is taught as a standalone however it's also incorporated into courses within assignments.  
• They begin with basic training and through the years move onto an advanced training.                                                                                      | • They implement BIM knowledge in first year to give the students the grounding because students come from different backgrounds and schools, thus they are on different levels in terms of literacy regarding computers.  
• So they try to introduce it early in order to give the students some foundation about how to use computers and begin to think of the fundamental principles of BIM at a very elemental level and use 3D modelling software (REVIT).  
• A course runs around 4 to 5 weeks in order to make students more aware about BIM, so roughly 4 to 5 lessons.                                                                             | • In the beginning years there is a standalone subject which is the teaching of the software and in third year which a cumulative year most important project which runs through the second semester is a complete integration of the theoretical and historical premises along with design and construction but it’s not accessed separately. |
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<td>Influences for the Incorporation of BIM</td>
<td>• Its practice at the moment, whatever is happening outside of university has been looked at in order to get students up to grade; they need to keep up with what’s happening out there.</td>
<td>• Feedback that they receive from the employers because they were complaining that they employ the students and have to teach them the BIM software and that wastes their time and money. • However the University argues as academics that they not here to produce students who should know how to fully utilise these software but to introduce them to the basics because these software evolve overtime and therefore they battle to keep up with these changes.</td>
<td>• The main reason is about the industry and they have to adhere to what the industry requires. • They are trying to ready the students for the industry. If you talk to people in the industry you will find it is not integrated that well yet, so we hope to influence students in that way.</td>
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<td>BIM Software</td>
<td>• Students are introduced to AUTOCAD first and then move onto REVIT.</td>
<td>• Focus on teaching AUTOCAD and REVIT.</td>
<td>• The University started of teaching AUTOCAD but now focus on teaching students to use REVIT.</td>
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<td>• These are the software taught at the University, however some students do learn other software by themselves, such as SKETCHUP, PHOTOSHOP, LUMION, RHINO and GRASSHOPPER.</td>
<td>• However students may use other software by themselves, such as SKETCHUP, PHOTOSHOP, RHINO and GRASSHOPPER.</td>
<td>• Some students dabble in the use of other software.</td>
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<td>• These are some clip on courses which are 3D modelling programs using meshes.</td>
<td>• If they are able to be linked to other software, they go for it, but if it cannot they try stay away from them due to licensing reasons.</td>
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| Teaching Methods | • They look at how one would start using BIM, start getting used to the idea that a model is a live thing and it’s one thing and the idea is to get used to the fact that a model, if you change it somewhere, it’s going to change your drawing somewhere else, because it’s one thing.  
• It goes from a basic teaching method to an advanced teaching method, basic meaning how to construct a wall, how to put in a door, a window, how to do your site.  
• Then advanced goes onto more families, scheduling, massing outside, form manipulation.  
• Within Architecture there’s design as a subject and there’s construction as a subject and they use that same model to create design drawings and construction drawings. They are different phased drawings, in the stages of work. These two subjects work hand in hand. | • There is a lecture and do process in that the lecturer gives a lecture and students work on their screens so it is more of an interaction of the students with the lecture and an assisting tutor, so it is really hands on kind of thing and one to one teaching.  
• In first year they teach the software separately but in third year the software is integrated with other subjects whereby all these software are packaged together in order to produce the final outcome of the project given. | • A typical scenario where there is a lecture and a project, for evaluation they have an online assessments.  
• A computer lab is used, where the lecturer uses a projection to explain the work and the students follow on their designated computers. |
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| Collaborative Practices| • In terms of collaboration between the different schools, they have not done that yet but would love to, because that’s the whole beauty of BIM, you can have a central file where everybody saves to and this embraces collaboration between the different fields.  
• If that could work in the future it would be a great idea. | • They do not collaborate with other professions mainly because they are isolated from the schools within the engineering and built environment due to the geographies and set up of the schools.  
• Collaboration is the way forward and with the #feesmustfall protests we must cut down on the assignments that can help us to do the things together and that can help us enhance the understanding.  
• This is the way we should be learning as this is how things are in the working industry.  
• So the key is looking at the curriculum and looking at where it can sensibly happen without any prejudice to any group. | • What they do in their department is quite isolated, they don’t just teach them Revit.  
• They integrate it into their projects sometimes these projects may go over to other engineering departments this maybe one project per year because it’s a lot of time to do such.  
• At this stage their course is efficient, however collaboration is a good idea and its worth pursuing. |
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| Difficulties in Incorporation | • Not much of a difficulty, except maybe looking at the costs involved. So the lengths of the workshops are only a certain amount of a workshop length, because of the costs.  
• Time is a difficulty as well. So the REVIT and AUTOCAD courses only happen in the second semester because the first semester is so full already.  
• It’s quite difficult to convince staff members to introduce it earlier, because nobody wants to move what they already had programmed. | • The difficulty is the people who will teach these courses as this is a highly specialised area. So the biggest challenge is to attract and keep the young people who can teach these courses as older guys are no longer interested.  
• The second one is the budget for these software packages as the university only gives out a limited budget and they have to fight and motivate why they need the latest software.  
• The third challenge is that students come from different backgrounds and schools and thus it becomes difficult to seat all of them in one class as the privileged group will be extremely bored while the disadvantaged group will be highly interested and wants to learn as they do not have any knowledge of computers. | • The main problem was linking it to the actual design programs that they have, what would be the point of teaching students a piece of software that would not be used.  
• They have to figure out how they use the software properly, at the beginning it was a challenge because other lectures didn’t understand the software properly but now more lectures understand it. |
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| Difficulties in Teaching       | • Students find it hard to grasp in the beginning because it’s learning a new program and they’ve already got so much work to do; now they also have to tackle doing the work and learning the program.  
• The hardest thing that I found, is the understanding that an intelligent piece of wall for instance in a BIM model isn’t affected in just the one view, but in every view, because it’s one thing. | • The facilities are a big challenge for instance, the one to one teaching.  
• For it to be effective you have to have a certain ratio first of all and so if you have 45 students in one session as we normally have then it is difficult for the lecturer to have total control.  
• For that 45 you need to have 10 other people so that you have 1:4 ratio so that the lecturers can go to 4 before losing the class, but imagine if you have one lecturer around 40 students the focus time is lost easily.  
• So we usually separate the class into two which is more money. | • It can be difficult to grasp the software.  
• The design aspects of the exams of the year, they have to design a building and contract document it properly, all of this gets done with Revit.  
• So it’s a big exam students have to do and the University just had to make sure that the students have more time to prepare for the exam so they had to move it from a second semester course to a first semester course. |
4.4 Data Analysis

