WORKPLACE-BASED LEARNING: A STUDY IN BIM-ENABLED CONSTRUCTION PROJECTS

By

Sivagayinee Gangatheepan

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Table of Contents

CHAPTER 1: INTRODUCTION 11

1.0 Introduction 11

1.1 Research Background 11

1.2 Research gap and justification 14

1.3 Research aim and objectives 16

1.4 Overview of research methodology 16

1.6 The structure of the thesis 18

1.7 Summary 18

CHAPTER 2: LITERATURE REVIEW 19

2.0 Introduction 19

2.1 Digitalisation 19

2.1.1 Benefits and Challenges in digitalisation 20

2.1.2 Digitalisation in Construction Industry 22

2.2 Technological change and skills 24

2.3 Building Information Modelling (BIM) 29

2.3.1 BIM usage in the construction project lifecycle 31

2.3.2 BIM maturity Levels and BIM Capability stages 33

2.3.3 BIM benefits and challenges 35

2.3.4 Learning in BIM 40

2.4 Learning 41

2.4.1 Need for 'Workplace-based learning' 44

2.4.2 Conceptualising view of learning 45

2.4.3 View of learning within Projects 48

2.4.4 Types of workplace-based learning 49

2.4.5 How learning happens in projects 51

2.4.6 Learning Paradigms 58

2.5 Connectivism 62

2.5.1 Characteristics of Connectivism 63

2.5.2 Global View of Connectivism 64

2.5.3 Conceptualisation of the learning model 65

2.6 Summary 70

CHAPTER-03: RESEARCH METHODOLOGY 71

3.0 Introduction 71

3.1 Research philosophy 72

3.2 Approaches to research: Abductive Approach 74

3.4 Research strategy and Research Method 76

3.4. 1 Adopted Research Methodology - Case study Approach 77

3.5 Research Design 80

3.5.1 Phase 1: Theoretical study (Literature Review) 81

3.5.2 Phase 2: Semi-Structured Interviews 81

3.5.3 Case study design 87

3.6 Data collection technique for Case study approach 89

3.6.1 Data Collection within Case study approach: Meeting observation, semi-structured interviews and project documents 91

3.6.1.1 Meeting observation 91

3.6.1.2 Semi-structured interviews within case studies 92

3.6.1.3 Project documentation 92

3.7 Data Analysis techniques 93

3.7.1 Coding process 94

3.8 Validity and Reliability 97

3.9 Ethical considerations 97

3.10 Summary 98

CHAPTER 4: DATA ANALYSIS AND FINDINGS 99

4.0 Introduction 99

4.1 Semi-Stuctured Interview findings (Phase 2) 99

4.1.1 How learning is perceived in the workplace in BIM-enabled construction projects 100

4.1.2 Learning opportunities provided in BIM-enabled construction projects 102

4.1.3 Learning factors related to individuals/team 103

4.2 Semi-Structured Data Analysis 105

4.3 Case study Analysis and Findings 106

4.3.1 Mechanical and Electrical Installation issues 108

4.3.2 Designing the vent above the door 114

4.3.3 Use of laser scanning 118

4.3.4: Pipe work installed on-site 122

4.3.5 Fittings of Lights for halo effect 127

4.3.6 Point cloud scan training 131

4.4 Summary 135

CHAPTER 5: DISCUSSION AND DEVELOPMENT OF THE MODEL 136
5.0 Introduction 136
5.1 Need for Learning in workplace 136
5.2 Learning in the workplace through the lens of Connectivism 139
5.3 A Model for Learning in the workplace 141
5.3.1 Transition for the Learning Model for workplace practice in digitally-enabled projects .. 141
5.3.2 Key Learning aspects in learning in the workplace in digitally- enabled construction projects .... **Error! Bookmark not defined.**
5.3.2.1.2 Learning Context 149
5.3.2.2.1 Learning through Participation and Interpretation 152
5.4 Summary 165
CHAPTER 6: CONCLUSION 166
6.0 Introduction 166
6.1. Objectives and Research Achievements 168
6.2 Limitations of the Research 171
6.3 Contributions of the Research 172
6.4 Directions for Future Research 173
6.5 A reflection on the research journey 174
Interview Questions 219
Case studies 231
Mezz underneath the stairs 231
Data assignment 232
Clashes between cable trays and beams 233
Toilet Connection 234
Pipe work location 235
f) Lighting settings out 236
Lift near the lobby 238
Conflict on window position 239
Structural movements and screeds 240
Cable tray clashes 241
Ducts in the lobby clashing with the pedestal 242
Projectors clashing 243
Clash between door heater and pipeline 244
Details about the sockets and distribution board 245

List of Tables

Table 2.1: Summary of BIM definitions 31
Table 2.2: Levels of BIM 34
Table: 2.3- BIM benefits 37
Table 2.4: BIM constraints 40
Table 2.5: A Summary of skills definition .... **Error! Bookmark not defined.**
Table 2.7: Different perspectives of learning 64
Table 3.1: List of Interviewees .... **Error! Bookmark not defined.**
Table 3.2: Selected case studys for data analysis 91
Table 3.3: Evaluation of case study evidence 93
Table 4.1: Ways learning is perceived in BIM construction projects 102
Table 4.2: Learning opportunities provided in BIM construction projects 103
Table 4.3: Learning factors that influence individual/team impact on learning in BIM construction projects 104
Table 4.4: Learning aspects from case study-1 113
Table 4.5: Learning aspects from case study-2 117
Table 4.6: Learning aspects from case study-3 121
Table 4.7: Learning aspects from case study-4 126
Table 4.8: Learning aspects from case study-5 130
Table 4.9: Learning aspects from case study-6 134

List of Figures

FIGURE 2.1: WHAT IS DIGITALISATION (SIEMENS, 2016) 20
FIGURE 2.2: BENEFITS OF DIGITALISATION (SEIMENS, 2016) 21
FIGURE 2.3: CHALLENGES OF DIGITALISATION (SIEMENS, 2016) 22
FIGURE 2.4: KEY SPECTS OF DIGITAL TRANSFORMATN (SCHOBER AND HOFF, 2016) 23
FIGURE 2.5: COMPARISON BETWEEN "TRADIIONAL" AND BIM PROCESS (AZHAR ET AL., 2012) 30
FIGURE 2.6: BIM USAGE IN PROJECT LIFECYCLE (COMPUTER INTEGRATED CONSTRUCTION RESEARCH PROGRAM, 2010) 33
FIGURE 2.7: BIM MATURITY MODEL AND BIM CAPABILITY STAGES (SUCCAR 2009) 34
FIGURE 2.8: LEARNING MODEL FOR WORKPLACE (JORGENSEN AND WARRING, 2011) 65
FIGURE 2.9: THE 3P MODEL FOR WRKPLACE-BASED LEARNING (TYNJALA, 2013) .... **ERROR! BOOKMARK NOT DEFINED.**
FIGURE 3.1: RESEARCH DESIGN OF THE STUDY 72
FIGURE 3.2: INDUCTIVE AND DEDUCTIVE APPROACH FOR THE STUDY 76
FIGURE 3.3: HOLISTIC MULTIPLE CASE DESIGN FOR THE STUDY 79
FIGURE 3.4: ANALYTICAL PROCESS FOR DEVELOPING A MODEL FOR WORKPLAXE-BASED LEARNING 80
FIGURE 3.5: LEARNING SPACE GENERATED THROUGH BIM MODELS-BIM-ENABLED PROJET-1 88
FIGURE 3.6: SPACES GENERATED IN BIM-ENABLED PROJECT 2 89
FIGURE 3.7: THE CODING PROCESS 95
FIGURE 3.8: LEARNING ASPECTS AFTER AXIAL CODING 96
FIGURE 4.1: THREE MAIN AREASIN SEMI-STRUCTURED INTERVIEWS 100
FIGURE 4.2: CASE STUDY SELECTION 107
FIGURE 5.1: MODEL FOR WORKPLACE-BASE LEARNING .... **ERROR! BOOKMARK NOT DEFINED.**
FIGURE 5.2: LEARNING CONDITIONS 147
FIGURE 5.3: LEARNER'S FACTORS FOR WORKPLACE-BASED LEARNING 148
FIGURE 5.4: LEARNIN CONTEXT FOR WORKPLACE-BASED LEARNING 149
FIGURE 5.5: LEARNING PROGRESS 151
FIGURE 5.6: SUB-ELEMENTS OF IBNSIGHT THAT IMPACTS WORKPLACE-BASED LEARNING 158
FIGURE 5.7: SUB-ELEMENTS OF ALIGNMENT THAT IMPACT WORKPLACE-BASED LEARNING 160
FIGURE 5.8: SUB-ELEMENTS OF ENGAGEMENT THAT IMPACT WORKPLACE-BASED LEARNING 162
FIGURE 5.9: LEARNING OUTCOMES OF WORKPLACE-BASED LEARNING 164

Abbreviation

2D-Two Dimension

3D-3 Dimension

AV-Audio/Video

BIM –Building Information Modelling

CAD- Computer-Aided Design

CEEMET- Council of European Employers of the Metal Engineering and Technology

CITB- Construction Industry Training Board

CoP- Community of Practice

COVID- Coronavirus diseases.

CSQ- Construction skills Queensland

HM Treasury- Her Majesty's Treasury

ISO standards- International Organization for Standardization

NBS-: National Bim Survey

OL- Organisational learning

PAS-Publicly Available Specifications

RICS-Royal Institue of Charted Surveyors

SSC- Sector Skill Councils

UKCES- UK Commission for employment and skills

UK-United Kingdom

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Abstract

Building Information Modelling (BIM) is a fast-emerging technology that has promoted digital transformation in the construction project lifecycle through changing the ways in which people work. However, empirical studies show that professionals in the construction industry are still reluctant to adopt BIM in their construction projects due to a lack of skills and suitable learning approaches. Furthermore, embracing an appropriate learning approach is still challenging in built environment projects, which are generally complex, temporary, unique and uncertain due to their fragmented nature. To achieve more successful BIM-enabled construction projects, a flexible and relevant learning approach for the workplace needs to be determined. Consequently, resolving this issue requires identification of the key learning aspects that influence creation of a suitable learning approach. The aim of this doctoral study is to explore how workplace-based learning could be designed and implemented in BIM enabled-construction projects.

Learning that takes place in construction projects is predominantly determined by complex social practices. On the other hand, BIM – which professionals desire to adopt in construction projects – is interwoven with both interactions with humans and artefacts. To holistically investigate the learning in BIM-enabled construction projects, 'Connectivism', a new learning approach for the digital age, is adopted in this study. This explains the complex learning that happens in the work environment through a combination of principles by understanding the unrelated unseen events (chaos), exploring the learning as a collective (network), investigating the position between order and disorder (complexity) and analysing unpredictable and uncontrollable learning that occurs due to non-linear interactions (self-organising). Understanding the continuous learning in both human and non-human activities through Connectivism has helped to identify the links between the key learning aspects in the workplace. Examining the identified learning aspects in a connected way has encouraged professionals to figure out the most suitable learning approach for their project team.

This study has been conducted in three phases: literature review, semi-structured interviews and a case study approach, in order to understand the learning that occurs in BIM-enabled construction projects. Semi-structured interviews were conducted with 20 professionals working in BIM-enabled construction projects. Two case studies were selected to analyse BIM-enabled construction projects in the £30-60 million scale. Furthermore, six case studies within those selected projects were chosen for an in-depth investigation on the in-project learning. Data within the case studies were collected through project documents, semi-structured interviews and meeting observations. Nvivo was used to evaluate, interpret, explain and analyse the data collected from both semi-structured interviews and case studies.

The study reveals that BIM-enabled construction projects are largely involved with information that is digitally linked with federated 3D models and project participants. Investigation shows that learning in in these projects is continuous, networked and depends on participation in addition to knowledge accumulation and knowledge creation. '*Participation*' and '*Interpretation*' as a combination have significant impacts on this complex learning that takes place in work environments. '*Participation*' at work shows how each individual wants to get involved, interpret and learn in each situation that they participate. On the other hand, the multidisciplinary nature of BIM-enabled construction projects confirms that project participants need to focus on interpretation to agree on a common meaning of artefacts and information. Therefore, '*Interpretation*' is identified as a form of thinking that comprises planning, monitoring one's activities and problem-solving. *Interpretation*, which is enabled via thinking and sharing experience, helps to shape the decisions and solutions during *Participation*. To help

construction projects in achieving a suitable learning approach which is vital for a success of a project, a model for learning in the workplace has been developed through merging the learning aspects that have been identified from chosen BIM-enabled construction projects.

The novel model for workplace-based learning is a combination of *participation* and *interpretation* which is linked through three learning modes: *Alignment*, *Insight* and *Engagement*. The combination of these learning modes has contributed to interpret the ideas while participating at work. Consequently, it enabled project participants to align on a common meaning in an informative collaborative environment. The proposed model of learning in the workplace presents a systematic approach for achieving suitable learning in BIM-enabled projects by connecting the key learning aspects at the project level. Furthermore, this can be also used to employ skilled people and promote common standards on skills expectations associated with BIM-enabled projects.

CHAPTER 1: INTRODUCTION

1.0 Introduction

New digital age is most ambitious in attempting to escalate the connectivity between people and artefacts as a result of new digital technologies and tools (Saykili, 2019). This study explores how learning takes place in BIM-enabled construction projects in the evolving digital age to improve learning and overcome skills deficiencies in the construction industry. The study is investigated in the context of BIM-enabled construction projects in the United Kingdom (UK). The aim of this study is achieved through three domains: digitalisation and BIM, workplace-based learning and concept of Connectivism. Workplace-based learning is considered from a connected perspective to encourage the connected learning that takes place in the digital age and to efficiently make decisions and solve problems in BIM-enabled construction projects.

This chapter discusses the research background of the thesis, overview of the research problem and justifies the rationale for the study. Following this, aims and objectives of the research are presented along with the research methodology chosen for this study. It also provides contribution of knowledge and finally concludes with the summary of an outline of the overall structure of the thesis.

1.1 Research Background

Construction projects are considered to be complex in nature due to uncertainties and risks associated with it (Cristóbal *et al*., 2018). McKinsey & Company Survey Report (2020) revealed that construction industry has underperformed for the past two decades. Particularly, it highlighted that construction industry is slow in innovations and digital transformation in comparison to other industries. The report concluded that although, full transformation can take time for the construction industry there is urge for industry improvement, leading to digital transformation agenda. Similarly, Shojaei and Burgess (2022) and Wong et al (2020) also believed that construction industry has betrayed in delivering the projects on time and cost due to its inefficiencies. Chowdhury et al (2019) in their study argued this is mainly due to slow adaptation of digital technologies. The study suggested that digital transformation can lead to solve issues such as minimising the waste, enhancing health and safety, speeding up the build time, minimising the defects and adding cost benefits to improve the economy.

Therefore, after realising the benefits of digital technologies from other industries, construction industry has started to utilise them to overcome these complex issues. Moerover, McKinsey and Company (2020) admit this change will drive the industry to transform the ways of working. Digitalisation is a transformation from analogue to digital methods (Siemens, 2016) which is achieved through several digital platforms and tools (Ernst and Young LLP, 2011). Even though, construction industry believes digitalisation can help to expand productivity and enhance the building quality along with safe working conditions, environmental compatibility which reduces project delays and cost overruns (Craveiro *et al*., 2019; Berger, 2016) overall uptake of these transformative technologies are slow in construction projects to embrace new opportunities to alter the operations (Sepasgozar and Davis,2018). Conversely, Parusheva (2019) pointed out there are also challenges in digitalisation such as aligning the right resources, proper management of right teams, motivating the employees and requiring adequate knowledge and skills for employees, integrating and upgrading new digital technologies and improving digital services for the adaptation while implementing these digital technologies in construction companies. Nevertheless, the studies conducted by Berger and Frey (2017) and Sepasgozar and Davis (2018) claimed that digital technologies within construction projects enables to introduce new ways of thinking and working methods.

The construction industry has slowly started to adopt Building Information Modelling (BIM). Although, scholars have viewed BIM differently, the study has viewed BIM as a cloud-based computer-aided technology where the integrated data and visualisation technologies with both geometry information and non-geometry information manages the whole project life cycle through focusing on planning, design, construction, operation and maintenance (Yang and Liao., 2016). Moreover, structured 3D models and enriched data using array of interoperable technologies within BIM encourages the construction professionals to improve the way of working to manage the digital processes within the construction projects. This structured 3D model in BIM includes complete project and asset information, data and documentation in electronic form. This comprised information can be adopted by the client to explain the project requirements, designer to investigate, design and develop the project, contractor to accomplish construction activities and facility manager to operate and maintain the project (Ozturk,2020; Grilo and Jardim-Goncalves, 2010). Several studies in construction (Ozturk, 2020; Kassem *et al*., 2015) stated BIM is beneficial in eliminating waste, increasing feedback, better quality production, fast delivery and empowering the team.

Although, BIM has the capability to tackle the challenges faced in construction projects, the implementation is slower than other industries and one of the key reasons behind it is lack of knowledge and skilled people who can work with BIM in construction projects (Fajaryati et al (2020; NBS, 2021). This major threat is reported in recent studies (Othman *et al*., 2021; Dadmehr and Coates, 2019) and have highlighted the need for changing and up skilling the skills sets, demanding for specialised skills and raising awareness about skills in construction industry.

According NBS (2021), BIM which is a newly emerged technology has raised more issues regarding skills, competencies and expertise among the people who are interested in implementing BIM.Skills in this study is belived as “an ability, usually learned and acquired through training, to perform actions which achieve a desired outcome” (Shehu and Akintoye, 2008). Whereas competencies for this study means “having ability, being capable, possessing certain skills and the knowledge to do what one is supposed to do” (Kousetelios, 2003). On the other hand experise are people who have extraordinary skills to achieve a superior performance in a specific domain (Addis et al., 2016). The Cabinet Office (2011; P9) has emphasised lack of skills within project teams is one of the key barriers for BIM implementation in construction projects. Likewise, Othman et al (2021) and Fajaryati et al (2020) believed insufficient skills in project teams are problematic to utilise BIM in construction projects. Furthermore, NBS (2021), National Infrastructure Plan report (HM Treasury and Cabinet Office, 2016) and Off-site manufacture for construction report (House of Lords, 2018) claimed that having necessary skills and knowledge to work with BIM is beneficial to achieve client’s expectations. Therefore, to resolve this issue studies in construction (Fajaryati et al, 2020; Haung, 2018) have urged for new learning approaches within the construction industry, especially in this digitally transforming sector to upgrade or develop new skills. This shows that BIM is implemented in UK however, it is not practiced as we wanted due to challenges. Part of this is due to lack of skills therefore, workplace-based learning needs to happen in BIM projects. The term workplace-based learning has been used in this study to capture the combination of tacit and explicit forms of learning at both individual and teams level.To evidence this the importance of workplace-based learning in rapidly changing digital world is highlighted in the studies conducted by Abbasnejad et al., (2020) and LinkedIn Learning (2020). Hence, workplace-based learning is important if we want to address the learning and skills needs from project to project. Nevertheless, the problem in learning is, it is slightly different in each projects and people learn in different ways (Dubois and Gadde, 2002). In addition, an approach to workplace learning is difficult because of the changing nature of project requirements, BIM usage and demands.

Learning in past has been only considered within the person through determining the human behaviours (Shuell, 1986), attitudes and actions by individuals and groups (Valli, 1996) and human performance resulted from experiences. Later, Lave and Wenger (1991) have viewed learning from multilevel nature and considered it as a social process. However, Hager (2004) and Hodkinson and Hodkinson (2004) considered learning as a combination of both humans and non-human artefacts. Furthermore, they argued the contemporary learning for the digital age is combined with knowledge creation, participation and knowledge acquisition. Knowledge acquisition refers to typical formal education provided in educational institutions (Hager, 2004; Hodkinson and Hodkinson, 2004). On the other hand, participation refers to learning that takes place in work environment through collaborating with project participants and tackling new challenges and tasks including how they want to participate and what they want to learn from the participation (Billett, 2004; Collin, 2005; Fuller *et al.*, 2005; Fuller and Unwin, 2003) whereas knowledge creation refers to creating a new knowledge (Paavola, Lipponen and Hakkarainen, 2004). Indeed, the idea of workplace-based learning has been adopted in previous studies (Poell, 2013; Tynjälä, 2008; Marsick and Watkins, 1990), but results from construction surveys still highlight the issues of skills deficiencies (RICS; 2020; NBS, 2021) are especially due to unclear learning approaches. Oraee *et al.*, (2019) stated BIM has set challenges for collaborative learning of different parties in construction projects. On the other hand, Abbasnejad *et al*., (2020) mentioned connection between learning content in BIM construction projects need to facilitate effective learning across both industry and academia. Although, the importance of learning has been highlighted in BIM construction projects, there is no clear learning approach to overcome the concerns about skills deficiencies faced in construction projects. Previous studies (Billett, 2004; Tynjälä, 2008) have considered the importance of workplace-based learning however, those studies have not focused on the learning that is connected and networked due to the introduction of new technologies and how it takes place in the workplace. Thus, considering the connected learning in a collaborative workplace and how it happens in workplace helps to link with other people including our physical, emotional and cognitive behaviours within specific environmental contexts and situations. This then leads to identify the skills that is lacking in the contexts.