4.4.1 Understanding of BIM
When asked about their understanding of BIM, all the interviewees defined BIM as an intelligent 3D modelling tool that is used for the flow of information. The interviewees seemed to only view BIM as a software tool rather than a process as they all mentioned software such as Revit in their answers.

4.4.2 Incorporation of BIM
In all the universities interviewed, BIM software has been incorporated for a while now. When asked about how it was incorporated, all the interviewees said that they incorporate these BIM softwares as ‘Standalone’ in the first and second year of study and in final year and postgrad it is then incorporated with other courses. In two of the three universities, special companies who develop these software come and teach students. This is what one of the interviewees said “What we’ve done is had a look at an external company who comes in and teaches it to the students, so we don’t do it ourselves, and when I was in practice, we were taught by that company, so I was asked to source that company and bring it into this school as an external source.” Also one of the interviewee mentioned that in their university they have a diploma. The interviewee mentioned that BIM is mostly integrated with design courses within the curriculum.

4.4.3 Motivation to Incorporate BIM
When asked about the motivation to incorporate BIM into their curriculums, all the interviewees said that the decision for them to teach BIM supporting softwares was based on the industry’s requirements. This is what one of the interviewees had to say “Firstly it is the feedback that we receive from the employers because they were complaining that we employ your students and we have to teach them the BIM software and that wastes our time and money, but we argue as academics that we are not here to produce students who should know how to fully utilise these software but our job is to introduce them to the basics because these software are different and evolve overtime and we therefore cannot really keep up with these changes”.

4.4.4 BIM Software
In two of the three universities, these are the BIM supporting softwares that are being taught, i.e. Revit, AutoCad, Grasshopper, Rhino, Photoshop, and SketchUp. In one of the universities they use Lumion software. The most common softwares being used in all the three
universities are Revit and AutoCad. In one of the universities, they only teach these two softwares only.

4.4.5 Teaching Methods
In all three universities, they teach the aforementioned software in a typical lecture teaching method where a lecturer stands at the front of the room and recites information pertinent to the software content in this case. In some of the universities there are tutors during the lecture who assist students with questions. In all the universities, practitioners or teachers from certain companies who develop these BIM supporting software teach, and this is done in a form of a workshop. However at the later stages, the Universities’ lecturers take over once the students have been taught the key basics of the software and are expected to apply them in projects or assignments.

4.4.5.1 How Teaching Methods Affect Learning Outcomes
Having supportive staff such as tutors, according to one of the respondents is helpful for the students, as they are able to consult with the tutors during the classes. It is clear that having a supportive team is helpful; students cannot get special attention when there is only one staff member teaching the students. Having professionals from companies such as Educad to teach the students at the beginning, as one respondent suggested that some lecturers do not have the full understanding to actually teach these software to the students in the short time span they are given.

Teaching students the software in a practical manner is essential for the students to be able to grasp the concept they are being taught. The students are able to see what they are doing on the computers while following the instructor from the projector in front of the class. All of the respondents made it clear that the software that the students are being taught are difficult and for students to have this type of teaching is essential to be able to grasp the concept rapidly.
4.4.6 Collaborative Practices
When asked if the teaching methods being used promote collaborative practices and if they do collaborate with other schools or departments within the built environment, all interviewees said they do not teach BIM in a collaborative manner as students from the architecture department only work on these software in an isolated manner. However, all the interviewees showed some enthusiasm in teaching BIM supporting softwares in a collaborative manner in the future when asked if they would adopt this type of teaching method in the long run. One of the respondent mentioned that they do collaborate with students from the engineering department but not in any BIM supporting process or software.

4.4.7 Difficulties in Incorporation
When asked about the difficulties of incorporating BIM software into the curriculum, all the interviewees mentioned that one of the difficulties is that the software is very expensive to buy and the license prices increase drastically. Another common difficulty is that it is a challenge to adjust the existing curriculum and incorporate the BIM software and integrate it with other courses within the curriculum. One of the interviewees mentioned that it is difficult to get people who can teach these software and this is what the respondent said “I can think of all these nice courses but who is going to teach? The difficulty is the people who will teach these courses as this is a highly specialised area. So the biggest challenge is to attract and keep the young people who can teach these courses as older guys are no longer interested.”
4.4.8 Difficulties in Teaching
When asked about the challenges encountered when teaching the BIM supporting software, all the interviewee mentioned that it is difficult to grasp the software especially with the time frames allocated to the workshops and also due to the already crowded curriculums. This is a challenge to both lecturers and students. However one of the interviewee mentioned that another difficulty in teaching BIM supporting software is that there facilities in the university are not sufficient enough to accommodate all the students, which makes it difficult for the lecturer to control the class and for some students to grasp the content.

Chapter 5: Conclusions and Recommendations

5.1 Evaluation of Empirical Questions
Do Schools of Architecture of South African Universities provide their students with the necessary skill sets of using BIM in order to meet the Architecture, Engineering and Construction (AEC) industry’s expectations?

In seeking to find out whether the Schools of Architecture of South African Universities do provide their students with the necessary skill sets of using BIM in order to meet the Architecture, Engineering and Construction industry’s expectations, the research study examined the teaching methods that the Universities within the Gauteng region used in order to teach BIM, the challenges that they encounter when teaching BIM, the course(s) in which BIM is incorporated into i.e. the courses that are integrated with BIM, the motivation to incorporate BIM into their curriculums.