In regards, this research falls into ‘workplace-based learning’ which is predominantly determined by complex social practices and highly connected to the efficiency of types of learning (Poell, 2013; Tynjälä, 2008). Although, studies have highlighted different ways of learning in a networked environment (Huemer and Östergren , 2000; Håkansson and Johanson, 2001; Mouzas, Henneberg and Naude, 2004) it is hard to picture the image of history, possibilities or the complexities of each activities when there are number of activities happening in a project (Wenger, 1998).Therefore, the construction industry has started to introduce various digital technologies in the networked project environment to move towards digitalisation. However, digital technologies have penetrated the human learning through focusing on how, why, where, and in which contexts learning occurs (Säljö, 2010; Frielick, 2004; Attwell, 2007). This change has shifted the learning that occurs in the work environment. Workplace-based learning has been explored by several scholars (Eraut, 2004a; Illeris, 2004; Tynjälä; 2013) however, it is now interconnected with digital technologies therefore, there is a need for more exploration in construction studies. Similarly, Soyoz (2010) mentioned that active involvement is important for the purpose of managing, researching, supporting or enabling learning with the use of technology. Thus, the aim of the study is to understand how learning is taking place and impacts BIM-enabled construction projects in this digital age to develop their ability to self-regulate their cognition, emotions, behaviours and environments in ways to facilitate achievement of the project goals to continuously learn to stand the ever changing project environment and to survive with the new working practices that has emerged due to the impact of COVID. This connected learning approach in this study is promoted through focusing on the connections and relationships that exist in the learning environment. Supporting these arguments, Bridgstock and Tippett (2019) and Goodyear *et al* (2004) stated that connected learning approach is essential within the network to promote the connections between learning and people within the community. On the other hand, Dede (2008) stated BIM construction projects are formed through connecting aspects that alter and shape the project environment according to the project needs. In this study, Connectivism approach which is conceptualised by Siemens and Downes (2009) is adopted to understand the structure and meaning of the connected learning that takes place in BIM construction projects.

Learning, in Connectivism approach, is considered as an actionable knowledge that connects essential information set within and outside of people. The rationale behind this approach is to capture the connected learning that takes place beyond individuals in the work envoronment. This connection helps people to improve their knowing from current status (Siemens, 2004). Therefore, learning through Connectivism is not solely an internal, individual activity due to knowledge distributed across the networks. In this fast-moving digital world people's behaviours and function changes to cope with the current situation. This also keep changing the decisions that are relied on constantly changing information. Notion of Connectivism believes the overall knowledge keeps growing and evolve but important' or 'valid' knowledge is not the same as prior knowledge. Therefore, it is vital to distinguish the important and unimportant knowledge while making decisions. Additionally, learners should be skilled to identify the up-to-date information along with essential secondary and extraneous information and apply it into the right sources to meet the needs. Siemens (2008a) claims that recognising the connections between the aspects in learning environment is vital to move along with the digital age. Learning in this information world does not happen in a vacuum and it involves human interaction or experiences through intersecting with prior knowledge, experience, perception, reality, comprehension, and flexibility. According to Siemens (2004) and Downes (2020) Connectivism helps to share cognitive tasks among people and technology to survive in the digital world. Hence, Connectivism has been considered in this study to effectively link different project participants and construction process through identifying the relationship between learning aspects connected to the learning that takes place in workplace. Even though, the connected learning is continuous, having in-depth understanding on the connected aspects attached to them might help to tackle the changes in construction world.

Summing up from the above, connected learning can be instrumental in achieving better outcomes in BIM-enabled construction projects. Nevertheless, the challenge is to recognise the key learning aspects that impact the connected learning in BIM-enabled construction projects and how this connected learning is taking place in the workplace. Therefore, the ultimate goal of this study is to develop a new model for workplace –based learning to explore the interrelationship between the learning aspects and to investigate how this connected learning takes place in BIM-enabled construction projects to support the collaborative project team to make decisions and solve problems.

1.2 Research gap and justification

Building information modelling has been started to be adopted in construction projects however, its uptake is slow in comparison to the other industries. Skills deficiencies is one of the challenges in utilising BIM in construction projects (NBS, 2021; Farooq et al, 2020; RICS, 2020). However, the studies show that workplace-based learning is the root cause for this skill deficiencies (Rajabi et al, 2022; Semaan, 2021; Kokkonen and Alin, 2015). Number of studies (Rahman, 2018; Abbasnejad *et al.*, 2020; Kassem *et al.*, 2015) have indicated focusing on workplace learning approaches can minimise the skills deficiencies that are faced during the implementation of new technology. However, most of the studies were investigated in the context of workplace. Studies such as Azhar *et al* (2012) and Ku and Taiebat (2011) argued that suitable learning approach is essential to work with BIM-enabled construction projects. Several others studies (Oraee et al., 2019;Kerosuo *et al.*, 2015; Succar *et al.*, 2014) highlighted the importance of learning in the collaborative BIM environment. On the other hand, existing literature in learning has been carried out in relation to workplace-based learning (Billett, 2001; Fenwick, 2010; Eraut, 2000) however, those studies have not taken digital changes into their consideration and therefore findings are limited. The construction industry now has started to shift towards digitalisation with the introduction of digital technologies. Thus, this rapid change in digitalising world has urged construction professionals to focus on changing their work practices to cope with this fast-moving digital world (Kokkonen and Alin, 2015). Hence, continuous and networked learning that takes place within multidisciplinary team in construction projects is looked beyond knowledge acquisition. However the problem is, there is no precise learning that needs to be followed in BIM-enabled construction projects. There is also lack of studies that investigates the interconnection between learning aspects that are essential for the connected learning that takes place in BIM construction projects. Although, scholars (Groleau *et al.*, 2012; Becerik-Gerber and Rice, 2010) are aware of learning that takes place in BIM-enabled construction projects it appears, that there are less studies undertaken to explore the learning that actually happen during BIM implementation. The existing literature also indicates that most of the studies on workplace-based learning have not considered the connected learning that is essential for the digital age. The shortage of the empirical studies in workplace-based learning during the implementation of new technologies such as BIM in construction industry is the main motivation for the researcher in conducting this study. Hence, this study represents an attempt to address the gap in the literature on workplace-based learning in the new digital age for minimising the skills deficiencies in the construction industry and to increase knowledge in this subject area. From the studies discussed above, it is clear that learning in practice workplace is vital to cope with the new digital age.

The research focus on ‘Workplace-based learning in BIM-enabled construction projects’ is justifiable due to the absence of suitable learning strategy in workplaces on implementing BIM in construction projects. Hence, there is an urgent need to change for the purpose of learning and to tackle rapidly changing digital technologies and significantly contribute to the learning outcomes (Kokkonen and Alin, 2015). While there is empirical evidence showing that focusing on learning can minimise skills deficiencies research has been traditionally on upgrading learning through academic institutions (Haung, 2018; Ballantyne, 2012). Although, previous studies have addressed conventional and abstract models to overcome this issue, these models are mostly based on rational logics and does not focus on specific situation where workplace-based learning occur (Sandberg and Tsoukas, 2011; Illeris, 2004).On the other hand, most of the studies on ‘Workplace-based learning’ have focused in relation to individual affordance, engagement and competencies (Billett, 2001; Garvan *et al*, 2001; Degeling and Prilla, 2011). In addition, few other studies investigated on typologies of workplace-based learnings (Manuti *et al.*,2015; Eraut,2004; Kyndt *et al.*,2009) and transforming workplace to a learning environment (Billett, 2004; Billett,2001). Studies have been also considered the benefits (Mathew, 1999) and challenges faced in workplace (Smith, 2003). This investigation on Workplace-based learning shows that there is an absence of literature on connected learning that takes place in workplaces. According to Downes (2007), understanding this learning that takes place in networks has the ability to construct and transverse those networks. Therefore, this research seeks to identify the interrelationships between learning aspects including investigating how they influence in a connected learning network that is vital for digitally driven environment. Learning aspects are determinants that stimulates learning in a context. Finding connection between them will guide the project participants to think how to perceive learning during implementation of BIM-enabled construction projects. Moreover, in-depth understanding of learning aspects will help to comprehend the learning that takes place in BIM construction projects. Consequently, this will also enhance utilisation of BIM through minimising skills issues in BIM-enabled construction projects. The model for workplace-based learning in BIM-enabled construction projects which is developed in this study is to show how learning can be improved in digitally-enabled construction projects. The purpose of this workplace-based learning model is to encourage a faster and connected learning approach in work environment.

1.3 Research aim and objectives

The aim of the research is to investigate workplace learning and developing a workplace-based learning model in BIM-enabled construction projects.

Objectives

- Objective 1: To review the literature on skills deficiencies and workplace-based learning
- Objective 2: To review existing literature on the impact of Building Information Modelling (BIM) on construction projects;
- Objective 3: To investigate the skill deficiencies and the need for workplace –based learning in BIM-enabled construction projects;
- Objective 4: To determine how workplace-based learning takes place in BIM-enabled construction projects;
- Objective 5: To develop a model for workplace-based learning in BIM-enabled construction projects.

1.4 Overview of research methodology

Level 2 BIM has been incorporated in a number of construction projects in the United Kingdom. Researcher in this study has chosen two BIM-enabled construction projects from West Midlands due to easy communication and data accessibility, suitability and universal application. To achieve the aim and objectives, primary data collection for this study is conducted in two phases: semi-structued interview and cases study approach. Initially, semi-structured interviews were conducted among BIM professionals to explore the significance of skills gap and the need for workplace-based learning in BIM projects. This is the further explored in case study approach.

After conducting the literature review (phase one), data for this study in phase two were collected through conducting twenty semi-structured interviews. These interviews took place in the second year of the doctoral study and lasted for other 8 months. The semi-structured interviews were conducted in researcher's office which lasted for 40-50 minutes. The interviewees participated in the interviews are BIM coordinators, BIM technicians and BIM managers. Interviews were chosen to obtain an in-depth understaning on their views on BIM, skills acquisition and learning and how BIM is been utilised in construction industry. Two pilot studies were conducted with the construction professionals working with BIM before conducting the interviews. This has helped to refine some of the questions with correct terminologies which made questions clear to the interviewees. At the end, few open-ended questions were employed to get a wider view of the situation and semi-structured interviews for the study is conducted across the UK. During these interviews analysis was done along the way. The data gathered through the semi-structured interviews explained how learning is taking place in BIM-enabled construction projects. Following this, two BIM-enabled construction projects were chosen for case study analysis to further explore the workplace-based learning. During this, separate semi-strutured interviews within the case studies were conducted along with document analysis.

A case study approach was adopted for this study to understand how people learn during digitalisation. The chosen 6 case studies were from a medium size fully integrated BIM construction project in the UK. The key purpose of engaging with these projects is to explore the learning in workplace environment. Moreover, this case study investigation helped to understand the learning opportunities along with how learning is happening in BIM construction projects. Data within the case studies was obtained through the observations, interviews and project documents. Data was collected between the periods of August 2016 to August 2018. Data includes: formal transcribed semi-structured interviews, project documents and observation of design meetings. In case study one; the design meetings related to BIM issues were discussed every fortnight and in case study two it was organised by arrangement. Notes were taken down during both interviews and observations in the cases studies. The data regarding each cases were kept anonymous and only were agreed to be used for research purposes.

According to Eadie *et al* (2013) construction project phases can be categorised as project inception, feasibility, design, construction, handover, operation, maintenance and eventual demolition. In this study, the researcher had access to these phases in BIM-enabled construction projects however, did not see any major difference in terms of learning in different type of projects. Hence, two educational buildings were chosen to view the learning in BIM-enabled construction projects. First BIM construction project selected for this study is a 100,000 square foot extension to the previous building built in 2015. This is a £31 million project which engages over 3,000 students and members of staff and features more than 650 rooms, a student hub and lecture theatres. Additionally this also includes new library, teaching and IT spaces. This high-tech university project has used Level 2 BIM throughout the project for its deliver and detailed planning which is completed in January 2018 for the new academic year. Second BIM project was an £57 million project featuring 9,000 square foot designed for media and art students for the purpose of teaching, rehearsal and state of art performance space. This building has included facilities such as jazz club, 500 seat conference hall, intimate 150 seat recital hall, 100 seat practice and rehearsal hall, organ studio and complete AV digital interconnection. This project has also adopted Level 2 BIM completed in September 2017. In both the educational building level 2 BIM has been used from the beginning of the project for coordination, collaboration, clash detection and clear scheduling. Nvivo in this study has been employed to evaluate, demonstrate and to explain the social phenomena regarding 'Workplace-based learning' in BIM construction projects. Data collected from semi-structured interviews and the case study were transcribed and imported into Nvivo. Purpose of this is to analyse the unstructured data by coding and discover the themes within BIM learning environment. These themes were represented by free nodes which are then categorised as parent nodes and child nodes to draw connections between the themes. Discussion was then recorded with the identified connections with the use of nodes.

Key learning aspects (Learning conditions, Learning Progress and Learning outcomes) for the development of the model for workplace-based learning were derived through literature review (phase one), semi-structured interviews (phase two) and case study observersion (phase three). To expand and explain the model these three main learning aspects were divided into different sub-categories. Detail discussion on these categories and sub-categories are discussed in chapter 5.

1.6 The structure of the thesis

- Chapter-1: Explains the background of the research. It provides introduction of the research background, problem statement, justification of research, aim and objectives, contribution of knowledge and the structure of thesis.
- Chapter-2: Discuss the literature review and provides a better understanding of digitalisation and workplace-based learning in construction project. In addition, it discusses about Building Information Modelling (BIM), skill deficiencies and workplace-based learning. Furthermore, a connective approach that has been adopted in this study is discussed under Connectivism.
- Chapter-3: This presents and justifies the research design and methodology in detail. Drawing from the literature review and philosophical considerations, it also explains the research approach (semi-structured interviews and case study approach) including research techniques selected for this study.
- Chapter-4: This chapter presents the findings of the semi-structured interviews with the professionals in BIM construction projects and case study findings (through the selection of 6 case studies out of 20) obtained through observations, semi-structured interviews and project documents.
- Chapter-5: This chapter discusses findings which were cross examined and supported with the theoretical review of validation. This has led to the development of the model for workplace-based learning in the new digital age.
- Chapter-6: Finally, this chapter synthesis the summary of the research and presents the conclusion through revisiting the research objectives, contribution of knowledge and limitations of the study. Recommendations and the future research have been also presented. In addition, references and appendices are attached at the end of the thesis.

1.7 Summary

This chapter has set out the background of this thesis. Firstly, the rationale for this research is explored in this chapter. Consequently, the research problem was established and justified the purpose of the research. Following that, the aims and objectives were presented along with the research methodology adopted in this study. Then, contribution of knowledge and structure of the thesis were briefly explained. The next chapter will focus on literature review and underlying theories relevant to the study to establish a model for workplace-based learning for BIM-enabled construction projects in the new digital age. This is to identify the way learning takes place to BIM construction project which will then optimise the usage of BIM in construction projects.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The construction industry is moving towards implementation of digital technologies. However, the benefits of digital transformation is not fully comprehended witin the context of construction industry. Skills definiencies is one of the key reasons that acts as a barrier for digital transformation in construction industry. This fundamental issue for skills deficiencies arises from unstructured, disconnected learning-approach to digital skills learning in workplace environment in construction projects. Learning in workplace has been views in different perspectives. This study has adopted Connectivism concept to understand the connected learning approach during the implementation of digital technologies in construction projects.

This chapter begins with discussion on digitalisation in construction industry (2.1). Following that, skills deficiencies during the technological change is discussed in 2.2. Next, BIM which is most adopted technology is explored in 2.3. This then leads to analysis of learning that happens in workplace (2.4). Connectivism concept was discussed to look at workplace learning through a connected approach (2.5). Finally, this chapter is concluded with a summary of this chapter (2.6).

2.1 Digitalisation

Digitalisation is a step change in the move towards technological innovations to reduce the demands for routine and manual tasks (Macías, 2018; Anke and Agnes, 2019). According to Berger (2016, p.3), digitalisation is about ‘‘…businesses encountering connected systems at every link in the value chain’’, which refers to working with tools and practices based on information and communication technology. In simple terms, digitalisation is a process of utilising the technology to enhance the business process and values (Stefanova and Kabakchieva, 2019; Hapon, 2020). On some occasion digitalisation and digitisation is interchangeably used however, digitisation is different from digitalisation which means transforming the information from the physical format to digital version. This has impacted on people’s daily life and workplace environment which has gradually increased for the past twenty years through transforming the analogue world into a virtual for the global community.

Digital transformation can mean different things such as increasing the efficiency, digital communication, transparency, visualisation, connectivity and automation. Digital transformation in construction industry is not only disruptive but also makes the changes to the construction process through to enhance the costruction project outcomes and productivity. Adopation of the right technology helps to provide client satisfaction through implementimg right information and communication.According to Furjan et al., (2020), digital transformation in construction is about digital technology based improvement to the business process.

Siemens (2016) in his study concluded that digitalisation is more about switching from analogue to digital (See Figure 2.1). In other words, changing the information from a physical format to digital one. On the other hand, Booz and Company (2012) reported the digitalisation mainly impact on Economy, Society and Governance. The economic impact of digitalisation covers the growth of GDP (Gross Domestic Product), job creation and innovation. Following that, social impact has been viewed from two levels: the level of quality of life in a society and the equality of access to basic services that a society requires. Finally, the governance relies on three metrics: transparency, e-government and education. The study concluded that policy makers focusing on systematic planning and tracking their efforts; evolving sector governance structure; adopting an ecosystem perspective; enabling competition; and stimulating demands can accelerate the digitalisation.

The Covid-19 crisis in the past two years has changed the way companies in all sectors works through spreading the adoption of digital technologies. According to Mckinsey Global Survey (2020), companies have accelerated the process through encouraging the digitalisation among their customers and supply chain interactions and internal operations. In other words, the shift towards digital channels has helped the companies to create new strategies and practices to stay competitive. For this, there is an urgent need for new strategies and practices to learn in workplaces in this pandemic. During this learning process, both making specific changes to the business such as which technologies to adopt and how to implement (tactic learning) and managing the changes that is different from the previous experience (organisational learning) need to be focused simultaneously. Although, the digital transformation pace during Covid-19 has forced the construction industry to speed-up the digitalisation, this is now need to be continued to compete the other industries.

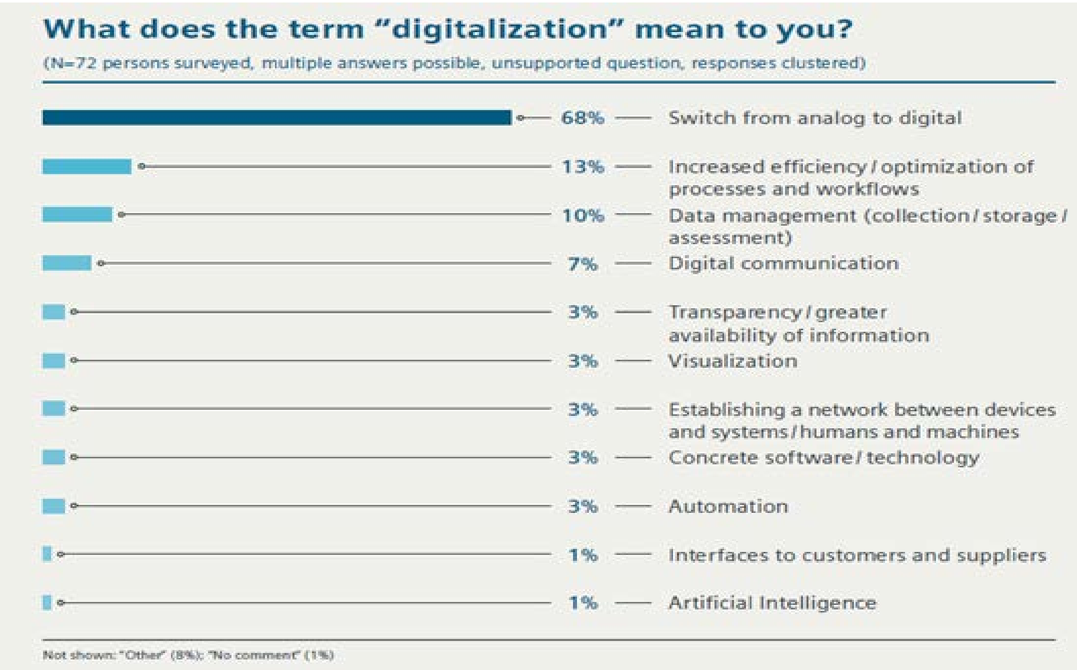

Figure 2.1: What is Digitalisation (Siemens, 2016)

2.1.1 Benefits and Challenges in digitalisation

Digitalisation in this fast moving world is one of the key concept that is hard to ignore. Digitalisation in different industries such as banking, manufacturing and retail has improved the efficiency in the operation (Aghimien et al., 2018). On the other hand, digital technologies also provides the employees as well as end users greater access of information and the means of communication and collaboration. During this, transforming the physical world will be replicated through digital communities that include several digital platforms and tools (Ernst and Young LLP, 2011). Moreover, digital technologies help to interconnect the people all over the world. According to Hashim et al., (2013) digitalisation in construction helps for the successful procuring process among the other competitors, enhance the quality of the process, provides more satisfaction to the project participants including client, enhance the responsiveness and productivity and conrols the anticipated project cost. Similarly, Staub-French and Fischer (2017) identified digital technologies are useful in diagnosing the clashes in project design, helps to schedule the construction programme and mitigates reworks and change orders in construction which leads to better cost control. Kagan (2021) also agreed these promising digital technologies in the construction industry have a great impact on organising the building and design through automated development of design documents and also helps to organise the different works through ensuring the whole range of resources and releasing the products according to the project stages. In addition, there are plenty of other benefits of digitalisation as shown in the Figure 2.2. Similarly, CEEMET (2016) stated that digitalisation provides flexible working environment in the organisation and new opportunities to enhance people's work-life balance.

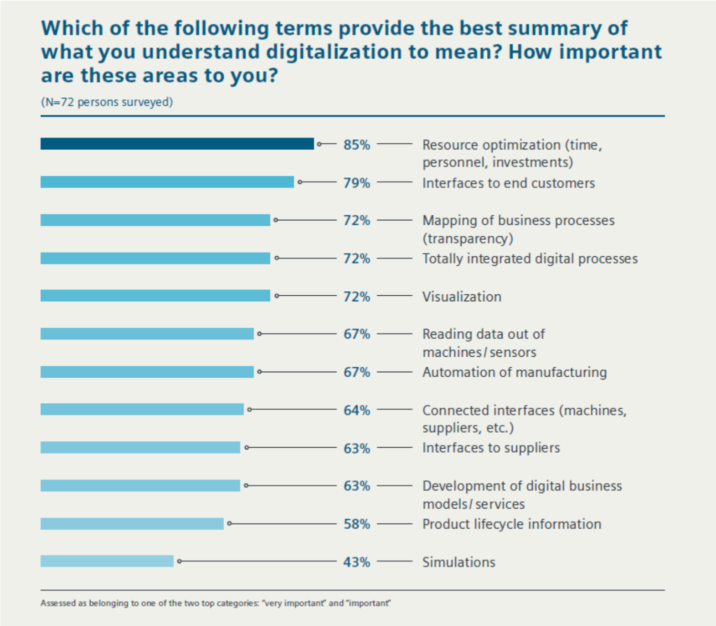

Figure 2.2: Benefits of Digitalisation (Seimens, 2016)

Although, there are numbers of benefits discussed on digital transformation, the construction industry is slow in embracing it compare to the other industries. Therefore, it is important to analyse the challenges faced during the implementation of digital technologies (Figure 2.3). Ylber et al., (2018) state that pace of changing customer expectations, cultural transformation, outdated regulation, and identifying and accessing the right skills are some of the challenges faced during digital implementation. Supporting this, Stefanova and Kabakchieva (2019) identified some challenges such as creating clear vision of digital transformation, aligning business goals with digital transformation, handling markets, competitors, customer analysis, finding experts with digital knowledge and skills for designing successful new solutions, managing risks and tackling the cultural change. Therefore, the challenges related to strategic transformation of digitalisation is centred on factors such as technology, strategy, leadership, organisational structure and organisational culture. However, businesses and organisations within the last 20 years have focused and implemented on digital technologies through digitalising their business processes to produce a better service or products for the customers. According to CEEMET (2016), many countries across the world are struggling to provide the right quantity and quality of skills to achieve sector's needs. Hence, he claimed managing people's work and workforce as a whole through concentrating on their skills and competencies is important to understand digital advancements. Similarly, Ylber et al., (2018) have also mentioned lack of knowledge and skills including resistance to change is a biggest obstacle for digital transformation. Therefore, it is clear that right knowledge and skills are important to be carried out for the digital transformation.

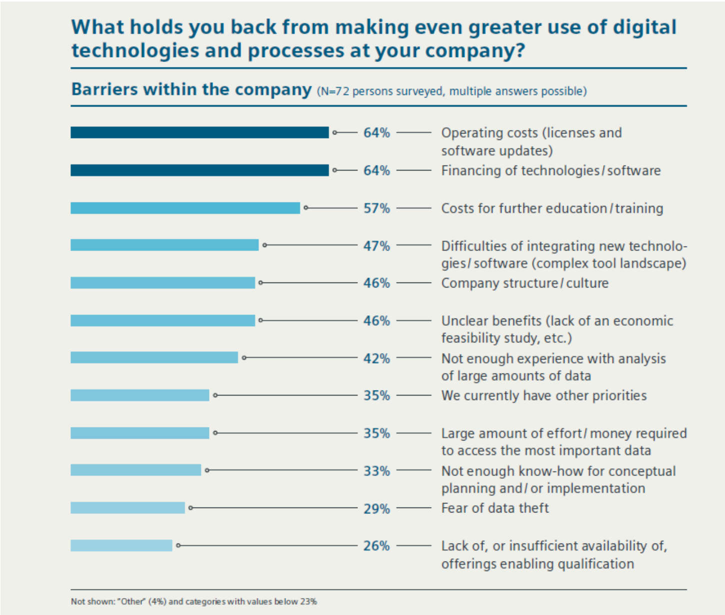

Figure 2.3: Challenges of Digitalisation (Siemens, 2016)

2.1.2 Digitalisation in Construction Industry

Digitalisation plays a vital role in the development of the construction industry (World Economic Forum, 2021). Implementing digital technologies in each stage and processes of construction projects add value to the overall achievement. The Booz and Company has divided digitalisation into four stages: constrained, emerging, transitional and advanced (El-Darwiche, Singh & Koster, 2012). In comparison to the other industries such as automotive, aerospace and ship industry, the construction industry is far behind in relation to efficiency, collaboration and standardisation, which could assist a digital transformation. Digital maturity is the ability to understand the value to the organisation while shift to the new technologies (Ernst andYoung LLP, 2011). Therefore, businesses in this digital age are in the state of redesigning or rethinking to develop a comprehensive digital strategy to deliver their services and products. According to the Construction Industry Council (2014), intelligent apparatus and systems are still at their initial stage of development in the construction industry. However, the ongoing technological evolution in construction is expected to improve productivity, design and speed, building quality, safe working conditions, and environmental compatibility and reduce project delays (Aghimien et al., 2018; Geno and Clay, 2016). On the other hand, technological innovations are challenging for construction when they lead to skills deficiencies due to technological change (Horváth,et al,2017), to an overall decline in employment due to automated technologies (OECD, 2016) and the introduction of new job roles (Berger and Frey, 2016). In contrast, critics argue that the industry as a whole is unlikely to be automated due to the variability of the tasks within each process (Autor and Handel, 2013).

A study conducted by Dixit *et al.*, (2019) stated access to tools and consumables, improper coordination and drawing management, material availability, insufficient labour skills, training and rework are key causes of poor productivity. To overcome these issues, it is vital to reshape the construction industry through new way of thinking and working patterns especially to adopt digital methods throughout the construction project whole life cycle. However, some scholars such as Ramey (2012) believe that moving into the digital world can rise social isolation by people spending more time alone, learning these emerging technologies and communicating through social network. Nevertheless, the overall aim of technological innovation in the construction industry is to evolve from its traditional analogue-based artefacts and processes to a new and more connected digital state.

The construction industry has started to incorporate new technologies such as digital sensors, intelligent machines; cloud computing, big data, wireless networks, mobile devices and new software into projects however, on overall uptake of these transformative technologies are slow (World economic forum, 2016). In addition, digital twin is an evolving technology that is part of advanced data analysis and Internet of Things (IoT) connectivity. According to Mandi (2019) digtal twin is a virtual representation of a physical system that is continuously updated with the aid of recent performance, maintenance and health status data during system's life cycle. Digital twins are advanced from Computer Aided Design (CAD) and IoT due to its focus on providing a near-real life–time comprehensive connection among physical and digital world (Parrott and Warshaw, 2017). The study conducted by Schober and hoff (2016) has identified that digitalisation in construction can be spilt into four ways such as digital data, digital access, automation and connectivity (see Figure 2.4). Digital data includes electronic data collection and analysis of data. Digital access is about the potential ways of accessing the data through mobile, internet and internal networks. Automation covers these emerging technologies that create autonomous and self-organising system. Finally, the connectivity is about finding the possible links to synchronise these discrete activities. The study concluded that the struggle is about capturing the potential benefits of digitalisation which is a cause for the slow adaptation. Digitalisation, which is a data driven process has a great impact on construction industry if the strategy and changes behind it is understood. Therefore, developing the skills and workplace based-learning to tackle the fragmented and conservative nature of the construction industry during the implementation of digital technologies can make a revolutionary change. On the other hand, Dixit *et al.*, (2019) argue that the continuous learning curve is important for the successful implementation of technologies.

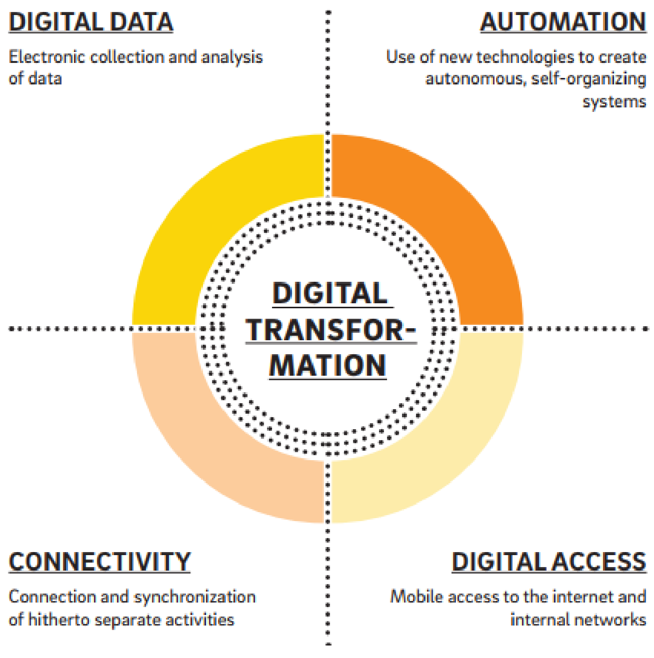

Figure 2.4: Key spects of digital transformatn (Schober and Hoff, 2016)

In recent years, the construction industry has started to focus on Building Information Modelling (BIM), which is an emerging technology to integrate processes throughout the project lifecycle (Aouad and Arayici, 2010).

The construction industry is in need to become digital however the adaptation of digital technologies are slow. This is mainly due to sector's poor vision on implementing, recruiting and filling the dital skills which are essential for digital transformation (CITB, 2018). Supporting this the report by Construction Leadership Council (2019) stated that technologies such as: cloud computing, artificial intelligence (AI), machine learning, autonomous vehicles, 3D printing, robotics both on and off site, and sensors are out there in the construction to transform the industry. However, high level of expectation in terms of being more digitally literate and collaborative are slowing down the digital transformation in the industry. Developing an understanding around skills is vital to address this problem.

2.2 Technological change and skills

The construction industry is challenging because of constant change in practice due to emerging and more complicated technological requirements (McKinsey and Company, 2020) and continuously changing over the last 20 year due to the introduction of emerging technologies. These technological changes has altered or created a new way of delivering the goods and services in the construction industry (Economic Forum, 2017; Carnoy, 1997). Moreover, it also has influenced in economic growth, employment, wages (Economic Forum, 2017; Carnoy, 1997), high performance work practice (Bresnahan et al., 2002) and skills development (Dachs, 2018; Pavlidou et al., 2011). Yisa et al (1996) argue this change cannot be avoided either by individuals or organisations involved in the construction industry. Construction works are engaged with variety of skills ranging from specialised to operative and have been growing complex as a result of technology advancement. This situation has raised client's expectation in terms of quality and quantity. Therefore, there is a constant pressure on current skills to cope up with client's expectations (RIBA, 2018; Kikwasi, 2011). While some of the construction firms are successfully managing the technological innovation, others failed by being static (Bett and Ofori., 1992; Rogers, 1995). According to Anke and Agnes (2019), digital changes are challenging and therefore all kind of occupations and professionals are subject to change to adopt the emerging technologies.

RIBA (2018), Brandon and Bett (1995), Latham report (1994) and Egan report (Murray, 1998) suggested it is important to adopt a client focus, improve teamwork among the participants and to introduce a change to enhance the effectiveness of the construction projects. Therefore, emerging technologies are being introduced continuously within the construction industry to make a change and to get closer to the clients. Development of emerging technologies and its effective implementation within the construction projects has been highlighted in several studies (Alshawi and Faraj, 2002). According to Carnoy (1997), the implementation of new technology can occur in three ways: changes in industrial development, changes in the structure of the demand skills and expanding the employment relationship and improving information flow. On the other hand, Alshawi and Faraj (2002) believe that this degree of change occurs according to internal and external factors such as efficiency of the business, the capabilities of internal staff, market condition, political system, availability of highly skilled people relation with external partners, budgets, economic situation. The introduction of new technologies have also led the production process to a different 'techno-economic paradigm' (Perez, 2010), which enhance the professionals to adopt new duties and skills (Christensen and Lundval, 2004). Study by Gerald et al (2020) indicated that higher and broader varieties of skills and skills specialisation are important to challenge the highly automated skills requirement due to new technological change. Supporting this, Carnoy (1997) highlighted that new technologies are effective mainly when incorporated into complementary inputs such as highly skilled management and flexible, self-confident labour to successfully complete the goals. In addition to this there are other valuable empirical studies highlights the relationship between skills and technology (Mandičáket al., 2018; UKCES, 2013; Chang and Hwang, 2003). Although, the positive side of implementation of new technologies were discussed in several studies, Whitfield (2000) identified that changes in technologies increase the complexity of jobs in the workplace, increase the demand of wide range skills and higher degree of technical competencies. On the other hand, Ayokunle and Monty (2021) and Stewart et al (2004) also identified number of barriers for the successful technological implementation in construction projects and they are fear to change and uncertainty on return on investment, limited IT expenditure on projects, low technology literacy of some project participants, tight project timeframes inhibit training and experimenting with IT, data access and ownership, security and privacy issues a and lack of leadership on projects.

Even though several studies have highlighted the skills issues in the construction industry. Recent studies indicate that this situation still remains the same and more challenging than before (Ayokunle and Monty, 2021; Chell, 2013). According to Wrenn and Wrenn (2009) skills can be also achieved through practice and from doing. Supporting this, Brown (2009) states interaction at workplace plays a major role in learning skills in the work environment. However, interactive ways of working will vary according to the individual, organisation and context, which have a great influence in up skilling people.

2.2.1 Skills issues in construction projects

Acquiring appropriate skills encourages economic performance (O'mahoney and de Boer, 2002; Bosworth, 2015), innovation and flexibility (Leiponen, 2005). Moreover, it helps to determine individual's employability to productivity (HM Treasury, 2006) and business profitability (Bosworth, 2015). This has been highlighted in Sami's (2008) study where he claimed more attention is needed to reskill, multi-skill or up skill professionals in construction industry to successfully achieve project targets. However, skills must be grounded and the meaning might differ according to its reference to context (Spenner, 1990) as shown in Table 2.5.

Author/s	*Year*	*Definition*
Becker	*1964*	*Capabilities of workers that they acquire outside the work place and the job on and the capabilities have meaning only when they translate into productivity and job rewards, such as earning.*
Mangham and Silver	*1986*	*Dexterity and knowledge of the workforce.*
Wood	*1988*	*Expertise that describes the quality of overt behaviour in a particular job.*
Odusami	*2002*	*Ability to perform the task well or better than average. Skills can also be described as the ability to translate knowledge into action.*
Boyatzis et al	*2002*	*Emotional intelligence which includes both self-awareness of one's emotional reaction to specific events, situations and unexpected circumstances and the coping strategies that may be developed to handle those feelings and concomitant reactions effectively.*
HM Treasury	*2006*	*Capabilities and expertise in a particular occupation or activity.*

Table 2.5: A Summary of skills definition

These definitions state that skills are centred on various different factors such as capabilities, people, physical and practical activities. However, skills in this study have considered as a navigator for BIM adaptation. Therefore, having appropriate skills during BIM implementation helps to successfully perform the tasks. Taking all these into consideration Odusami's (2002) definition is adopted in this study which states that

Skills are not only about completing the task better than average but also translating the knowledge into action.

The UK Commission's Employer Skills Survey 2019(UKCES, 2019) and Wiley (2021) have highlighted the impact of skills deficiencies especially due to lack of dital skills in construction industry. Moreover, these documents pointed out that common reason behind the need for digital skills are introduction of new technologies and equipments. On the other hand, current skills challenges within the construction industry have been reported in number of construction studies (Seidu et al., 2019; HM Government, 2007) and are mainly due to skill gaps, skills shortage and latent skills shortages (Shearer and Morrison, 2018; UKCES, 2012, Breuer, 2012). Skills gap happens due to employees in workplace not having appropriate skills to achieve the organisation's objectives (Campbell et al., 2001). On the other hand, skills shortages also occur when there is shortage of skilled people in labour market to fill in the vacancies (Barnes and Hogarth, 2001). Campbell et al (2001) argued that there are more skills gaps in construction industry and Bloom et al (2004) believed skills shortage due to informal learning plays a significant role towards the economic growth. Apart from this, latent skills shortage is also an issue, which is a situation where establishment fall short of what might be considered good or best practice. This might be the reflection of low skills or poor business performance, even though there is no report of recruited problem or skills gap (Hogarth et al, 2001). Generally, this occurs when the organisation starts to manage a project with existing skills without being aware of necessary skills. Chan and Cooper (2006) claimed that this situation is more frequent in the construction industry because construction practitioners often do not know what skills they need to produce to achieve their project outcomes. In addition, currently the construction industry is now more concerned about the having weak digital skills capabilities (Wileys, 2021; Feijao et al., 2021). Therefore, skills challenges due to technological changes in construction industry are problematic to move towards the digital world. This is evident through slow adaptation of BIM in construction industry although it helps to drive a step-change to increase the productivity of the construction process, tangible quality improvement in the end product and associated reduction in true cost (NBS, 2021; ICE, 2018; HM Governmnt, 2012).

2.2.2 Skill deficiencies during BIM implementation

In the AEC industry even though skill issues are common, Building Information Modelling (BIM) which is an emerging technology has raised more issues regarding skills, competencies and expertise among the people who are interested in implementing BIM (NBS, 2021).This is clearly highlighted in the Government Strategy paper (Cabinet Office,2011; P9) where 'lack of high level skills appropriate to projects and programmes within the project team' is noted as one of the main barriers for BIM adaptation in construction projects. This issue is also highlighted by Farooq et al (2020) stated that inadequate skills and knowledge is one of the barriers for design and construction team for not utilising BIM. Moreover, in this study learning curve and training, top management support, lack of experience and resistant to change are some of the reasons pointed out as the barrier of BIM adaptation. On the other hand, the Study by Smith and Tariff (2010) highlight that one of the causes for the skills issues in the design and construction industry is due to the rate of BIM implementation which is faster than availability of skilled professionals (Barison and Santos, 2010a). Following that, Barison and Snatos (2010b) emphasised that availability of people with sufficient knowledge is less in the construction industry and recommended to provide suitable training especially in BIM software. Brown and Robert (2009) came across similar issue and suggested to upgrade students' knowledge in computer skills and software.

Construction studies have identified that having necessary skills and knowledge to work with BIM is beneficial to achieve client's expectations (NBS, 2021) and to produce better organisational performance (Bolı´var-Ramos, 2012). Therefore, Wong et al (2011) suggested that support from professionals trained in BIM applications is essential to adopt BIM in the construction industry. However, Ballantyne (2012) and NBS (2021) pointed out that the education (formal) and training (vocational) concerns regarding BIM in construction firms should be provided in all levels within the organisation. Moreover, Grilo and Jardim-Goncalves (2010) and BCIS (2011) specify that strong training requirements in BIM will upskill the industry practitioners and to raise the awareness of role of universities and institutions in delivering BIM training. Kiviniemi et al (2008) found that traditional parameters like constant software upgrading, costs and education are the main obstacles in closing the skills gaps, while implementing emerging technologies like BIM. Therefore, urgent need for training to improve the skills and competencies to adopt BIM is stressed in the Royal Institute of Charted Surveyors (RICS) survey report (2020), and NBS (2021). Likewise, appropriate staffing and distribution of the right set of skills has been highlighted in Winterbotham et al (2020). Although, training is a solution for re-educating or upskilling the professionals, Yan and Damien (2008) concluded that staff training would be more expensive, which leads to impediments in BIM adoption. Nevertheless, research conducted by Bloom et al (2004) identified that traditional boundaries need to move away from the narrow definition of skills to minimise the skills gaps or skill deficiencies of employees.

Currently, the Sector Skill Councils (SSCs) have taken actions to improve supply-including apprenticeships, increase higher and vocational learning to minimise the skills gaps and shortages to improve the productivity, service performance and opportunities to develop the skills through improving (Duff, 2003). However, Chan and Dainty (2007) highlighted that the current skills research and policy agenda in the UK are still inadequate in addressing skill problems that affects UK construction industry due to the ambiguity of the concept of skills, the abdication of the responsibility for skills developments by employers and lack of involvement of individual employees in solving skills crisis. Therefore, the BIM Task group has introduced a ‘BIM Learning Outcomes Framework’ to provide essential BIM training and to guide the industry practitioners, academia, provate eductors and organisations. However, this LOF is now updated with ISO 19650 series to align to the UK BIM Framwork after collaborating with academia, industry eduction professionals and BIM Framework member organisations, British Standards Institute (BSI), Centre for Digital Built Britain (CDBB) and the UK BIM Aliance (UKBIMA). The main aim of this framework is to maintain the consistency of outcomes of the BIM construction projects. Currently, even though the basic skills have been identified to work with BIM, it is essential to improve digital skills to work with the technological change. Therefore, digital skills should be rapidly evolving to embrace the digital technologies introducted in construction industry. According to Boston BIM Forum (Brattberg, 2014) limited training budgets, limited training time, continually updating software, employee turn-over, fear of learning new software and processes and lack of expertise to provide mentorship are some of the corporate training challenges. Although, several actions has been taken to minimise the skills issues in construction projects during the implementation of emerging technologies, studies conducted by Vokes and Brennan (2013) and CITB (2013) state that there is still no clear idea about skills benchmarks and approaches to minimise the skills issues. Therefore, UK commission believes that a new approach to learning is needed for employers working in the construction industry to upgrade or develop new skills. Therefore, as an initial step is important to explore the learning that take place in BIM construction projects.