5.2 Key Findings
All the interviewees understand BIM as a software tool rather than a process of generating virtual models that represent building facilities. This is evident from the data analysis in that all the interviewees referred to Revit as BIM.

In all the universities interviewed, BIM is taught in different ways based on the level of study. In the early stages, it is taught as a standalone course and this is done through a workshop approach where practitioners from the companies that develop these software come and teach the students, and after some time the University’s lecturers take over and teach the students in a more application approach way. The teaching is done in a typical lecturer method where a lecturer stands at the front of the room and recites information pertinent to the content of the software.
In all the universities BIM supporting software are integrated with design-related courses. The reason for the incorporation of BIM into the curriculum was based on the call from the industry that a lot of graduates lack the skills of using BIM and its supporting softwares. The choice of software is also industry driven.

The challenges that the universities encounter when incorporating and teaching BIM is that the supporting software are very expensive, the curriculums are already crowded and thus it is difficult to incorporate and integrate BIM with other courses. Also the software is hard to grasp both by students and lecturers and thus becomes hard for University staff to teach them. This results in unnecessary costs to some Universities as outsourcing people from the software companies is costly.

Lastly, the universities do not teach other BIM related tools more specifically collaborative practices and this is one tool that is required by the industry. However the Universities are looking forward in adopting this method especially regarding the BIM supporting tools in the long run.

5.3 Contribution to the Construction Industry

This study aims to investigate the current BIM education status, the pedagogies used and the challenges faced when incorporating BIM into the curriculum, within the Schools of Architecture in South African Universities (Gauteng region).

The primary research question of the study is that “Do Schools of Architecture of South African Universities provide their students with the necessary skill sets of using BIM in order to meet the Architecture, Engineering and Construction (AEC) industry’s expectations?” Since it has been said that the Universities within the Gauteng region are moving towards the right direction in meeting the industry’s requirement with regards to BIM education, and that these Universities are lagging behind in teaching collaborative practices associated with BIM, it is therefore recommended that in order to fully meet the industry’s needs, these Universities must consider teaching BIM supporting software in a collaborative manner where students from different schools/departments within the AEC faculty come together and do a real life project using BIM software. This will be very beneficial to the students in that they will be able to fully understand their role at work after graduating and this will address the problem that the industry faces pertaining to graduates that are not BIM educated. According to Macdonald (2012) BIM education is best done in a collaborative manner and this is the best method of learning (Barison and Santos, 2016).
It is also recommended that the industry must play its role in helping the academia sector to meet its required call by providing some resources such as information and capital in order to address the challenges that are encountered by academia and also the alternative teaching methods that must be used in teaching BIM. Thus in short, there must be a close relationship between the two sectors.

5.4 Recommendations for Future Research
Further research is needed to determine how the collaboration of schools within the AEC sector can be achieved through the already crowded curriculums. As it has been noted during the interviews within the different Universities that additions into the curriculum proves to be quite a difficulty as it not only increases the students’ work load but finding a slot to fit in the addition is a problem as lecturers of other courses don’t want to rearrange and reduce their allotted times.

Furthermore, research is needed in order to comprehensively define what BIM is as there is a lot of confusion regarding the understanding of BIM. A lot of people within the AEC industry and beyond think that BIM is a software tool just like Revit and AutoCad.

5.5 Conclusion
It is evident that BIM is gradually being adopted in the South African AEC industry and also based on the literature review it can be seen that a lot of countries are starting to use BIM in their projects and thus it is imperative for graduates to enter the industry with the necessary
skillsets in order to meet the industry requirements. Thus graduates who do not have these necessary skillsets can be at a disadvantage when it comes to employment.