2.2.3 Need for Learning in BIM Construction projects

The construction industry is generally complex, temporary, and unique and uncertain due to lack of complete specification which occurs in a short period. Moreover, it involves new materials and sophisticated technologies and increasing client demand in combination with growing competition among the construction companies. Consequently, there is a need for sharing learning between the project team members. However, learning processes in construction network is challenging because they can change radically from projects to projects, therefore the ability of members to form cognitive structure that supports learning is problematic (Dubois and Gadde, 2002). Learning can happen through identifying new possibilities (exploration) or refining and implementing what is already know (exploitation) (Levinthal and March,1993; March, 1991) however, learning which is not static needs to be considered within a context during the technology change such as BIM (Harty, 2005; Linderoth, 2010). This is because there is a connection between technology's feature and the context which it is adapted depending on the practices that takes it up (Linderoth, 2010). Therefore, the need for learning in BIM construction projects is mentioned in several studies. Kerosuo et al (2014) acknowledged the recent developments such as BIM have set challenges for collaborative learning of different parties in construction projects. Moreover, they suggest learning is essential for expansive use of BIM to manage the difficulties that emerges in complex network activity in BIM environment. The need of learning is highlighted to handle different interests, motives and perspectives towards a common construction goal. Similarly, Azhar et al (2012) highlighted the importance of a learning curve for BIM trainees to optimise BIM performance. Likewise, Becerik-Gerber and Rice (2010) acknowledged that there is a steep BIM learning curve even though, people are ready to invest in the new technology. According to Hartmann and Fischer (2007), BIM is missing the vertical integration between the parties involved in the construction projects. In general, construction practitioners tend to ignore the value of collaborative learning in BIM projects, but the study has emphasised the need for trained people in BIM construction projects. Ku and Taiebat (2011) pointed out that the learning curve and lack of skilled personnel is one of the key barriers in BIM implementation. Moreover, the study suggested that knowledge increment, which is achieved from suitable learning, is crucial to work with BIM in construction projects. Likewise, Azhar et al (2012) admitted that lessons to improve the learning for BIM trainees need to be identified to increase the BIM performance in construction projects. Similarly, Succar et al (2014) argued that necessary knowledge and skills are essential to engage with the collaborative workflow and integrated project delivery. Thus, they identified that acting as a knowledge base for BIM learners and learning providers, including aggregated competency which is a combination of theoretical knowledge,skills and applied knowledge, is essential to develop BIM modules in terms of satisfying learning requirements for several parties to encourage BIM learning. There is also no appropriate guidance and best practice to learn and build up the capacity for BIM use to increase productivity, efficiency, quality, and to achieve competitive advantages in global market to and to attain the targets in environmental sustainability (Arayici et al., 2011). The study by Arayici et al (2011) viewed BIM adoption and implementation from a socio-technical perspective, which considers both the technology and the socio-cultural environment that provides context for its BIM implementation. The results show that BIM technology should be taken from bottom-up approach, rather than top-down approach to engage people in the adoption, ensure that people's skills and understanding improves, build up their capabilities, for successful change management and to avoid resistance to change. In addition, it showed that the efficiency in BIM projects are achieved through the piloting projects and through continuous upskilling of the staff members. Furthermore, the study explicitly shows that 'Learning by doing' and forward thinking has an important role, while implementing emerging technology like BIM. However, implementing BIM efficiently depends not only on learning new software application but also in reinventing the workflow, training the staff and assigning responsibilities and the way of scheduling project tasks (Eastman et al, 2008). Even though the object-oriented tools are available to build in the models for the construction projects, it is challenging to integrate people to involve in BIM process and to organise the information related to it (Howard and Bjork, 2008). Succar et al (2013) claimed that organisations need to enable the individuals with BIM abilities through developing the BIM competencies. These BIM competencies not only need to be learnt, it should be applied in the job measured for the purpose of performance improvement.

Conversely, a study conducted by Cao et al (2017) claimed that organisational BIM capability is influenced by BIM implementation motivations. Nevertheless, he admitted that the lack of knowledge in adjusting traditional ways of working process and lack of expertise in BIM is still a barrier in the Chinese construction industry (CCIA, 2013). On the other hand, Won and Lee (2010) identified that information sharing, a master BIM model team/manage and leadership of the senior management are most important factors controlled for success of BIM construction projects. In addition, the 'learning curve to adopt BIM' did not fit into the most important factors in determining the BIM function.

To carry out a smooth and successful BIM construction project, many aspects in BIM need to be effectively managed, such as outlining work procedures, collaborative planning, sharing information among project participants, and avoidance of legal problems. However, to manage all of these simultaneously, we need a suitable learning approach to determine the most appropriate methods to complete the BIM task successfully. BIM learning is highlighted in several studies however, a connection between BIM Learning content is important to facilitate effective BIM learning across the industry and academia (Succar et al., 2014). Supporting this, a study conducted by Merschbrock and Munkvold (2014) highlighted that establishing a BIM environment is essential to gather capabilities and maturities for collaborative BIM work. BIM in construction projects should not merely be adopted as a tool, but instead a comprehensive approach for information management and team work is essential (Sacks and Pikas, 2013). Personal BIM skills (Russell et al., 2014) and BIM enable collaborative learning environment help to prepare the students with the collaborative problem solving skills to involve in the BIM projects (Mathew, 2013).

In this rapidly moving digital world, BIM has acted ad foundation towards digital transformation to alter or change the work patterns using structured 3D models and enriched data using an array of interoperable technologies. BIM platform helps to store the relevant data connected to a project in a single federated model and then apply the relevant details into the digital environment when needed. Data involved in this centralised BIM model are used to increase productivity, efficiency, quality and to achieve competitive advantages in the global market to attain their set targets.

2.3 Building Information Modelling (BIM)

The concept of BIM has been started to develop in the period of 1970s when computer aided design and computer aided manufacturing were two separate technologies (Latiffi et al.,2014). Later in 1963, the first Computer Aided Design (CAD) was developed by Ivan Sutherland with the aid of graphical user interface ‘Sketchpad’. After this huge breakthrough, in 1975, Charles Eastman has introduced a prototype called Building Description System (BDS) that explored the ideas of parametric design, high quality computable 3D representation using a single integrated database for visual and qualitative analysis. Following this, in 1977 he generated Graphical Language for Interactive Design (GLIDE) which represents most of the characteristics of BIM which is in current usage. The real BIM awareness began when Gabor Bojar developed the first software ArchiCAD for personal computers in 1982. BIM started to get popular in 1990s with IM and Architecture, Engineering and Construction (AEC) merging together and introduction of BIM software in 2000 has increased the BIM implementation (Bergin, 2010).

BIM in the AEC industry has been evolved with a number of emerging technologies. Initially, BIM has been inherited from CAD’s paradigm of numerical precision. In terms of technologies embedded in BIM process, some relies still traditional CAD process and built BIM solutions around them. For example, Bentley and Nemetschek still use CAD as the basic platform. On the other hand, some other technologies such as Autodesk entirely develop their own modelling engines. However, in all cases the combination of CAD and emerging technologies have introduced to 3D parametric modelling (Wierzbicki et al., 2011). Following that, this will be then integrated with an Information Management system that provides a BIM solution.

BIM has been around in the construction industry for the past two decades, it substantially started growing in the UK after the Cabinet Office (2011), announcing the Government’s intention to require collaborative 3D BIM (with all project and asset information, documentation and data being digital) on its construction projects by 2016 through the Government Construction Strategy. BIM plays a key role in AEC industry which is primarily a three dimensional digital representation of a building and its intrinsic characteristic. Moreover, it provides consistent and coordination views and representations of the digital modes with the relevant data on it. BIM as a virtual process includes all aspects, disciplines and systems of a facility within a single virtual model that allows all project team members to collaborate more accurately than the traditional processes. The model created will be continuously refined and altered by the project team members to ensure that model is accurate before it is used (Carmona and Irwin, 2007). Therefore, as shown in Figure 2.5 BIM process is different from the traditional construction process.

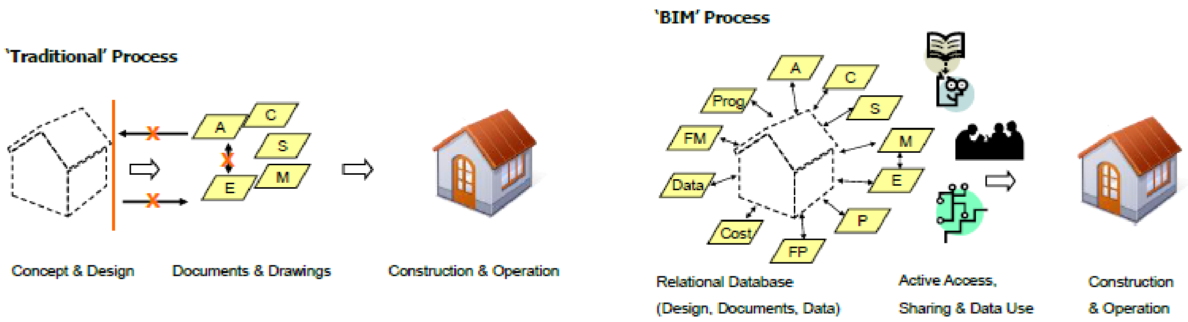

Figure 2.5: Comparison between "Tradiional" and BIM process (Azhar et al., 2012)

Hatmoko et al., (2019), Smith and Tardif (2009) and Kymmel (2008) state one of the purpose of BIM is to construct a building facilities virtually in advance to physically building it however, it is not restricted to geometry representation (Rahimain, 2020). However, similar to building projects BIM also has started to become a promising technology in infrastructure projects (Vilutienė et al., 2020). According to Jones et al (2017) BIM in infrasturucture projects has helped for document preparation, to ensure reproductability, reduce errors and for accurate time and cost calculation. Overall, BIM in both construction and infrastructure projects helps to identify the problems and to find out the potential adjustments in the project before it is constructed and avoid mistakes and errors in the beginning of the construction project through effective communication. Jaehyun and Hubo (2017) and AGC (2006) consider BIM as a software database where its application to a process requires the database to be populated initially and then maintained as the project progresses. This helps to generate each project team members to create their own model with relevant information instead of 2D drawings. In relation to this idea, BIM is about how it creates an object-oriented database, meaning that it is made up of intelligent objects (Elvin, 2007). On the other hand, according to Eastman *et al* (2008), BIM is considered as an integrated practice in construction that should be used as building model repository. The final resulting BIM model, which is a data rich object-oriented parametric representation of the facility, will be used to extract and analyse the project data throughout the project lifecycle by different project participants according to their needs (Azhar *et al*., 2008).

However, there are also different other ways of looking at BIM as methodology, technology, process, digital model and digital representation as shown in the Table 2.1. BIM as a technology advancement has speed up the construction process with advanced information systems (IS) and offers opportunities to improve collaborative working and integration. However, many organisations are still struggling to work with this technology and many implementations have failed in several situations (Merschbrock and Munkvold, 2014).

Author/s	*Year*	*Definition*
Autodesk	*2007*	*A building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction.*
Eastman et al	*2008*	*A computer aided modelling technology for managing and generating building information, with the related processes of producing, communicating, and analysing building information models.*
Vanlande et al	*2008*	*The process of generating, storing, managing, exchanging, and sharing building information in interoperable and usable way.*
McGraw Hill	*2009*	*The process of creating and using digital models for design, construction and or operations of projects.*
Nisbet and Dinesen	*2010*	*A digital model of a building in which information about a project is stored. It can be 3D, 4D (integrating time) or even 5D (including cost) – right up to 'nD' (a term that covers any other information).*
National BIM Standard (NBIMS)	*2014*	*A digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.*

Table 2.1: Summary of BIM definitions

With all these arguments and definitions in this context of this study BIM has been considered as a technology which is a part of digitalisation and is described as:

Cloud based computer-aided technology where the integrated data and visualisation technologies with both geometry information and non-geometry information manages the whole project life cycle through focusing on planning, design, construction, operation and maintenance (Yang and Liao., 2016)

2.3.1 BIM usage in the construction project lifecycle

Construction project lifecycle is divided into different stages and BIM has its own benefits in each stages. The construction project lifecycle can be categorised as project inception, feasibility, design, construction, handover, operation, maintenance and eventual demolition (Eadie *et al*., 2013). Similarly, Enshassi et al (2016) in their study chategoriesd the project life cycle into inception phase, design phase, construction phase, operation phase, and demolition phase. In contrast, Crawford (2011) added reuse or recycling with the other five construction project lifecycle: raw material extraction, manufacturing, construction, operation and maintenance and demolition and disposal. Lifecycle stage in this study involves the natural resources, energy and water during the whole range of works in construction projects. On the other hand, Benett (2014) has divided the construction project life cycle in six phases according to its purpose and characteristics: pre-project phase, planning and design phase, contractor selection phase, project orientation phase and project closeout and termination phase.

The BIM industry working group (The BIM Industry Working Group, 2011) and Arayici and Auoad (2010) show that the UK Government believes that BIM usage can bring many efficiencies and benefits across the project lifecycle. BIM can be used in every single stage of construction project lifecycle, regardless of the type of project delivery (Jati et al., 2019, AIA, 2007; Eastman *et al*., 2008) and this clearly shown in Figure 6 generated by Computer Integrated Construction Research Program. (2010).

Stakeholder engagement plays a major part in the initial design stages of construction projects. Therefore, during this BIM is used to centrally disctribute the information which can be accessed by all the interested project participants. This provides all the project participants to have a shared vision and a common plan (Sinenko et al., 2020). On the other hand, design information are clearly presented at the beginning of the project which helps to make efficient decision to manage the construction project in a better way (Fischer & Kam, 2002). Accordin to Aranda-Mena et al. (2009) it will also lower the project life cycle cost through the available information and performing value engineering using BIM technologies. Similarly, Hannon (2007) mentioned that cost saving in BIM construction project in design stage happens through avoiding potential delays, change orders, claims and information requests. In addition, BIM also benefits in identifying the errors and clashes in the design stages that wll again lead to cost reduction and legal disputes. 3D visualisation in the design stage also provides better communication among the parties to rigorously analyse and make decisions (Young et al., 2009). Consequently, quantity take off can be also accurately extracted in the early stage using BIM federated model to use in Bill of quantities and procurement documents (Sabol, 2008). Detailed and reliable cost estimation prepared in the early stages of the project helps to receive early cost feedback and control the budget from the start of the project (Eastman, et al., 2008). Therefore, as many research have highlighted that BIM usage in the initial design stage of the construction project achieves more benefits (Eastman *et al*., 2008; Smith andTardif, 2009) which can highly influence in project cost.

BIM model in design stage includes individual built assets, sites or geographic information system with attributes that define their detailed descriptions and relationships that specify the nature of the context with other objects. Therefore, this information can be used for cost estimating, project planning and control, sustainability (Life cycle analysis and life cycle costing) and eventually for management of the operation and maintenance of the built asset. The use of BIM in early design stage can improve the collaboration between the project team members and also provides opportunities to derive maximum benefits (CSQ, 2014). In addition, architects can test their models in terms of whether the right materials have been used including energy analysis. BIM also helps the construction manager to produce constructability, sequencing, value and engineering reports. Most importantly clients can visually see the expected design and also can walk through the actual generated design. In this stage usage of BIM increases the productivity (Al-Ashmor et al., 2020; Kaner *et al*., 2008; Eastman *et al.*, 2008), reuse data for visualisation, improve communication (Al-Ashmor et al., 2020;Kiviniemi *et al.*, 2008) and improve the clarity of design drawings (Kaner *et al*., 2008). Moreover, the benefits of using BIM are highlighted in studies conducted by Svetlana and Jonathan (2019) and Azhar *et al* (2012).

It has been identified that there are also plenty of beneficial use of BIM in preconstruction and construction stage. Preconstruction stage includes maintenance scheduling, building system analysis, asset management, space management and tracking, disaster planning and record modelling which help to maintain the building throughout its lifecycle (Svetlana and Jonathan, 2019;Azhar *et al.*,2012). In addition, the Building Automation Systems (BAS) which controls and monitors the use of mechanical and electrical equipment can be linked to the record model to provide a successful location based on maintenance program. During the construction stage detailed design facilitates coordination of fabrication or computer controlled manufacturing details, coordination of installation, automated estimated quoting and accurate off-site manufacturing details (Yu, 2021; Svetlana and Jonathan 2019).According to Kunz and Fischer (2012) and Khanzode (2010) BIM implemenetation in construction stage helps to reduce the request for information and change orders which leads to achieve the productivity. Moreover, focusing on waste reduction, customer satisfaction and continuous improvement with the aid of BIM has benefited to gain productivity in construction project (Tahrani et al, 2013).

Apart from design and construction stages BIM also have benefits during operational and maintenance stages which is based on facility management (Pinti et al., 2022; Zheng et al., 2017). In this stage, BIM can act as a tool for the owner to manage and operate the structure of the facility. Moreover, BIM provides repository of detailed information of the built assets for FM. For this stage, BIM provides a tool which can retain the records of updated information of built assets. This will be beneficial for all the project stakeholders to get the information quickly when it is needed. During operational stage, building performance can be measured through building system analysis that includes energy, lighting and mechanical. Moreover, using BIM in this construction stage helps the user to measure productivity at any stages of the project.

BIM has been also used in the decommissioning stage of the project and later in Circular Economy (EC). At the completion of the project BIM will be useful to supply the information regarding built asset construction, material and whole life history. Due to the BIM usage the information to identify the hazardous regarding built assets materials or elements or repair works can be extracted from the stored project information. Moreover, usage of BIM in this stage reduces the risks that need to be managed and increases the sustainability through handling the materials in appropriate manner. In recent years, the concept of CE has been emerged in the construction industry due to resource conception and environmental concerns. BIM integration in CE in construction projects optimise material efficiency, increases energy use and minimise wastages through chosing sustainable materials (Xue et al., 2021).

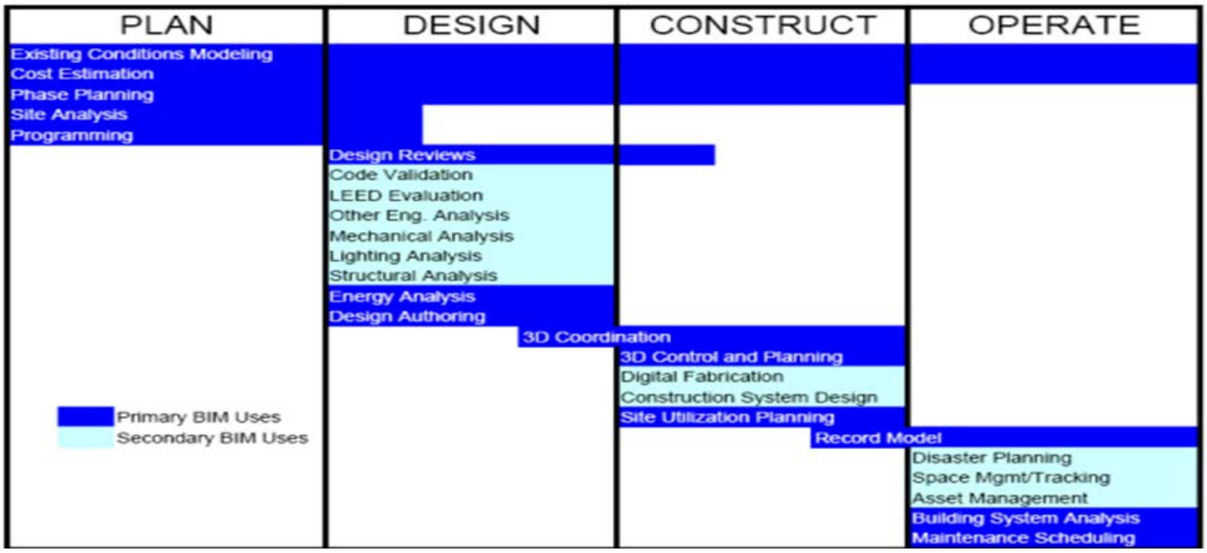

Figure 2.6: BIM usage in project lifecycle (Computer Integrated Construction Research Program, 2010)

2.3.2 BIM maturity Levels and BIM Capability stages

Succar (2010a) refers BIM Maturity level as the quality, repeatability and degree of excellence within a BIM Capability. While looking at the lenses of data and process set, BIM can be categorised into four different levels (Bew *et al.*, 2008).

Level	Description
Level 0	This is the use of unmanaged CAD with electronic paper as the likely exchange format. In this stage there is no coordinated connections to the models of other disciplines or requirements regarding documentation of information exchange.
Level 1	This is managed CAD in 2D or 3D format where the company engaged with industry standards with the process such as BS1192 with commercial data is managed by stand-alone finance and cost management package.

Level 2	This is managed 3D environment held in separate discipline tools with parametric data and commercial data and managed by Enterprise Resource Planning. During this stage, integration occurs on the basis of proprietary interface or bespoke middleware. These federated models are interoperable, or are integrated on the basis of proprietary interfaces. Level 2 may also utilise 4D programme data and 5Dc cost element.
Level 3	This is fully open interoperable process and data integration enabled by IFC which can be accessed by all project participants. This is named as integrated BIM, the data and information are managed by a collaborative model server.

Table 2.2: Levels of BIM

Succar (2009) with the understanding of BIM levels (Table 2.2) has developed BIM capability stages and acknowledged the minimum requirements or the major milestones that needs to be achieved by the organisation to implement BIM technologies and concepts. This mainly focus on BIM Level 2 which is highly adopted in construction industry at that time of research however, this is now superseded by UK BIM Framework/ ISO 19650 series. Initially it starts with Pre-BIM stage that identifies the status of the industry prior to the emergence of the BIM concept. Following that is Stage-1: object-based modelling focus on the organising the project. For this BIM authoring software such as Vector works, Bentley and ArchiCAD are essential. At this stage data exchange among the stakeholders is unidirectional and communications are asynchronous and disjointed. Stage 2 is about model based collaboration that helps to operate BIM effectively on multidisciplinary collaborative BIM projects. In stage 3, organisation needs to be implementing network-based repository platform to share object-based models. During this stage interoperable data exchange across disciplines will occur. The final stage is Post-BIM covers a variable endpoint with evolving connotation, which deploys virtual integrated Design, Construction and Operation (viDCO) tools and concepts (Succar, 2010a) (See Figure 2.7).

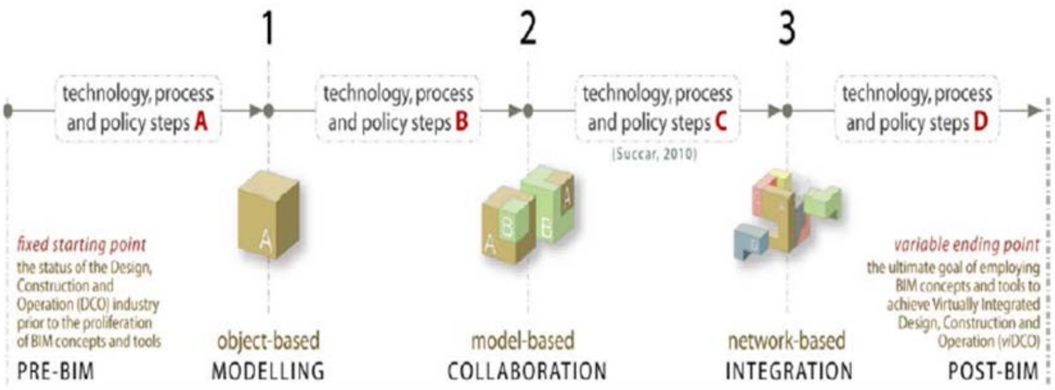

Figure 2.7: BIM capability stages (Succar 2009)

Early stages of BIM need open communication and information exchange to make collaborative decisions and foster greater level of risks (Rezgui et al, 2013). Adaptation of BIM in the construction industry has introduced new working practices through model-based collaboration and multi-disciplinary teamwork (Davies, 2013). The level of interactions depends on the technical and organisational revel required for the project (Merschbrock, 2012). The higher level of interdisciplinary interactions and integrations are tackled with the aid of spawned concepts such as Knotknowing

(Engeström and Engeström, 1999; Hannele et al, 2013) and Big Room (Temel et al, 2019). In these interdisciplinary collaboration traditional boundaries between the professionals are eased but there is more focus on new process management tasks (planning and execution of information) and new model management activities (coordinating discipline related datasets). Due to new activities emerging on-site in BIM practices improvisation of data exchange standards and protocols are mostly based on visualisation and outside modelling systems. On the other hand, in BIM projects there are number of stakeholders such as designers, suppliers, manufacturing partners, and clients are involved in supply chain (Jupp and Nepal, 2014). Therefore, to cover these wide range of BIM users in the supply chain and to manage the ad-hoc basis interfaces. Stakeholders involved in BIM-enabled construction projects need to work with wide range of concepts, tools and workflows that are essential to complete the works. Moreover, understanding the principles and aspects of BIM is vital to implement it in the construction projects (Succar & Sher, 2014; Suwal et al., 2013). According to Tsai (2019) lack of learning in BIM is one of the key reasons for not utilising BIM to its full capacity.

2.3.3 BIM benefits and challenges

2.3.3.1 BIM benefits

Building Information Modelling is introduced within the construction industry to view the virtual process which incorporates all aspect, disciplines and systems of facility with a single integrated model that can encourage all the project participants to work in an efficient way. Integrated virtual BIM model is the root of all BIM benefits which includes both geometric and non-geometric data and the benefits will differ across different stakeholders and project types. Initially this integrated virtual BIM model will be constructed and after completion precise geometric and relevant data can be extracted to support design, procurement, fabrication and construction activities (Eastman *et al*., 2008). Moreover, this model can be also used for the operation and maintenance purposes. Therefore, with the aid of integrated BIM virtual model potential BIM benefits can be achieved in different stages of projects lifecycle as shown in Figure 2.6.

BIM is a thriving technology that has transformed the way buildings are planned, designed, constructed and managed throughout the project lifecycle (Svetlana and Jonathan, 2019; Azhar *et al*., 2009, Wong *et al*., 2010) . Although, scholars and practitioners have identified the impact of BIM in construction projects, the adaptation is still slow in comparison the other industries. BIM shares knowledge and helps to make decisions during the lifecycle from the early conception to the ultimate end-of-life through providing readily available graphical and non-graphical building information by the use of relational database (Woo, 2007). This helps to explore both physical and functional characteristics digitally before constructing the building to deliver the projects faster, more economically and reduce environmental impact (Kelly *et al.*, 2015). It is beneficial for all stakeholders involved in the BIM project such as facility mangers (Olatunji, Sher and Ogunsemi 2010), construction agents (East, 2009) and also for project owners (Riese and Shelden, 2008). Involvement in both geometric and non-geometric data in BIM projects expects to envision efficient collaboration (Arayici *et al.*,2011; Kymmell, 2008), improved data integrity (Ellis,2006), intelligent documentation (Popov *et al*.,2006),change in business process (Howard and Bjork,2008),accurate way of working (Holzer, 2007), reduce waste (Azhar,2011),distributed access and retrieval of building data and high quality project outcome through enhanced performance analysis, as well as multidisciplinary planning and coordination (Fischer and Kunz, 2004;Haymaker *et al*., 2005). In addition, more benefits such as creating sustainable communities (Nawari, 2012) and improve accuracy (BIMHub, 2012; Bentley, 2012) are highlighted in BIM related studies. However, there are also benefits of BIM such as energy performance, early supply chain involvement, project information used in facility management which cannot be immediately observed in construction projects (Dzambazova, Krygiel, and Demchak, 2009). Even though the benefits of BIM to the AEC industry has been widely acknowledged in several studies as listed in Table 2.3, BIM adoption is slower than the anticipated rate due to several BIM challenges.

Author(s)	**Year**	**Benefits**
Fischer and Kunz	2006	supports the exchange of data between software to speed up analysis cycle times and reduce data input and transfer errors
Ballesty	2007	Faster and more effective processes, better design, controlled whole life costs and environmental data, Better production quality, automated assembly, better customer service, lifecycle data, integration of planning and implementation processes, ultimately a more effective and competitive industry and long-term sustainable regeneration projects.
Foster	2008	Visualization, scope, clarification, partial trade, coordination, collision, detection/avoidance, design validation, construction sequencing, planning/phasing plans / site and logistics
Eastman et al	2008	Easy Verification of consistency to the design intent, extraction of cost estimates during the design stage, extraction of cost estimates during the design stage, generation of accurate and consistent 2D drawings at any stage of the design, clash control, energy analysis and earlier collaboration of multiple design discipline.
Young, Jones and Bernstein	2008	Easier coordination of different software and project personnel, improved productivity, improved quality control
Azhar *et al*	2008	improved profitability, reduces costs, better time management and improved customer/client relationships
Zuppa *et al*	2009	BIM as enhancing coordination, productivity, and business operations; whereas contractors see improvements in scheduling, estimating and drawing processing.
Fong *et al*	2009	Managing the client's asset, reduced risks, improved productivity, streamlined production, maintenance of design intent, facilitation of quality control through clear communication and sophisticated analytical tools
Arayici *et al*	2011	Linking project information, effective reuse of information from BIM database, Effective information exchange between stakeholders, ability to check drawings, accurate timing and energy performance, leading to standardise lean process and better linkage will be established with the knowledge database and BIM.
Khosrowshahi and Arayici	2012	Information management for building lifecycle, increasing efficiency leading to improve design, helping client develop BIM capabilities themselves, visualisation to manage client expectation and enable awareness for training, guidelines, implementation support and monitoring, 2D walkthroughs, visualisation, quick analysis of alternatives, quick revisions of schemes, material supplier integration, better modelling and high quality documentation
CSQ	2014	Cost estimating, project planning and control and management of operation and management has number of advantages such as increased utility and speed, enhanced collaborations, better data integrity and quality, visualisation of data, enhanced fault finding and overall project productivity

Omar and Dulaimi	2015	Enhances the collaboration, the coordination, homogeneity anD interoperability (the use of a single software database system) between the project parties from the same stage and the different stages (conception and initiation, definition and planning, execution, performance and control, and project close).
Azhar *et al*	2015	Reduce the design errors, save time and money, enhance the effectiveness of facility management such as providing accurate as-built drawings to facilitate maintenance and operation.
Mohamed and Ashraf	2018	Lack of BIM experts, resistant to change, lack of support from top management, difficult to set the roles and responsibilities, insufficient interoperability, lack of BIM model management, lack of demand from Government/employer, cost related to BIM implementation, lack of skilled resources, unfamiliarity, following traditional ways and unclear intellectual property rights.
Sonia *et al*	2018	Avoid redesign, reduce change order and save cost and time
Al-Ashmori *et al*	2020	Increase productivity and efficiency, assess time and cost associated with design change, eliminate clashes in design, improve multi-party communication and maintain synchronize communication, integrate construction scheduling and planning, identify time-based clashes, and monitor and track progress during construction.
Rodrigues *et al*	2022	Supports safety management, increasing the accuracy of the whole project life cycle process, collaborative work environment, provides functional performance, reduce cost, helps to achieve more sustainable results, increase safety and mitigates accidents and helps to achieve on-time completion.

Table: 2.3- BIM benefits

2.3.3.2 BIM Challenges

The challenges faced during the implementation of BIM differ according to the countries and project types. Findings from Gu and London (2010) indicated that both technical and non-technical issues are barriers in implementing BIM in construction projects. They have mentioned that technical issues are due to varying practical experience knowledge of project participants. Moreover, they concluded that availability of tools, efficient working with legal, procurement and cultural needs to be considered during BIM adoption. Several studies (Singh *et al*., 2011; McAdam, 2010; Sieminski, 2007) have highlighted the legal and contractual issues in BIM implementation and believe that this is one of the key reasons holding back BIM implementation in construction projects. Firstly, risk and liability is one of the problems regarding legal issues. While different project participants access the project information the reliability and confidentially (Li *et al*., 2008) cannot be guaranteed. Moreover, studies conducted by Breetzke and Hawkins (2009), Christensen *et al* (2007) and Udom (2012) clearly emphasise that legal issues need to be solved through construction contract in order to reduce the associated risk. Secondly, due to model being an integration of different pieces of information made up of a contribution from the multidisciplinary project actors, ownership cannot be vested in a particular party (Sebastian, 2010). In addition to these issues, barriers such as lack of awareness and training

(Bernstein and Pittman, 2004), fragmented nature of the AEC industry (Johnson and Laepple, 2003), industry's reluctance to change existing work practice and hesitation to learn emerging concepts and technologies (Johnson and Laepple, 2003), cost for training and resources (Azhar *et al.*,2011;Crotty,2012) and the lack of clarity on roles, responsibilities and distribution of benefits and lack of knowledge and skills within the project participants (Lindner and Wald, 2011) have identified as barriers on BIM adaptation in the literature. Additionally, Ku and Taibet (2011) indicated that cost, learning curve, software shortage, reluctance of the others and limited knowledge are some of the constraints for BIM implementation. Consequently, this study recommended self-learning, seminars/workshops, in house training and hiring previous trained personnel to overcome these issues. Moreover, Seaman (2006) highlighted irrelevant data input, no standards for BIM contract documents, reluctant of producing digital data and interoperability are the constraints for BIM adaptation.

Even though BIM provides a collaborative environment in their projects, challenges regarding individuals, environment and technology are difficult to overcome (Khanzode *et al.*, 2008; Espadanal and Oliveira, 2012).People working in silos in a BIM environment and not having wider exploration are some of the reasons for these difficulties (Leeuwis, 2013). On the other hand, construction related studies show that interchanging the technical factors of BIM information are successful nevertheless this needs to be done alongside interpersonal communication (Davies and Harty, 2013; Dossick and Neff, 2010). Moreover, the change in practice and organisational relations in projects is highlighted in BIM adoption studies (Gu and London, 2010; Love *et al.*, 2013). Although a number of challenges has been highlighted in several studies having new skills attitudes is the initial stage to implement BIM successfully in future UK construction project (Eastman *et al.*, 2008; Smith and Tardif, 2009). Similarly, CSQ (2014) and Arayici *et al.* (2009) believed there is a need to upskill the existing construction workers at varies level of the workflow. In relation to these studies, the importance of training for BIM implementation has also highlighted in several construction studies (Yan and Damian, 2008; Mihindu and Arayici, 2008). Apart from these there are number of challenges to BIM adoption addressed in other studies which are listed in Table 2.4.

Author (s)	Year	**Constraints of BIM**
Tse et al	2005	Lack of client demand for implementing BIM
Thompson and Miner	2007	Risks and challenges in using a single model, Legal issues
Foster	2008	The absence of standard documents
Young, Jones and Bernstein	2008	Inadequate training, Liability and legal issues related to accountability and taking responsibility for data exchange
Azhar, Hein and Sketo	2008a	Non-stipulation of precise / standard requirements for ownership of the model. The daunting task of making changes to 'entrenched business cultures'
Davidson	2009	
Smith and Tardif	2009	The daunting task of making changes to 'entrenched business cultures' The growing propagation of non-standardised BIM applications by myriads of software developers
Arayici et al	2009	Changing the traditional work processes
Gu and London	2010	Data security and user confidentiality
Jung and Joo	2011	Business benefits may be intangible, organizational changes may occur as a result of the introduction of a new system, business benefits are evolutionary over the life-cycle of the

		system, diverse stakeholders involved with subjectively evaluate the system and may have conflicting options, users may feel intimidation or fear of the new system and how it will affect their job negatively and practical difficulties such as improper utilization, interconnected systems and inability to divide related systems and benefits
Sebastian	2011	Three-dimensional visualisation and detailing, clash detection, material schedule, planning , cost estimate, production and logistic information, and as built documents
Khosrowshahi and Arayici	2012	Firms are nor familiar enough with BIM use, Reluctance to initiate new workflows or train staff, benefits from BIM implementation do not outweigh the cost to implement it, benefits are not tangible enough to warrant its use, BIM does not offer enough of a financial gain to warrant its use, Lacks the capital to invest in having started with hardware and software, BIM is too risky from a liability standpoint to warrant its use, resistance to cultural change, no demand for BIM use.
Omar and Dulaimi	2015	Inadequate BIM experience, inadequate support from the top managements to adopt BIM, Resistance to change, Difficulties correlated to workflow transition due to changes in roles and responsibilities, inefficient Interoperability, Difficulties of managing BIM Model, Lack of skilled resources and complexity of BIM software, lack of demand from the governments/clients to use BIM, Not all stakeholders are using BIM, costs associated with the implementation of BIM, unclear Intellectual Property Rights (IPR),AEC Traditional procurement methodology
Abdulaziz	2017	Market is not ready, the clients do not demand BIM ,Training Costs and the learning curve are too high, The difficulty of having everyone on board to make BIM effort worthwhile, Too many legal barriers exit and they are too costly to overcome, Issues of model ownership and management will be too demanding on owner resources, Designers or Architectural Engineering firms do not usually prove empirically the benefits of BIM to customer, Construction Insurance companies do not have BIM projects risk specific policies, Technology risk and barriers technology is ready for single discipline design but not integrated design, BIM is not having a full support of upper management or decision makers.
Rana and Sadeq	2017	Lack of support and incentives from construction policy makers, Standards and codes are not available, Lack of awareness about BIM, No client demand, Resistance of change, 6) Lack of a BIM specialist, Necessary training is not available, Cost (software, hardware upgrade, training, and time), BIM requires radical changes in our workflow, practices and procedures.

Shakil	2018	Resistance to change, traditional way of contarcting, cost on BIM software, Lack of awareness on BIM usage, Improper university curriculum in engineering, in sufficient BIM experts' and lack of BIM training for the staffs.
Amjed and Sawsan	2019	Culture resistance, lack of protocols for coding objects within building information model and lack of qualified staff to adopt this technology
Sriyolja, Harwin and Yahya	2021	Cost of the BIM software, Lack of awareness on BIM usage, still using traditional ways (culture), lack of understanding on BIM processes and management, lack of demand, lack of skills to use BIM, insufficient training, undefined standards and contracts.

Table 2.4: BIM constraints

2.3.4 Learning in BIM

The UK Government mandated procuring public construction projects to deliver through Level 2 BIM to improve cost, value and carbon performance. BIM Level 2 and the superseding UK BIM frameworkprovides a wider range of applications to CAD (Computer Aided Design) which is more than a technology.

CAD in used to create accurate floor plans and models. On the other hand, BIM in construction projects are focusing beyond creating 3D model which helps to generate better documentataion, sustainable buildings and collaborative environment. Therefore, learning needs for BIM are different from CAD hence, different learning approaches and methodologies are adopted to learn and teach BIM to the tertiary students in construction related courses (Besné et al, 2021). This is to apply BIM in their future career (Wong, 2010) to embrace the opportunities and to overcome challenges in BIM construction projects to remain current and relevant. Similarly, Tsai et al., (2019) and Eastman *et al* (2008) argue that BIM's potential to change the construction industry depends on construction education which can be achieved through practice, teaching and research by AEC community.

In today's digitalised world, it is important to understand the responsibilities and tasks of each disciplines working in a construction project team (Laura et al., 2019; Michael *et al*., 2004). All disciplines works towards a common goal of designing and construction of a building or infrastructure that meets the determined design in a safe manner within the agreed budget and time. However, due to the complexity and uncertainty of today's economy there is a need to educate the construction disciplines. At the sametime, understanding the fundamentals of BIM is also beneficial to learn this evolving technology quickly and to make efficient decisions.Generally, cognitive and behavioural approaches are used, while designing the Built and Environment courses. Cognitive approach focuses learning in a formal way where the most important methods are adopted. On the other hand, behavioural approach considers that practice can be learnt through successful behaviours of others. These learning approaches have worked well when BIM was introduced to construction industry and helped to design BIM models and understand how the objects are generated. However, when industry practitioners have started to realise the BIM values, concepts, collaborative implementation process and skills to operate the BIM tools (Abdirad and Dossick 2016) these approaches started to become ineffective due to the negligence of the multiple intertwined factors such as BIM skills, ability to do teamwork, learning atmoshphere, individual knowledge and level of understanding the appliactions. Therefore, to be a successful, both traditional learning methods (Weber, 2003) and learning-by-doing are important (Peterson *et al.*, 2011). Similarly, Hieltsing (2008) from his constructivist point of view suggested that both theoretical based learning and problem/design-based learning are vital to understand the concepts behind BIM with the team of students. The theoretical understanding of BIM can be provided at universities whereas practical knowledge can be given in construction sites. Camps (2008) stated background education is important to build up the BIM knowledge. In presence, several universities and educational organisations have started to offer wide range of courses that include BIM content and strategies in place to fully integrate BIM across the curriculum to meet the BIM demands and provide experience to handle the new working methods and tools (Holland *et al.*, 2010). Meantime, BIM Academic Framework (Underwood, Khosrowshahi, Pittard, Greenwood, & Platts, 2013), IMAC framework and New Zealand's national framework are some of the framworks introduced for BIM education in Academia. On the other hand, Kumar's roadmap (UK), Kumar's framework (UK) are introduced for BIM eduction in the industry. Education frameworks such as Collaborative BIM education framework from the BIM Education Working Group (EWG) (Australia) and Learning Outcomes framework (UK) BIM TASK GROUP and BAF are common for BIM education in Academia and Industry. The intention of LOF is to provide training to industry professionals, academia, private educators and organisation which mainly forcus on three functions: Strategic, Management and Technical (Ahmad et al., 2016). Although these frameworks provides supporting dcuments and guidance to set-up a BIM construction projects there is no accepted learning-strategy especially considering the essential digital skills for BIM. Hence, Kassem *et al* (2015) believe that there is a need to up-skill the current workforce in practice.

2.4 Learning

Changes in the digital world with rapidly changing technologies have increased the competitions among organisations, including developing the demands for skills to tackle the ever-changing working environment. In these fast moving and ever changing environments, learning has certainly played a major role to cope with these changes within these environments. Learning involves closely with competency which is about acquiring and modifying knowledge, skills, strategies, attitudes and behaviours. In the beginning, philosophers started their learning experiments in the animals and later on applied in human beings. They have found that human learning is fundamentally different due to complex, elaborate, rapid and typical involvement with language. According to Dewey (1959), the learning process has two sides - one psychological and the other one is sociological. Although, philosophers believed that the concept of learning is related to psychology they then focused on formal education, recently the importance of learning has extended to the idea of 'Workplace-based learning'. Learning that occurs in the workplace and in other circumstances include everyday learning and complex personal development for both individuals operating in the learning society and for organisations competing in national markets. Therefore, there is a need to focus on how learning takes place in workplace in this ever-changing environment. Most of the construction studies have considered less about workplace-based learning due to its complexity compared to the learning that takes place in educational institutions or placement environments.

Learning is centre for this study however, it has several perceptions and has been viewed in different directions in past years. The term learning can be used both as a verb, which indicates the process function of it and as a noun, which refers to the product that has been produced by the change process (Fenwick, 2010). Although, both process and product are connected to each other. They are considered as different phenomena. Learning as a product shows the outcomes such as knowledge development or behavioural change (Fenwick, 2006). Hager (2004) argues that generally people believe learning as acquisition of skills and information in this act as mediator, which can be created, used, exchanges and stored. In contrast to this view, Fenwick (2010) stated that knowledge acquisition attained by the individual is different from ongoing human developments such as emotions, intellectual and social actions and also different from networks of information flow or level of knowledge-making. Therefore, he suggested that learning as a process of meaning - making it vital to consider in practice. Wenger

(1998) suggested that this can be achieved through joint participation, shared enterprises and mutual engagement. Learning as a process that embraces the meaning-making is further supported by Billett (2000) who mentioned learning takes place when people are acting and thinking at the same time. Conversely, Sense (2004) has defined project learning as a product of community, rather than of the individuals within it. On the other hand, learning is viewed as continuous active improvisation (Tikkanen, 2002), or continuous collective construction of a social reality (Samra-Fredericks, 2003). In reality construction projects are carried out by numerous individuals from different organisations with different professionals and hierarchical layers towards producing one product, while considering their own goal. This fragmentation raises a need for networking learning between project team members which is more than individuals and is about transferring the knowledge among others through interaction and reflection. According to Billett (2004), learning can be interpreted as permanent or semi-permanent from the way individual think or act. While an individual starts engaging in the process of thinking and acting beyond executing a task or process, a change in knowledge happens mostly towards the process. Bloomer and Hodkinson (2000) state that although learning is not reserved for specific settings or period some experience may provide richer learning outcomes compare to others. Thus, from cognitive perspective individual's engagement in most routine activities in workplaces is about reinforcing or improving what is already known (Anderson, 1982). In this individualistic view, learning is used to refine the procedure and render tasks with minimum option to conscious thought however, it frees up memory to focus on other tasks. Hence, this allows individuals to use their cognitive resources more selectively and deliberately. Nevertheless, Mead (1934) claimed that learning is a continuous process of conscious thought that contributes to individuals' cognitive processes over a lifespan. Thus, in the workplace individual learning is not the only form of learning instead, it takes place within groups, communities, organisations, inter-organisations and sometime between nations. Moreover, the definition of learning only depends on this unit of analysis. Fenwick (2010) argued that the critical problem in conceptualising is mistaking learning as single object when it associated with various other objects.