To answer the research question, it can be said that the Universities in the Gauteng region are moving towards the right direction in preparing graduates to meet the AEC industry’s expectations with regards to BIM despite the challenges they face when incorporating and teaching BIM and its supporting software. However these Universities are lagging behind in terms of promoting collaborative practices and this is something the industry requires, thus it must be addressed as soon as possible.
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Annexures

Annexure A

University of the Witwatersrand
School of Construction Economics and Management
Participant Information Sheet

Study title: Teaching BIM in Schools of Architecture within South African Universities.

To whom it may concern

We, as Quantity Surveying Honours students from the University of The Witwatersrand, are conducting research on the education of BIM. Emerging professionals within the South African Architecture, Engineering and Construction (AEC) industry lack the knowledge and skills necessary to utilise BIM to its full potential. This results in companies spending more money and time on their Continuing Professional Development (CPD) programmes, whereas these BIM abilities could be taught at a tertiary level. This study aims to investigate the current BIM education status, the pedagogies used and the challenges faced when incorporating BIM into the curriculum, within the Schools of Architecture in South African Universities (Gauteng region).

We are inviting you to participate in our research study as a programme/course co-ordinator in one of the selected South African Universities. Your involvement will require you to engage in discussion through a semi-structured interview in which we will ask of you to share information pertaining to BIM education in relation to your school of Architecture. The duration of the interview may be between 30 to 60 minutes long depending on the pace of our discussion, relevant aspects that may arise, as well as your availability. The interview could preferably take place at your offices or any place of your choosing and at your convenience.

Aside from undertaking this interview in order to complete our research successfully, we want to ensure that the experience is beneficial to you as well. A summary of the findings of this research study may be shared with you if requested, which may supply you with information regarding other Universities on what BIM software is being taught and how they teach BIM concepts and tools. Creating awareness and sharing this information should not be of detriment to the individual participants nor to the University which they are representing and we do not see any risks that may occur through our research study.

Please note that your participation in this study is completely voluntary and refusal to participate or withdrawal at any time will not have any negative consequences. If any time in the interview, you feel uncomfortable answering specific questions, we will disregard that question. Your identity and the University which you represent will be kept anonymous along with any information deemed confidential. The Universities part taking in this research study will not be directly identifiable as they will be referred to as University A, B, C, etc. All research data will be stored and secured under password for at least five years.

Below are contact details if you require further information or have queries concerning the study.

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Simphiwe Radebe 740516@students.wits.ac.za 073 983 7743
Kurhula Mathye 549237@students.wits.ac.za 072 417 0591
Supervisor: Adeyemi Akintola adeyemi.akintola1@students.wits.ac.za 073 538 8583
Head of School: David Root david.root@wits.ac.za 011 717 7663
Annexure B

University of the Witwatersrand
School of Construction Economics and Management
Research Instrument - Interview Questions

Below is a list of questions that will be asked during the interview with the programme/course co-ordinators from the Schools of Architecture of the chosen South African Universities in the Gauteng region. Since these are open ended interview questions, probing questions may arise during conversation, which will enable us to retrieve more depth on certain aspects.

1) Could you please give us a brief description of your job as programme/course co-ordinator?
2) It would be helpful if you could briefly tell us about your understanding of BIM.
   a) Has BIM influenced the way you do your work in any way – if so in which ways?
3) Here in the School of Architecture, has BIM and knowledge related practices/processes been incorporated into your curriculum?
   a) Could you describe how this was done? (Standalone, part of existing courses, etc.)
   b) When were they included and in which specific courses?
   c) If not, do you plan on incorporating them in the future and if so when?
4) What influenced the decision to incorporate/include BIM and related practices into the curriculum?
5) What BIM software is being taught in the relevant courses?
   a) Are there any particular reasons for the choice of software?
6) Could you tell us in some detail, which approaches and methods are used in teaching BIM?
   a) Are methods of instruction that promote learning of BIM collaborative practices employed (between students from different Schools within the Engineering and Built Environment Faculty)?
   b) How is this achieved?
7) Are there difficulties faced when incorporating BIM into the curriculum?
8) Are there difficulties faced when teaching BIM?
9) If so, what are the difficulties and how were they addressed?