According to Fenwick (2010), learning has been divided as an organisation and individual/team and forms of learning are not intertwined or cooperation with each other. Likewise, Lehesvirta (2004) has referred learning in three levels: individuals, groups and organisational, which also identified four processes (intuiting, interpreting, integrating, and institutionalising) for learning. On the other hand, learning from a multilevel nature has been primarily viewed by Lave and Wenger (1991) where they have considered learning as a social process, while people are interacting with each other. This is also referred as 'Communities of practice' (Lave and Wenger, 1991) or social-constructionist view (Gergen, 1994; Burr, 1995). Authors in this view consider that learning only happens in a certain situation or context, which is considered as co-factors of the learning process and outcomes. Moreover, Lave and Wenger (1991) and Rogoff (1995) denote learning as a direct participation in social practice. Furthermore, Rogoff (1995) states that learning happens through moment-by moment accumulation of knowledge through interacting with the social world as micro-genetic development. In this social process view, although learning is believed as a participation of work, the engagement in and what is learnt from socially determined practices are not solely determined by social practices. Instead, involvement of individual is also vital to choose how they want to participate and what they want to interpret and learn from their participation (experience) (Billett, 2004)

Illeris (2002) has viewed learning as combination of both inner psychological process and social interaction between the individual and their environment. According to his concern, learning only takes place when both interplay and acquisition processes are active. Moreover, he believed that learning considered solely as a social process (social constructionist view) or inner psychological view will end up in erroneous conclusions. From this view there is always some sort of direct and indirect interplay collectively involved in the learning process. In addition, Illeris (2003) stated that all process of learning leads to change in capacity although, learning has been viewed from emotional, physical, cognitive or social point of view and learning has nothing to do with biological maturation or ageing. This means that learning does not stop with knowing about new thing or adding to what is already known but also leads to several other learning outcomes such as personal development, socialisation, qualification and competence developments. Illeris (2003) in his study has divided learning into two diverse categories and three dimensions. Two categorisation of learning process are interaction among the learner and the surroundings and mental acquisition and elaboration processes. Interaction process is about social logic which is applied when learning take place whereas mental acquisition is about biological structural logic which has been followed for a long time. The three dimensions that are mentioned in his study are cognitive, emotional and social-societal. Cognitive dimension incudes knowledge, skills understanding, meaning and functionality, whereas emotional dimension refers to motivation, attitude, sensitivity and mental balance and lastly socio-societal dimension contains empathy, communication, cooperation, sociality (Illeris, 2003)

Sfard (1998) has described the understanding of learning through two metaphors. First metaphor 'The acquisition' considers learning as process of knowledge acquisition and secondly 'The participation' refers learning through participating in practices of social communities. In addition to these metaphors, Paavola et al (2004) introduced a third metaphor 'knowledge creation' where learning is seen as a creation of new knowledge. The first metaphor on knowledge acquisition refers to the typical formal education whereas participation and knowledge creation metaphors better describes leaning that take place in practice. In the participation view, learning is considered as a social process and people learn through participating in various workplace practices through collaborating with project team members and tackling new challenges and tasks. But 'participation' in this context does not mean socialising people into existing practices instead it is used to develop new practices. Generally, this is encouraged through problem solving and developing the conceptual understanding with practical problem solving (Tynj¨al¨a, 2008). Knowledge creation metaphor integrates the cognitive and social aspect of learning. Similar to this idea Hager (2004) has highlighted the necessity to develop workplace-based learning through two learning paradigms: standard paradigm and emerging paradigm. He defined standard paradigm with combining assumptions of focus on mind, interiority and transparency. He argues that learning is initially focused on mind where individual's cognitive processes happen through mental structures and accumulation. Then relates interiority to the first one but it isolates the mental life from outside the world. In other words, learning is focused on thinking rather than action. The study concluded that transparency can be observed while achieving measurable learning outcomes. On the other hand, non-transparency which is considered to be less important refers to the tacit knowledge. Conversely, emerging paradigm describes learning as an action that not only happens within the learner's mind but also in learner's environment. In this view. Learning is inherently contextual which leads the learner to a new set of relations in an environment (Hager, 2005). Comparing Hager's paradigms, with metaphors discussed above knowledge acquisition metaphor can be compared to standard paradigm whereas participation and knowledge creation can be included into emergent paradigm. This shows that acquisition paradigm is more related formal educational systems where is emerging paradigm belongs to other learning categories apart from intentional and formal learning (Hager, 2004; Hodkinson and Hodkinson, 2004). Thus, participation and knowledge creation metaphor that are compatible to emerging paradigm is more suitable for workplace-based learning. Participation metaphor has been commonly used to describe the learning that takes place in work environment (Billett, 2004; Collin, 2005), however knowledge creation metaphor has been applied in the context where learning is considered as an innovation instead of reproductive activity (Jarvis, 1992). Learning in workplace practices is generally categorised as creating new modes of action, new practices, new procedures and new products, which is independently linked to individual's thinking and acting and their social sources. Workplace is combined with both humans and non-human artefacts. Therefore, learning is conceptualised initially as being inter-psychological (individuals in the social world) before intra-psychological attributes (cognitive attributes) (Vygotsky, 1978). Inter-physiological view which is interdependent is not passive of socialisation or provided local knowledge to the individual instead it is determining the worth of what they have experienced and how they can engage and learn from it (Goodnow, 1990). Supporting this Valsiner (1994, 2000) states that co-construction of knowledge take place through relational interaction with social source. The importance of interaction and co-participation in terms of what individuals afford and how they engage with what is afforded are discussed in several studies (Rogoff, 1995; Billett, 2002). However, it can be shaped through negotiations (Suchman, 1996) and ordering (Engestrom and Middleton, 1996). At the same time, situational factors are not just alone sufficient to understand workplace learning. Therefore, it is important to understand the way of individual's agentic actions (both social and cognitive) and internationalities (Bloomer and Hodkinson, 2000; Somerville, 2002) to shape how they participate and learn through work.

The aim of the study is to understand how learning is taking place in construction projects which contains both humans and non- human artefacts. Therefore, both individual learning as well as social learning will be considered in this study to understand how learning is taking place in construction projects during technological implementation. The unit of analysis is 'Workplace-based learning' that includes case studys involved in BIM construction project. Several construction studies (Bresnen, 2009; Forgues and Koskela, 2009; Ruikar *et al*., 2009) have selected 'group of individuals' as their unit of analysis in line with workplace-based learning literature. Thus, workplace-based learning is mainly viewed in a multiple level where individuals are part of it. This is because individuals are also vital to choose how they want to participate and what they want to interpret and learn from their participation (experience) (Billett, 2004). Learning in this study is considered as a combination of participation, knowledge creation and knowledge acquisition. (Hager, 2005; Paavola e., 2004). Hence, wider view of workplace-based learning is intended to be studied in this research. Therefore, case studies in BIM construction projects are chosen not only to understand the individuals or group, but also to explore how learning aspects are connected to each other within that environment.

2.4.1 Need for 'Workplace-based learning'

Rapid change in digitalising the world has urged construction professionals to focus on changing their work practices to cope with this fast moving world (Kokkonen and Alin, 2015). The complexity and issues in construction projects are extended in social science, but the application on these issues are still selective (Bresnen *et al*., 2005a). On the other hand, specific features of social science has opened up a potential to investigate the reality of actual work practices on projects (Bresnen, 2009). According to Sandberg and Tsoukas (2011) studies in construction have addressed conventional and abstract models to overcome this issues, however these models are mostly based on rational logics and does not focus on specific situation where workplace-based learning occur.

Workplace-based learning is interconnected with skills and knowledge upgrade that are attained at that place of work. Literature has defined workplace in several ways, however in this study, the researcher has adopted Collin *et al*'s (2011) workplace definition where they have perceived it as an ever-present practice that occurs through customary work systems. According to Fenwick (2010), learning that has been adopted from 'practiced-based' is almost related with ongoing practice itself. Practice that is embedded in workplace-based learning can mean different things to people. Fenwick (2010) believes practice is related to knowledge circulation and learning that takes place in the workplace is referred to as a web of micro-interactions socializing workers and their tools to a community. In some situations, individuals take the responsibility to participate fully in a practice, but in other cases groups of people are involved to get an outcome of change or reconfigure the practices. Therefore, in this situation practice is reified whereas learning is limited to actions recognisable within an existing community of routines (Fenwick, 2010). On the other hand, Schatzki (2001) has stated that practice is about actual practice that an individual perform in a situation. This comprises the way individual learn, act, what they expect, how to speak as well as how to make sense of their environment (Nicoilini, 2013). In other words, learning is central for performing the practices. According to Corradi *et al* (2010), the concept of practice is categorised into three: interconnection activities, sense making process between practitioners, and social effects granted by the practitioners. Eraut (2004) claimed that evidence-based practice or assessing practice is something that can be seen. Therefore, he believes practice is a person's or team's capability to achieve something that has been observed. Learning that is gained through practice or the workplace can be applied to change or stabilise the organisation or retain their existing practices (Feldman and Orlikowski, 2011). Traditionally, learning in organisational studies has seen workplace-based learning from an individual viewpoint where learning is more focused on cognition and decision making process which is fundamentally about learning that takes place in human minds (March, 1991; Simon, 1991). Practice approach have been discussed in organisation studies (Gherardi, 2009; Corradi *et al*., 2010), however it is less widely discussed in project levels. Even though this study has considered workplace-based learning as an ever-present practice, practice has been perceived as a combination of interconnection activities, sense making process between practitioners and social effects granted by the practitioners (Corradi *et al.*, 2010).

Social scientific practice theory comprises a number of theories and ideas related to nature of the practice in social life (Lave, 1988). Lave (1988) stated that the aim of the practice theory is to link the individualist and structural approaches to study the organisations of human activities. The individualist approach views the organisations of activities as a feature of individuals and their interaction whereas structuralism approach that, is mostly adopted in practice theory, considers organisation of human activities beyond individuals and their interactions (Schatzki, 2001). Although there are two different approaches for workplace-based learning, Sandberg and Tsoukas (2011) believe combining both individualist and structural approaches could avoid the dichotomy of separating subject and world as two separate entities. Likewise, an overall understanding of practice theory states that the nature of social world and human activities is processual and emergent (Nicolini, 2013). Therefore, knowledge is not only being acquired it is also recreated along the learning process, which is then reflected on the learner. Studies researched on workplace-based learning show that the concept of learning are centred on 'Community of Practice' (CoP) (Lave and Wenger, 1991) described as process.

2.4.2 Conceptualising view of learning

2.4.2.1 Concepts adopted from situational learning and Community of Practice

Workplace-based learning is related to different approaches such as situational learning (Lave and Wenger, 1991) and communities of practice (Lave and Wenger, 1991, Wenger, 1998). Initially, Lave and Wenger (1991) believed that learning for practitioners depend on social interactions at the workplace. Therefore, they established the idea of situational learning, which discuss about novices becoming as expert through working alongside the experts and involving in complicated tasks. This situational learning in culture of practice is referred as 'legitimate peripheral participation' which concentrates on physical surroundings and most importantly with relational character of learning through knowing the negotiated character of meaning, and the engaged, or problem-solving, nature of learning activity for the individuals involved, rather than focusing on their cognitive view. In other words, the concept of situational learning is more than learning in situ, or learning by doing (Lave and Wenger, 1991). Although the concept of "legitimate peripheral participation" is used to describe participation in social practice, it includes learning as an integral part. Therefore, this concept has been criticised for considering learning as a socialisation of newcomers into existing practices, whereas community of practice as a context is more suitable for developing new knowledge and understanding (Brown and Duguid, 1991). Moreover, Brown and Duguid (1991) believed situational learning only focuses on the activity of novices, while the experts are seen as representing the role of the ‘teacher, facilitator or coach’. Similarly, Fuller and Unwin (2002) argued that although newcomers have fresh views and up to date knowledge and teach ‘old-timer’ new things, all novices, newcomers and experienced employees have to learning within work environment.

Later, Wenger (1998) have considered workplace-based learning in relation to practice and identity where individual trajectories of participation plays an important role. During this, CoP was considered as an entity combined with three interconnected dimensions: mutual engagement, joint enterprise, and a shared repertoire. Firstly, the mutual engagement refers to the interaction between the participants to form a shared meaning on the issue or a problem. Secondly, ‘joint enterprise' refers a process where participants are engaged and works together to achieve their desired common goal. Finally, ‘shared repertories’ refers to common jargons or resources that participants adopt to negotiate meaning and facilitate learning within groups (Wenger and Lave, 1998). Although these dimensions shows the outline process of individual’s interactions with groups, what differentiate them from other structures is still uncertain. Furthermore, Illeris (2003) stated there is no discussion on how and why individuals learn within the community.

CoP then has been shifted to a social constructivism view where Wenger et al., (2002) shifted his idea of CoP as a tool for organisation to manage ‘knowledge workers’ instead of seeing it as an individual’s learning and identity development. In other words, rather than considering learning as a knowledge transmission, this idea of CoP theorises the meaning and process of learning as part of social activity. This has been developed through the combination of three elements: the domain, the community, and the practice. Firstly, domain builds a common ground among the project participants and creates a boundary among them to decide what is worth sharing and how they are going to present it. Secondly, community is about generating the social cultures that facilitates learning through interacting and maintaining the relationship with others. Finally, practice refers to shared repertoires of resources that comprise documents, ideas, experiences, information, and ways of addressing recurring problems (Wenger *et al.*, 2002). Although the combination of these three elements in CoP can optimise and disseminate the knowledge within the groups, it is less clear on how to achieve these within the workplace environment.

Generally, the notion of CoP is positive. However, in the early-stage Pemberton *et al* (2007) argued CoP is critical due to the trust and mistrust that occurs between the members. Furthermore, they have also indicated that management in CoP is problematic where there is debate on whether CoP can or cannot be managed, which are usually seen as ‘emancipatory’ rather than as driven by instrumental logic with managerial control. However, the latest work by Wenger *et al* (2002) indicates that CoP represents a decisive shift to a new discourse where community of practice is seen as a management tool rather than identity development (Cox, 2005). On the other hand, Cairns (2011) further summarised the critiques of communities of practice and presented six points of criticism regarding: (1) definitional issues, (2) the issue of learning something new, (3) the lack of checking what has actually been learned, (4) the unit of analysis, (5) the role of language, and (6) the role of individual agency. In general, community of practice has positively impacted on learning in a workplace environment. However, the quality of studies varies from loose descriptions of practical experiments to systematic analyses of the prerequisites for the development of practices in communities. The studies show that the concept is still in use vary in their interpretations. Furthermore, it illustrates that more qualitative meta-analyses should be in place to synthesise this broad research field, to elaborate the concept and to provide directions for further development.

On the one hand, different philosophical ideas were also adopted in research related to community of practices. Some scholars’ have mentioned that practice theoretical ontologies should align with micro-oriented epistemologies (eg: ethnomethodology) (Schatzki, 2005). Whereas some others have argued that their practice studies do align with epistemologies with their ontologies that maintains ontological shift (Thompson, 2011). However, some scholars have highlighted that their ontological approaches differs across empirical studies (Feldman and Orlikowski, 2011). This shows that there are multiple philosophical views adopted in practice studies. Theses different views and opinions have led to confusion and fail to explain and predict the novel observation and phenomena of interest (Lakatos, 1970 a and b, Kilduff *et al.*, 2006).

Learning as a production of participation creates a negotiated meaning among the participants involved in the learning situation, not because to neglect other meanings but because to share the learning that is needed to solve that issue or a problem. In this study, the researcher has considered the view of learning through combining situation learning (Lave and Wenger, 1991) and community of practice (Wenger, 1998). The study perceived learning through participation with the entire community associated with the project. However, this is different from situational learning because it has shifted from looking only at the newcomers and moved towards the entire project team. Conversely, to both situational learning and community of practice, this learning view has focused on both individuals and groups involved in the project, rather than just considering the individual approach.

2.4.2.2 Concepts adopted from organisational learning for Workplace-based learning

This PhD study have adopted Community of Practice approach, however it is also vital to create a favourable environment and other prerequisites needs for learning for the individuals, group of people and the entire community (Lehesvirta 2004; Argyris and Schön 1996 Lähteenmäki *et al*., 2001). Nonaka and Konno (1998) highlighted that creating a space for learning is important and mentioned this idea came from a Japanese concept 'Ba'. The word 'Ba' means a shared space for emerging relationships which can represent physical, virtual, mental spaces or mixture of these that helps to form a forum to develop individual or collective knowledge. Participation in this common space allows the individuals, group of people or community to surpass their limits or boundaries. Furthermore, Nonaka and Konno (1998) divided 'Ba' into three types. '*Originating*' ba is a space where people meet face-to-face to exchange their feelings and mental models. Following that, interacting ba offers a space for externalisation where people not only share their mental model but also reflect on and analyse them further. This is to make the tacit knowledge into explicit. Consequently, Cyber ba is a space that combines all the phases of knowledge creation to combine an explicit knowledge with another explicit knowledge. This generally happens through online networks, documentation and databases. Finally, exercising ba helps to internalise explicit knowledge. So in this space, tacit knowledge is in process, however explicit knowledge is used in action. Utilisation of these spaces helps people involved in the practice to learn effectively.

The next concept adopted from organisational studies is expansive learning (Engeström, 2011; Dochy *et al*., 2011). Expansive workplace-based learning starts when people raise questions regarding existing practice and then it carries on with modelling, testing, and reflecting on new solutions which mostly ends up in a radical transformation in organisation. Engeström (2011) believes working pattern involves co-configuration where collaboration plays a major role and refers this as 'negotiated knotknowing' which is used to define the characteristic of transformative expertise. Knowknowing is about tying, untying, and retying the movements or separate threads of activity within an organisation for the purpose to negotiate meaning and problem solving. In this situation, people get together to achieve their purpose and then move along with the other team members to achieve another purpose, however this may be reformed again later on. This new way of interlaced working is vital to perform expert work activity within the organisation (Engeström, 2011). Expansive learning, including the characteristic of co-configuration and knotworking, is more demanding that requires boundary crossing and collaboration with and across the organisation (Henneman *et al*, 1995: Engeström, 2011; Dochy *et al*., 2011). Knotknowing is also similar to the concept of networking, which involves either individuals or organisations to achieve a purpose. Several scholars argue networking within an organisation and people allows people to learn innovatively and impact on organisational success strategies (Engeström, 2004; Miles *et al.*, 2005). However, Hakkarainen *et al* (2004) believe that the knowledge created in community of practice is relatively static where innovative knowledge communities purposely pursue creating new knowledge and transforming practices. Therefore, they suggested that knowledge that has been created through networking can be referred as innovative knowledge communities instead of community of practice. Moreover, Hakkarainen *et al* (2004) state networking increases the competencies through social interaction, knowledge sharing, and collective problem solving.

2.4.3 View of learning within Projects

Learning is important to spread the knowledge and information in the networks, especially if this involves informal and emergent communication practice (Trinder, 2017). However, it is gradually becoming complex and affects interpersonal relations, information co-ordination in projects, including causing project failures and low success rates. Therefore, external learning and sharing experiences within the organisation is important to determine and apply learning mechanisms and internal valuation of projects (Sorensen *et al*., 2015). The learning that takes place within projects has been explored by several researchers. Ayas (1996) mentions that learning within construction projects does not happen naturally, instead it needs deliberate attention, and continuous investment of resources and this is because of different activities within the network as well as different members involved in the construction project (Weick and Roberts, 1993; Chiu, 2009). Moreover, people within construction networks are less connected and more fragmented and likely to change. Lipshitz *et al* (2002) in his study has highlighted the need for learning that developed five values, which promote learning: transparency, integrity, issue-orientation, inquiry, and accountability. Similarly, Sense and Antoni (2003) found three key factors those learning influences which are individual authority level, project sponsor actions, and organisational environment. Wasif *et al* (2012) also focused on increasing learning in projects to enrich work tasks and increase people’s ability to tackle the challenges such as new customer demand, technologies and high-tech materials.

Organisational learning (OL) in a project context can take place through different ways such as previous experience, sharing other person’s experience, combining knowledge and conducting experiments (Sethi and Farooq, 2014). Although this encourages to provide the inputs for learning, sharing the knowledge, introducing innovations, competitive advantages and insufficient business confidence are some of the issues in OL (Tennant, 2013). In contrast to OL, situational learning is an instructional approach which encourages to learn through active participation (Lave and Wenger, 1991 and Wenger, 1998). However, this also has its own drawback when setting up authentic contexts and activities, while accessing expert performance and investigating different roles and perspectives (Herrington and Olive, 1995). On the other hand, Constructivism approach is grounded on learner’s experience and reflection. In this situation, knowledge is considered to be personal, but it can be developed through interacting with the physical world through collaborating with social settings and through getting involved in cultural and linguistic environment. According to critics, constructivism theory is subjective and deviates from traditional empiricist view and does not reveal the practice of science (Osborne, 1996). Conversely, Social Constructivism theory states that learning takes place through the social context of people’s knowledge and the social processes of knowledge construction. Nevertheless, criticism levelled against social constructionism debates that it only reflects on epistemological claims and neglects ontological ones (Andrew, 2012).

In these approaches, there has been very limited consideration for the connections and relationships between learning aspects within the learning environment, which are crucial for the information world.

Learning aspects in this study refers to the key areas that influences workplace-based learning. Moreover, elements refer to the sub-learning aspects which are factors that influence workplace-based learning environment (eg: people, resources and skills). Learning is interactional and is constantly changing, so there is a need for systematic and structured learning to connect the learning aspects and their interactions within the project environment to achieve successful project outcomes. One of the ways to improve learning within projects is to generate a suitable learning approach that allows a connection between the project aspects. The connection between these aspects are discussed in chapter 5.

2.4.4 Types of workplace-based learning

Workplace-based learning is predominantly determined by complex social practices and highly connected to the efficiency of types of learning (Poell, 2013; Tynjälä, 2008). Learning takes placed in various forms such as ‘formal’ and ‘informal’ learning which is sometimes referred to as ‘non-formal’ learning (Eraut, 2001). Formal and informal learning are both common in workplace, however they sometimes overlap each other. This following sections individually describes these different types of learning and how they are used in workplace.

2.4.4.1 Informal learning

Informal learning that takes place in the workplace is an unintentional activity which is a side effect of or by-product of working (Marsick and Watkins, 1990). Lohman (2005) and Garavan *et al*., (2002) refer to informal learning within a context such as workplace or organisation comprising the expenditure of physical, cognitive or emotional effort, and result in the development of professional knowledge and skills or change in behaviour. However, the acquisition of knowledge and skills not only occur through organised programmes but also by critical moments of need, embedded in the context of workplace. At the same time, informal learning in some instances includes some form of sanctioned learning such as mentoring, coaching, job rotation, job shadowing and special projects or assignments (Marsick and Watkins, 1990, 2001; Garavan *et al*., 2002). This generally occurs in non-routine conditions, while people become aware of tacit knowledge that has been taken for granted when their normal routine fails. People in this situation tend to see the problem in a new way and it helps in the transition of professional practices through reflecting on their nature of beliefs (Marsick and Watkins, 1990; Baert *et al*., 2000). Eraut (2004b) argued informal learning is mostly invisible in a workplace and there are also equal opportunities for formal learning through education and training. In addition, he identified informal learning characteristics, including implicit, unintended, opportunistic and unstructured learning and absence of teacher. On the other hand, Watkins and Marsick (1992) have characterised informal learning through 1) learning from experience, (2) the organisational context, (3) a focus on action, (4) non-routine conditions, (5) the tacit dimension of knowledge, (6) delimiters to learning (which influences the way a problem is framed and the extent of work capacity) and (7) enhancers of learning. Furthermore, Tjepkema (2002) states that informal learning occurs spontaneously and unconsciously without out any prior stated objectives in terms of learning outcomes and happens wherever people have need, motivation, and opportunity for learning. On the other hand, Lombardo and Eichinger (1996) believe that informal workplace-based learning occurs through people doing itself (experience), interaction with others in an informal way and working closely with problem solving. Moreover, he stated that informal learning in social context such as workplace is an ongoing process where learning is obtained through collaboration, problem solving and sharing experience.

Marsick and Watkins (1997) have highlighted, four central features of informal learning in work practice for the workforce or individuals: context (learning outside classroom), cognisance (intentional or incidental learning), experiential (practice or judgement) and relationship (mentoring and team working). Colley *et al* (2002) and Hager (2004a) believe these significant features are more effective than classroom-based learning. The degree of learning awareness that is influenced by learner's role, identity, organisational tenure, occupational conditions help to predict, motivate and to transfer learning that influence learning outcomes (Finegold *et al*., 2005; LePine *et al*., 2004). Typology of informal learning is categorised in three levels. Firstly, implicit learning is about independently acquiring the knowledge with the conscious attempt to learn when there is no explicit knowledge about what was taught (Reber, 1993). However, awareness of explicit learning does not mean that there is no implicit learning taking place. Secondly, reactive leaning refers to an intentional learning that occurs in the middle of an action but people actually have less amount of time to think. This consists spontaneous reflecting on past experiences, noting facts, asking questions and observing effects of actions and helps to identify possible future learning opportunities. Finally, in contrast deliberative learning has set goal and time for both to obtain knowledge and engagement in deliberative activities such as planning and problem solving (Tough, 1971). Therefore, in this, there is a clear based goal with learning as probable by-product and generally involves in discussion, review on past actions and experiences and engagement in decision making and problem solving, which is highly linked with project work. Similarly, Eraut (2001) looking from psychological view, has used these categories to describe the learning that takes place in workplace, but he has adopted the word 'non-formal' in his study instead of 'informal learning'. This is because he argued that informal learning is ubiquitous that comprises several features such as dress, discourse, behaviour and diminution of social differences, which have less impact on learning (Colley *et al*., 2002).

Although a number of researchers have acknowledged informal workplace-based learning positively, the study conducted by Dale and Bell (1999) has listed few drawbacks of informal learning: lack of learning ability or skills to complete the tasks, less confidence level, difficult in applying formal qualification and can sometime leads to wrong lessons.Fuller and Unwin (2003) believe over valuing informal learning can lead to fewer opportunity for the participants to participate in formal training, raises issue in knowledge control, and reduce opportunities for expansive. However, Ashton (2004) that form of control involved in informal learning are shaping employee's identities and subjectivities in a way to match with the interest and needs of the organisation. At the same, questions related to what counts as valid knowledge, who defines and whose interest will such knowledge serve are not answered yet (Blackler, 1995; Spencer, 2001). Fenwick (2001) believes that learning is through gaining skills, critical awareness of workplace contexts and through investments of knowledge. Therefore, he stated that informal learning within workplace does not know what kind of learning is necessary and how that is achieved. Fuller and Unwin (2002) note that multiple definitions are needed in informal learning to understand personal relationship, power, own potential and aspiration, however Colley *et al* (2002) mentioned that these different definition and terminologies have caused confusion among the practitioners. Usher and Solomon (1999) and Garrick and Usher (2000) on the other hand, stated that informal learning leads to job intensification, which is been hidden due to the work culture and subjectivities of novice.

2.4.4.2 Formal learning

Formal workplace-based learning is inevitable and most of the workplaces still follow formal learning in their organisations (Billett, 2011a). Formal workplace-based learning is defined as a structured learning that occurs off the job and outside the working environment (Marsick and Watkins, 2001). This is referred as a 'standard paradigm' of learning, which is a form of tradition 'educational' pedagogical frameworks, based on didactic interaction (Beckett and Hager, 2002; Hager, 2004a,b). Generally, in workplaces, formal learning is achieved through sequences of planned activities that help the individuals to obtain specific knowledge, awareness and skills to perform their job. According to Raelin (1998), formal workplace-based learning are processes and activities where employees are required to participate and to immediately apply the obtained knowledge in employee's job duties or roles. These processes and skills can vary from basic to high skills in technology that can be achieved through developing competency in management. This can be achieved through institutionally sponsored and endorsed programmes, which are usually training and development programmes offered by organisations. Mostly, large companies put a lot of effort into providing cooperate training and some others have established through cooperate universities (Allen 2007; Qiao 2009). Formal training organised for learning purpose in a work setting involves a prescribed learning framework, organized learning event or package, presence of a designated teacher or trainer, award of a qualification or credit, and external specification of outcomes (Eraut, 2000, p. 114). However, Eraut (1994) mentioned learning in the work environment is more efficient in comparison to formal learning because learning job-related skills and knowledge are less appreciated in formal education and frequently lack to put the theory into practice. On the other hand, according to Baert *et al* (2000), it takes a longer time to set up a formal learning procedure thus, it is solely not sufficient to predict the evolutions in society.

2.4.4.3 Non-formal learning

Schugurensky (2000) has referred to non-formal learning as all the education that takes place beyond the boundary of school or educational institution. This is organised or even it is loosely organised it may not lead to the formal curriculum. In comparison to informal learning, this is structured that also includes learning objectives (Kyndt *et al*., 2009). In this, learning both content and the emphasis of practical experience are important (Fordham, 1993) or as a by-product of more organised activities (OECD, n.d.).

2.4.4.4 Incidental learning

Incident learning is a ‘‘by-product of some other activity and error experimentation’’ (Marsick and Watkins, 1990, p. 8). In other words, it is a by-product of some other activity, for an example task accomplishment, interpersonal skills interpersonal interaction, sensing the organizational culture, trial-and-error experimentation, or even formal learning. This is different from informal learning that takes place even when people are not aware of it (Marsick and Watkins, 1990).

Although formal and informal learning has its own characteristics in a workplace environment, the combination of both are essential to learn in workplace. Formal learning is important to generate explicit knowledge. Whereas informal learning generates tacit or implicit knowledge. In most of the contexts, formal learning is embedded in informal learning and vice versa and there are only a few exceptional cases either informal or formal learning is present alone in a context (Colley *et al*., 2003). However, Billettt (1999) argues that informal and formal learning needs to be distinguished in workplace environment. Furthermore, he stated that informal workplace-based learning is ‘ad hoc’ which is inferior to the learning that takes place in formal educational institutions (Billett, 2002). Moreover, he added that the workplace is generally a well-structured environment which focuses on work practice and structured goals directed to the activities that are fundamental for organisational continuity and interactions and judgements about performance, that are also shaped to those ends. Billett (2014) arguments not only move learning from formal and informal, but also widen the focus through looking at the structure, norms, values and practices in workplace environment that concretely provides an opportunity for participation and learning. Although formal and informal learning happens alongside each other (Colley *et al*., 2002), learning that occurs continuously in a structured workplace environment should look through the concept of participation and participatory (Billett, 2004). The next section discusses how learning is taking place in project environment.

2.4.5 How learning happens in projects

Learning in construction can occur through both internal and external sources to achieve the project goals. A study by Paranagamage *et al* (2012) suggest that lessons learnt in the construction projects would lead learning for similar projects in future, to avoid mistakes and to repeat success, to provide edge over other companies and to learn lessons for consecutive stages of ongoing projects. Similarly, Williams (2008) highlights that learning lessons from a project review are vital and integral part of the learning organisation to achieve competitive advantages. ‘Learning from experience’ was identified as one of the 12 key factors in project-oriented organisations, however Kotnour’s (2000) survey mentioned these project learning activities and level of lessons learned activities need to be related to inter project learning. This is because learning in projects expects to influence the risk analysis (Neale and Holmes, 1990), improve project management (Azzone and Maccarrone, 2001) and decision-making (Neale and Holmes, 1990; Azzone and Maccarrone, 2001). Even though project learning is beneficial, reasons for not learning lessons are due to “lacking knowledge of project debriefing methods” and “lacking enforcement of the procedures” (Schindler and Eppler, 2003). On the other hand, Cooke-Davies (1996) argues this is due to ‘culture of searching for improvement and structured processes’. Harris (2002) claim that existing routines are one of the reasons lessons are rarely learned. Moreover, he mentioned that learning from past mistakes, or building from past successes is considered as an exception rather than a necessary. This is because only few systematic approaches are found (Huemer and Östergren, 2000) and only few companies are systematically managing and transferring the knowledge from project to another project (Anke and Agnes, 2019; Disterer, 2002). Supporting this, Kofman and Senge (1993) describe that systematic thinking is essential to learn lessons.

Håkansson and Johanson (2001) and Henneberg and Naude (2004) claim that networking through regular interactions or learning through collaboration with other firms has an influence in increasing the learning in projects. Moreover, these studies highlighted that people tend to learn more in networks through the number of connections they have with other firms (Håkansson *et al.*, 1999) where the interactions also help the people in the network to solve their problems (Holmen and Pedersen, 2003). Supporting this, Bechky (2006) argues that information to the project team members may pass through the traditional or formal learning route but project members’ roles need to be continuously learned through communication within the networks. Likewise, Anderson and Lettl (2009) and Veal and Mouzas (2010) have highlighted the need for knowledge and learning at the level of the network to understand the communication processes and to enhance the network learning among the project team members. The concept of ‘communities of practice’ (CoP) where individuals who have similar work-related activities and learning comes together has a connection in learning within projects. This gathering of personnel seems to have a reflection on learning that occurs within the projects (swan *et al*., 2002). Similarly, Pyrko et al (2017) mentioned that mutually engaging concept in CoP helps to share the knowledge in workplace.

Learning histories is another way of learning in projects. This is a document that chronologically describes the events of a project with a story telling approach, including both participant quotation and commentary from analysts (Roth and Kleiner, 1998). In addition, Styhre *et al* (2004) claim that people learn through mentoring and discussing the problem. In addition to this, learning in projects occurs through brain-storming sessions (Schindler and Eppler, 2003) and mapping method (Brander-L¨of *et al*., 2000). According to Lave and Wenger (1991), context is a key category in learning, which is generated by the involvement of individuals in an organisational practice which leads them to learn.

2.4.5.1 Context

Context is one of the category influences workplace-based learning. Several researchers have mentioned that learning in an organisation or project is related to specific contexts (Lave and Wenger, 1991, Tyre and Hipple, 1997; Kakavelakis and Edwards, 2011). Learning that takes place in the workplace is different from traditional learning theories, which is entangled with materiality (Nicolini, 2013), institutional and organisational structures (Hotho *et al*., 2002), socio-cultural context (Handley *et al*., 2006) and historical conditions (Nicolini, 2013). Thus, Carlile (2002) argued that learning is poorly transferred across the communities mainly when the knowledge is tacit. Furthermore, with the other influential factors, contextual factors also play a major role in workplace-based learning. The importance of context while learning in construction projects is evident through number of studies. The relationship between learning, social processes and practices in construction projects has been investigated by Bresnen *et al* (2003) and concluded that learning in project depends on social context which is a combination of social patterns, practices, and processes. On the other hand, Styhre (2006) explored the temporal context between construction project team members and identified that learning in project happens through practical engagement, know-how and experiences with peers and these phenomena are embedded in a temporal context, including the past, present and future. In addition, Styhre (2011) stated that construction work practices are associated with material and social relationship. Groleau *et al* (2012) has investigated the conflicts between institutionalised and local practices due to the introduction of new software and the way technology generates meaning to guide the practice that leads to socio-historical traditions through adopting a practice-based learning framework. Likewise, Bailey and Barley (2011) explored the way technology and environment as a context impacts on teaching and learning activities and amend the organisation structure. Moreover, they identified different engineer groups have different learning patterns, which have an impact on different environment and technological contexts. This study with the combination of several social theories and practice theory concluded learning as a social activity.

2.4.5.2 Participation

Ashworth (1997) defines participation as ‘‘to have or take a part or share with others (in some activities, enterprises, etc)’’. Following that, Wenger (1998, p.55) mentioned participation, which includes both action and connection, is referred to as ‘‘a process of taking part and also in relation with others that reflect this process’’. Participation which can be personal or social allows the individuals or team to gather the information which is not available in documents or any other explicit forms. According to Gherardi (2006), an individual learns in the workplace through participating in the day to day organisational activities. Participation provides access to the knowledge, as well as, influence organisational knowledge through interacting with others. Through participation, an individual becomes a part of a group and also gets opportunities to influence the group’s participation. Participation is a central concept of practice theory (Elkjaer, 2004; Handley *et al*., 2006) and the idea is to learn about individual activities and social structures through participating in individual activities (Wenger, 2000) and organisational structures (Rouse, 2007; Nicolini, 2013).

Bresnen (2009) and Forgues and Koskela (2009) have investigated participation at the project level. Forgues and Koskela (2009) discussed participation in relation to different kinds of contract and concluded that participation of key team members in integrated projects is beneficial to work in a collaborative way. On the other hand, Bresnen (2009) studied partnering between clients and contractors in a construction project and suggested participating in activities such as social events or workshops only involved senior staff and not other project participants. Hence, it did not benefit the project team as expected. Moreover, he also highlighted that most of the learning in projects are happening in an informal way. Another study conducted by Gustavasson and Gohary (2012) focused on the participation in a collaborative construction project that occurred between practitioners from different professions and organisations. This study highlighted that crossing boundaries depend on three different boundary bases: different stakeholders, professions, and geography while participating and improving learning (Gustavasson and Gohary, 2012). Therefore, participation of either individual or groups are vital to illustrate the learning that takes place in the workplace.

Participation has been obtained in different ways in a good learning environment (Billett 2002a; Fuller and Unwin 2004). Fuller and Unwin (2011) have distinguished the participation into two: expansive and restrictive approaches for work environment. An expansive approach provides time for reflection and sees learning as a way to progress in their career that also allows the participants to cross boundaries. On the other hand, restrictive approach is limited with the job involved at that time and only values a particular person or groups. Managers in expansive learning tend to act as facilitators instead of controllers whereas restrictive approach depends on the old practices without looking for any innovations. Therefore, as discussed above workplace-based learning is not only about informal or incidental learning but also intentional. According to Tynjälä (2013), workplace-based learning is more semi-informal and planned practices where people learn from each other and with each other. Similarly, Billettt (2004) stated the workplace involves goals and practices and participation through activities and interactions that occurs in workplaces, which helps to afford learners and how individual choose to participate. Moreover, he argued that affordance and individual's participation is related to intentionality and continuity. Which contradicts with Hodkinson and Bloomer (2002) and Davies and Brady (2000) where they believe that learning that happens in workplace is ad hoc, structural and informal. Therefore, in this, participation and learning are interdependent with each other and are central to the on-going existence of these practices and regulated by the workplace (Lave, 1993). Moreover, Billett (2001) claimed that affordance to participate and direct and indirect supports are key factors that determine the quality of learning that takes place through participation. Similarly, Hodkinson and Bloomer (2002) have mentioned that demanding tasks of learning new knowledge and refining what is already known depends on their interest and agency including the direct and indirect guidance provided to them. According to Beth and Piaget (1966), this new learning is referred to as 'accommodation' and refining new knowledge is considered as 'assimilation'. The affordance of both unintended activities such as everyday activities, observing and listening and intended activities such as modelling, coaching, analogies, diagrams, questioning are vital to learn the knowledge required for workplace performance (Billett, 2001).

According to Wenger (1998), to negotiate a meaning during participation, it is vital to create a relationship between different modes of identification (Wenger, 2010). Engagement has a close relationship with participation, which is about getting involved with activities through doing things, interacting with people and artefacts. Furthermore, Wenger (1998) in his studies consider engagement beyond an activity that builds the community with the aid of inventiveness, social energy and developing knowledge ability. He argues that it is a direct experience to manage the competence which can be achieved as an individual or group (Wenger, 2010). This process of identifying competence and in-competences guides to the development of participation and non-participation. In addition, engagement also permits individuals to interpret and share their ideas among the group of people they are engaging. According to Wenger (1998), the infrastructure of the engagement is mainly created through mutuality, competence and continuity. Although, engagement allows people to learn, there is still space to expand through adding areas such as history possibilities or complex systems. This is important to place a position among others, to reflect on situations and explore new opportunities (Wenger, 2006). A number of tools of imaginations (e.g, language, pictures, maps and stories) are used to interpret the participation that takes place in the social world. Imagination can create a relation of identification, the same as derived from the process of engagement. This relation of identification or connections identified through imagination helps to move forward to a new context. In a learning context, boundary crossing not only helps to develop participant's knowledge and skills but also to change them entirely to the new environment. Imagination to be used in a learning context needs to be encompassed with facilities such as orientation, reflection and exploration (Wenger, 1998). Imagination which is beyond engagement can open identities and practices, however it does not connect learning to broader enterprises (Wenger, 1998). Therefore, engagement without alignment does not mean anything in a context. Alignment can be done through coordinating the activities, interpreting the ideas to others, negotiating with people, communication with the team members and many other. However, to have an effect at the end of a process, all these actions in alignment needs to be considered as a two way process rather than just passing the information to others (Wenger, 2006). According to Wenger (1998), infrastructure of alignment is combined with convergence, coordination and jurisdiction.

Participation across different enterprises has adopted different strategies and perceptions due to the size of the enterprises where their work goals and activities differ to each other (Billett, 2001).Furthermore, Billett's (2004) view has considers learning as a product of cultural practices, social norms, workplace affiliations, cliques and demarcations. In this, people who have authorisation to control and divide the labour with their interest and affiliation with the workplace regulate participation to maintain the continuity of the workplace through regulatory practices (Grey, 1994). Therefore, participants tend to adopt the most suitable engaging ways to serve their purposes, such as assisting their career trajectory (Bloomer and Hodkinson, 2000), securing opportunities, or even locating easy work options. Consequently, the engagement in thinking and acting are intertwined with each other (Lave, 1993; Rogoff, 1995).

Participation and workplace-based learnings are continuous and individual's participation deliberately contributes to the enterprise's goals and continuity (Schmidt and Boshuizen, 1993) (Billett, 2001a). This directs to maintain the work practice viability in terms of skills utilisation or quality of service. Overall, participation serves to distribute opportunities in new work activities and access to guidance and support. However, the individuals might experience different kinds of and degrees of affordances, depending on their affiliation, associations, gender, language skills, employment status and standing in the workplace, because of these regulatory practices (Billett, 2004). Workplace-based learning is generally multi-faced, negotiated, regulated and contested. Therefore, most of the learning takes place through participation supports the participants to learn what cannot be learnt alone.

2.4.5.3 Meaning production

Learning is led by meaning production which refers to the process of producing meaning individually or collectively (new or altered) to solve problems, emerge solutions, or engage in collective inquiry (Corradi *et al*., 2010; Fenwick, 2010). This can be an explicit or tacit process (Rouse, 2007) and reflective meaning making is done through language to present the world and shape it (Nicolini, 2013). In practice, theory language is considered as a discursive practice (Shatzki,2001) and at an individual level meaning production is considered as a continuous process that takes place in everyday practice (Weick *el al*.,2005). In general, individuals form their meaning through their interaction with the social environment and activities that allow them to learn. Nevertheless, meaning creation is not just a simple reaction to the environment, instead it is created through active perceiving. According to Turner (2000), active perceiving is related to previous understanding of rules of processing information, therefore it is partly a social activity. Styhre *et al* (2006) mentioned that meaning is formed in different ways, for instance, written communication (eg: documents and protocols) and verbal communication. However, they highlighted verbal communication is more common between co-workers during learning in a workplace. A study conducted by the Hallgren and Maaninen-Olsson (2009) focused on the way deviation is managed in construction projects through reflection. In this study, it is observed that sudden deviation in construction projects are managed through informal methods because a formal route was considered too slow. This illustrates the importance of meaning production to solve the unexpected problems in the workplace. Furthermore, it has been used to sort day to day problems (Styhre *et al*., 2006). Svensson *et al* (2004) have investigated the nature of the reflection and the factors that influence meaning during the construction of work. This was seen as a prompt for individual critical reflection, a forum for meaning sharing among individuals, and a forum for conflicting meanings that must be worked through to create new knowledge. This study found that collectives are used to mould particular meaning among the team members such as agreeing with the opinions of those in power. Furthermore, Jørgensen (2004) and Billett (2001) suggested that collectives are brought together by the individuals to find and shape the meanings in the activities they are involved and identify what is afforded for them to participate and learn.

Wenger (1998) believes that meaning is simply made up in the working environment rather than creating it from scratch. Even though anumber of researchers as discussed above have researched on ‘meaning’, Wenger has introduced a new terminology called ‘Negotiated meaning’. He defines it as ‘‘a process that is shaped by multiple elements and that affects these elements’’ (Wenger, 1998, pp54). Moreover, he mentioned that negotiation, which involves both interpretation and actions, constantly changes the situation until it provides a sensible meaning to the participants. In this, interpretation refers to thinking or understanding, whereas action is about doing or responding to a situation. The purpose of negotiated meaning is to create new relationships with the social practice through creating new circumstances or new meanings. Although studies have emphasised the importance of meaning production in construction projects they sometimes dissatisfy with work practices (Snell, 2002), and fail to sufficiently account for power relations in workplaces and knowledge hierarchies (Fenwick, 2010).

2.4.5.4 Interpretation

Eraut (2004) suggested that interpretation, which is a form of thinking that comprises planning, monitoring one’s activities and solving problems is a key aspect to learn in the workplace environment. Generally, people think and share their experiences during the decision making process. Therefore, interpretation is centred on the thinking process, which refers to constant interaction of doing and communicating. Activities in the workplace are related to both engaging with inanimate objects and human beings. When the changes take place within the context it is called ‘hot action’ and when changes are related to performer’s own action or discovery of new information the event is referred as ‘cold action’ (Eraut, 2004). However, Eraut (2004) stated that plans and decisions in static model are developed at the beginning of the project does not suit in most of the workplace environments. In this context, model refers to a theoretical image that presents the interrelationships of the ideas that are found through the investigation. Therefore, dynamic models that includes changing inputs and conditions with constant modification of plans are appropriate and realistic for the changing work environment. During this performant’s role is influenced by feedbacks provided through sense making and observation reaction (Eraut, 2004). On the other hand, Billett (2001) mentioned that openness and support for learning is also essential for everyday workplace activities. As discussed above, interpretation is intertwined with engagement and imagination and alignment (Wenger, 2010)

2.4.5.5 Reflection

Boud (1985) has referred reflection as intellectual and affective activities where individuals are involved to explore their experiences for the purpose of generating new understandings and appreciations. Moreover, this is generally organised as a common process in daily life which is achieved by individuals (Kolb, 1984; Schön, 1983) or groups reflecting collaboratively (Dyke, 2006; Hoyrup, 2004). According to Pilla *et al* (2011), it has been divided into three elements: going back to experiences, re-evaluating these experiences in the light of current insights and knowledge, including experiences of others, and deriving knowledge for future activities from this, including the planning and implementation of changes. Supporting this, Eraut (2004) has claimed that in comparison to other mechanisms, reflection plays a major role in the work environment. An understanding of previous experiences not only helps to move towards the work context but also avoids less fruitful modes of thinking, while achieving the outcomes (Pilla *et al.*, 2011). Furthermore, reflection can occur at the individual and collaborative level and bound with both negative and positive experiences. In this, technological world computers have started to support the reflection to enhance learning (Fleck and Fitzpatrick, 2009; Scott, 2010). This highly depends on the tools and the importance of it is demonstrated in the theoretical model of reflection. However, they generally consider learning as a cognitive process (Boud, 1985; Kolb, 1984, Schön, 1983). Krogstie *et al* (2012a) have introduce a computer model that supports reflection in the work environment that encourages collaborative reflection through the roles of the tools.

2.4.5.6 Identity and Agency

Billett (2011) has stated that the central idea of workplace-based learning is participating in affording the opportunities for learning as well as how they choose to engage in the workplace with the guidance given in the workplace. Active engagement is the key element in workplace-based learning, where agency plays a key role in it.

Individuals in workplace-based learning are not passive in participatory practices and learning (Hodkinson and Bloomer, 2002) or the construction of occupational identities (Somerville, 2002). Agency is connected to the concept of identity, where identity is formed when there is a tension between continuity and change and how individuals exercise their agency modifies the identity. On the other hand, the way individuals perceive their professional identity reflects how agencies exercise in their work environment. Agency in the workplace determines how the workplace afford is interpreted and judged and decides the process to learning in an effortful way for the purpose of participation (Billett, 2001). Eraut *et al*., (2004b) noted that some people in the workplace are proactive to improve their knowledge with wider networks whereas some do not have much interest in it. They also highlighted that receiving short term and long term feedback is vital for the learning process where the learning process is mostly occupied with short term feedback, which provides confidence to workers. On the other hand, personal histories that are generated through the involvement of various social practices throughout the life histories motivate particular ways of knowing, understanding and social world engagement (Scribner, 1985). These personal histories are unique and will be shaped through various social practices throughout life histories (Billett, 1998; Hodkinson and Bloomer, 2002). Therefore, participants in some cases dis-identify with the social practices that they are engaged in (Hodges, 1998); resist to engage with the team due to different cultural mores (Darrah, 1996) or training opportunities that compromises their employment options (Billett, 2001a), and will avoid new recruits and deny affordances that intended to assist their participation (Billett, 2001a).

A study conducted by Brown *et al.*, (2007) has investigated the identity among engineering, nursing and telecommunication professionals and concluded that professionals are willing to move towards ‘entrepreneurial’ work attitude based on multi-skilling, flexibility and adjustment to continuous change, which will be also beneficial for individual’s work orientation. Alternatively, Billett *et al*., (2006) highlighted the need for active engagement in learning and reshaping cultural practices for effective work practices. Vähäsantanen and Billett (2008) found that teachers develop their professional identity through professional development, passive accommodation, active participation, balancing and withdrawal. Furthermore, subjects and agency are intertwined with the surrounding social context (Billett 2007; Billett *et al*., 2006). Hänninen and Eteläpelto (2008) stated that personal agency can be strengthened through special empowerment programme. Change is not always negative rather it should be considered as a place where new opportunities raise and exercising of a sense of self. Therefore, it is clear that agency and identity have a strong bond between them in the work environment. Apart from this, personal affiliation also influences in determining the participation and how co-worker’s efforts are acknowledged. Individual’s engagement with the familiar and new tasks and interacting with co-workers, especially with experienced workers, helps to shape the quality of learning outcomes. This knowledge is held to be socially sourced and its construction mediated by social processes (e.g. access to guidance, observation and interactions with other workers) and artefacts/signs (e.g. workplace and its artefacts) (Valsiner and van de Veer, 2000), along with other participatory factors are central to understand how workplaces afford opportunities to learn (Billett, 2001). Individuals in the work environment are active agents in what and how they learn from these encounters (Engestrom and Middleton, 1996), therefore, human agency cannot be ignored in a workplace.

2.4.6 Learning Paradigms

Carr and Kemmis (1986) have categorised the learning paradigm into three: technical, interpretative, and strategic. The technical paradigm in the organisation is related to acquisition of specific knowledge and skills to achieve the tasks or job requirements. The interpretive paradigm deals with interactions between the team members to understand the situations, events, experience and personal judgement. This is centred on the past experience and judgements. The final paradigm, strategic paradigm, involves the critical examination of underlying assumptions, values and beliefs on both the part of teacher (facilitator) and learner (Marsick, 1987, p. 13). Mostly, tools included in this paradigm are open dialogue, which promotes discussion of ideas, views and opinions. Mezirow (1981) has generated a similar model for learning where the domain has categorised as instrumental, dialogic, and self-reflective. Instrument learning is focused on tasks and is about how the job is been completed, dialogue learning refers to individual's understanding and interpretation of norms, policies, procedures and goals. Self-reflected learning is concerned with the individual's self-understanding. In this self-reflective is about the personal change including self-understanding. The understanding of the learning paradigm in projects and organisations is vital to understand the fundamental functions and technical skills before workers investigate about the assumptions or start applying their skills. Therefore, a fundamental understanding on different types of techniques is important before selecting the right method and reflecting on it critically. However, interpretative and strategic paradigms can be applied to a particular case. This is evident through Mezirow highlighting that "Instrumental, dialogic, and self-reflective learning cannot easily be separated in any given situation" (Marsick, 1987, p. 17). Supporting this, a study conducted by Eraut (2004b) highlighted that workplace-based learning takes place directly and indirectly. Moreover, he has divided the learning factors into categories. Firstly the work context includes confidence and commitment, challenges and value of work, feedback and support (Eraut, 2004). The study shows that confidence is vital to learn in the workplace where learning occurs through doing things and being proactive in learning opportunities. However, confidence in the work environment is gained through successfully achieving the challenges in one's work with the aid of support within those endeavours. However, the study concluded that there is less support or challenge to motivate the confidence level within the workplace environment. The result included feedback as an additional support for especially motivating the client and their career progress. On the other hand, commitment was comprised as a complementary factor that impacts on workers to proactively adopt learning opportunities. Even though commitment is provided through social inclusion in teams and through appreciating the value of co-workers, Eraut (2004b) has highlighted that it cannot be taken for granted. Also, inadequate feedback in the study has not only weakened the motivation but also lessened the commitment of workers. During this investigation, the author mentioned most of the ideas derived from Bandura's (1982) concept of self-efficiency concept, which is about the ability to execute a specific task or successful perform the role. Next, context in this study includes structure of the work, encounters and relationship with people at work, and expectations of each person's role, performance and progress. In the work environment most of the works are new and challenging for the novice workers, whereas experienced people tend to expand their knowledge, while involving a wide range of tasks. Therefore, managers or senior workers through extending their capability can balance the demand of job against the needs of workers (Eraut *at al*., 1999). However, Eraut (2004b) stated that there is lack of understanding about the development of individuals and collective capacities to strengthen the practical implication of informal learning, thus managers need to be appointed to facilitate learning at work. Therefore, the manager's role, depending on their education and capability and management style, has an important part in improving the quality in workplace learning.

Learning in practice has been supported through several conditions in the workplace. Identifying learning conditions also helps to provide further education for the workers, especially for the workers with lower level of knowledge (Kyndt *et al*., 2009). Kyndt *et al* (2009) mentioned workplace-based learning is developed by feedback and knowledge acquisition. They suggested that generating occasions to provide feedback such as working in a team, debriefing or peer feedback helps to acquire knowledge. This new knowledge could be the results of inquiries, key decisions, about assignments and new skills. Knowledge that is embedded in the performance can be seen as explicit or tacit. Knowledge that is explicit is easy to consider, however uncodified tacit knowledge that is mostly used in practiced is neglected (Becher *et al*., 1981). Eraut (2004) stated that this uncodified knowledge is learnt informally through social practices and most of them are taken for granted.

Kyndt *et al* (2009) claimed that more access to the learning approaches (e.g. permanent learning and complex assignments), communication tools (e.g. phone, internet and common space) and information acquisition (e.g. library and community of practice) are beneficial. In addition, they have suggested that coaching is beneficial according to the type of the organisation (profit organisations focus on coaching others and non-profit organisation focus on being coached). In this context, coaching refers to improving the performance and knowledge of an individual especially the new starers. Kyndt *et al* (2009) have also spotted that learning in work practice is now encouraged by new learning approaches and communication tools such as permanent learning and work emails. However, Gartner (2012) stated that a number of organisations have restricted their employees from using social media sites. Conversely, Hart (2012) argued that social media is important to improve the collaboration and engagement. On the other hand, usage of technological tools and Web 2.0 processes supports the organisations (Boateng *et al*., 2010, p. 20) through influencing the development of desired behaviour and collaboration (Schneckenberg, 2009). Supporting this, Tian et al (2018) stated that organisational support needs to consider technology and train people to adopt Web 2.0 tools. However, Lyle *et al* (2012) suggested that Web 2.0 technology is encouraged in the environment, which are heading towards cultural changes. Apart from these factors, the following factors also have a significant impact on learning on workplace.

2.4.6.1 Learning approaches

Workplace-based learning is affected by the characteristics of the workplace and the condition of the environment. Therefore, to improve workplace-based learning in terms of the project's or organisation's efficiency, productivity, profit or quality, it is vital to consider the factors that affect workplace-based learning (Mathew, 1999). According to Jacobs and Washington (2003), learning initially happens in an individual before affecting the group. Moreover, he stated that the purpose is more about developing the individuals instead of developing skills or innovation in an organisation. Holliday (1994) explored how individuals learn and respond to change and concluded that it depends on five conditions: self, personal meaning, action, collegiality and empowerment. Self refers to individual's need for a positive feeling about themself. Personal meaning is about individual's ability to reach an understanding about them. Action refers to the ability of an individual to develop, apply and measure their own and other people's ideas and to learn from their experiences. Collegiality is an individual's capacity to learn from other team members both directly and indirectly. Finally, empowerment is an individual's ability to feel the sense of ownership, autonomy, self-control and self-direction over their decisions and actions, including over the processes and outcomes of their learning. Similarly, Straka (2000) investigated how to promote individual's self-directed learning capability and to understand the work in relation to develop the processes and learning styles. The key findings of this study showed that self-directed learning of a person depends on the presence of whom there are working with. In addition, it also highlighted that self-directed learning of an individual relies on person's internal conditions such as knowledge, abilities, motives, concepts, interests and emotional disposition. Alongside this, person's focus on the content, goal and strategies will also have an inpact on self-directed learning in a project.

Berings *et al* (2007) have stated that awareness of people's learning style in the job is essential to improve the flexibility to use the appropriate learning strategies. Furthermore, learning styles in work practices are a set of orientations and attitudes that describe the basic individual's preferences that help the person's interactions with the learning environment (Berings and Poell, 2008). Similarly, Marsick (1987) suggested that types of learning, including the learning styles, have an impact on the learning paradigm in organisations, which is directed by goals, strategy, flexibility, and willingness and ability to take risks. This has also been agreed by Holliday and Retallick (1995), where they also highlighted other factors such as provision of time and information, the change of culture, the speed of change assimilation, possible feelings of loss, struggle, anxiety, and resistance to change that needs to be considered, while introducing a change in the workplace environment. Illeris (2004) pointed out human learning is complicated due to complex patterns of motivation, understanding meaning, emotions, blocking, defence, resistance, consciousness and sub consciousness, which is completely different from how computers or other technology utilise the information.

2.4.6.2 Experiences

Schutz (1967) mentioned that people in their life are surrounded with the continuous flow of experiences. He has viewed the experiences in two different ways. Firstly, discrete experiences is noticeable and creates meaning when attention is provided to reflect upon them. In other words, experience is provided through the 'act of attention'. Experiences given attention can be used according to the contexts it takes place and in some cases these experiences can be applied in relevant situations through extracting from long term memory without further reflection. Secondly, explicit experience is about simply living across the area of conscious thought without noticing. According to Nisbett and Ross (1980), unusual incidents are more noticed and remembered. Therefore, they mentioned it is important to take these kinds of experiences into account through creating the awareness and cross-check by collecting additional information to avoid bias information. However, forgetting the experiences due to going through number of them is problematic (Eraut, 2002b). To apply this concept in the workplace, experience needs to be transformed and resituated in the form that can be fitted in the chosen situation, which is not a logical reasoning and combination of several areas of knowledge to recreate a problem-solving resolved by insight that can be explained easily.

Schutz (1967), in his studies, stated that there are many linkages where each one creates different meanings. Expertise plays a significant role in workplace-based learning. Researchers have characterised experts as highly content and specific, knowledgeable, reflective, organise people and who generally contain automated basic strokes and integrated knowledge structures (Chi *et al*., 1988; Feltovich *et al*., 2006). However, Schmidt and Boshuizen (1993) pointed out that the ability of each expert is different in terms of applying their knowledge using their experiences such as how rapid, efficient and effectively they incorporate their experiences in the current situation. Experiences commonly take place in a social context where each individual can have their own interpretations according to what they notice and remember. However, this can be remembered by a socialisation process through conscious learning with others (eg: engaging with cooperative work, tackling challenging tasks) and through norms, values, perspectives and interpretations of events that are shaped by local workplace culture. Dreyfus and Dreyfus (1986) have analysed the path to become an expert: novice, advanced beginner, competent, proficient and expert. Several scholars have discussed the benefits of experts in the workplace, such as improving the quality of performance (Ericsson, 2006) and problem solving (Schmidt and Boshuizen, 1993).

Experts in workplace-based learning have an influence in making decisions quickly using their prior knowledge and confidence level (Eruat, 2004). Similarly, Klein *et al* (1993) stated that decisions are mostly made using prior knowledge instead of explicit knowledge. Moreover, they highlighted that real-life decision making has shifted from a classical-decision making model to naturalistic decision making where decisions are made using fixed choices of known alternatives related to stable goals, purposes and values. However, ill structured problems, incomplete, ambiguous or changing information, shifting, ill-defined or competing goals, multiple-event feedback loop, time constraints, high risk, contribution of multiple participants, and balancing personal choices and organisational norms are challenging in the decision making process (Klein *et al*., 1993). Right decisions can be made through organising a problem through using the knowledge, interpreting it, and finally through choosing the right information to sort the identified issue. Sometimes in the decision making process, the information selected or distorted might be different from existing schema, however speedy assessment, search, selection and interpretation of relevant information can be useful when information is overloaded within a period of time (Klein *et al*., 1993). According to Eraut (2002b), scarcity of time has a high influence in workplace-based learning and, in some cases. Not having a certain time limit, can lead to misjudgement.

2.4.6.3 Competencies and Skills

Competence can be defined in many ways, however competence in the workplace plays an important role. Eraut (2004b) stated that competence viewed from the individual perspective is related to personal attributes or quality, whereas the social view definition refers to social expectations. An apprentice develops their competence through engaging in more workplace activities with the combination of peripheral participation. However, competence keeps on moving in relation to the practices (Eraut, 2004). As defined in chapter 1, skills is a major component in competency. On the other hand, studies investigated workplace learning in relation to worker's ability learn and develop skills (Hoddinott and Hoddinott 2004; Winther and Achtenhagen 2012), measuring workplace- based learning (Hager 2004), learning through mistakes (Bauer and Mulder 2008; Harteis et al., 2008), importance of reflection (Gartmeier et al., 2008), importance of personal epistemologies (Billett 2008), sharing experience (Collin and Paloniemi 2008; Collin and Valleala 2005), and training opportunities (Festner and Gruber 2008) have investigated the significance of skills. Eraut (2004b) has viewed skills as both cultural knowledge and personal knowledge in relation to the focus of the attention. Firstly, personal knowledge is related actions solely based on procedural memory and secondly, usage of skills is related to process with the combination of procedural knowledge, as well as, other forms of knowledge.

2.4.6.4 Leaning avenues

According to Eraut *et al* (2004b), relationship between knowledge and work practice has an impact on the success of learning. On the other hand, Eraut (2002b) stated that emotional dimensions are part of relationships that takes place in the workplace environment. Supporting this, Illeris (2004) suggested that emotional elements are involved in the learning process, including psychological phenomenon like blockings, distortions, defence, and resistance. Eraut *et al* (2004b) recommended that training, manuals, reference books, protocols, documentation and intranet are essential for the learning that takes place in the workplace. Furthermore, apprentice-type arrangements for trainees, coaching for newcomers, as well as, experienced workers during the introduction of emerging technology, support in the spot to fulfil specific needs and informal support are provided to learn in workplace (Eraut *et al*., 2004b). Similarly, Carnevale and Carnevale (1994) stated that organisations to improve learning has started to involve their employees in training programmes to achieve their demands placed on employees as well as, organisations.

In this digitalising world, framing the workplace-based learning is important to see how the world works and helps to link the relationships with other people, including our physical, emotional and cognitive behaviours that occur in relation to specific environmental contexts and situations. Since the learning aspects are connected within an environment, change in one part affects all of the other learning aspect.

The construction industry has recently seen the introduction of various technologies beyond the gadget-oriented view to attain their goals in terms of time and cost. Therefore, the concept of the workplace needs to be understood by the communities to work with these emerging technologies and to be connected with the related aspects to achieve their targets. Moreover, this also helps to enhance people's understanding within a particular situation and leads to take right decisions at right time.

2.5 Connectivism

The idea of Connectivism: theory of digital age was initially conceptualised by Siemens and Downes (2009). Connectivisim concept that views social learning through a network and is now considered to be one of the new digital age learning theoeries. This helps to define the learning that happens in a fast moving digital world. Learning in the past has been viewed as an accumulation of knowledge or improving the knowledge. However, Connectivism differently believes learning is all about gathering the desired information and connecting them to the relevant aspects such as information, idea, and people (nodes) in a meaningful way. The purpose of this is to understand the structure of knowledge as a network and use learning as a process of pattern recognition. In construction projects, identifying the connection between learning, knowledge and the way of working will improve the construction process. Knowledge is an information in context and internalised. However, the information system is a continuing process. Therefore, transforming the information into a meaning takes place through learning. Appropriate way of working is important to make the connection between learning and knowledge including producing the precise meaning to the adopted information. On the other hand, knowledge is not individualised and understanding the change in knowledge is essential to understand the workplace-based learning.

The application of Connectivism in construction projects can help the project participants to effectively learn and accelerate the construction process through connecting different stakeholders and necessary information within the project. Although project participants do not need to know all the information incorporated in the project, instead they should know where to gather and access the required information when it is needed. Downes (2005) and Siemens (2004) together believed use of networks in understanding learning enhance the effective learning through connecting the appropriate learning aspects and making meaning out of them. Therefore, people need to start making connections with the accurate and current learning concepts and information in their working environment. In this study, Connectivism is adapted to find learning aspects that influence BIM construction projects and to understand how learning can take place in digitally enabled projects.

The concept of Connectivism is focused on learning that takes place in rapidly changinfg digital environments. This comprises principles explored by chaos, network, complexity and self-organising theories. Chaos theory explains how unrelated events can be noticed, while they are studied together and forms a pattern to show the relevance beyond the individual events themselves (Salmon, 1999). Supporting this, Siemens (2005b) believed that people who are trying to learn something new can no longer experience everything by themselves. Consequently, creating a network with relevant people, technology, social culture, and power grids is important to share the ideas and knowledge within the learning environment. However, each and every systems or environments are complex and comprise different learning aspects. Complexity can be positioned between order and disorder. Thus, development of each system is unpredictable and uncontrollable despite the non-linearity of interactions. To solve this, systems need to be self-organised with the intention of producing global coordination and interaction. Heylighen (2008) mentioned that final structure mostly functions as a network with stabilising operations through linking the connections between the agents. Therefore, with the amalgamation of these theories, Connectivism is about self-organisation and understanding the patterns between the connections within networks in order to learn something new.

Connectivism theory describes how connections are formed in a network through learning aspects (Bannister, 2016). Learning starts to commence when knowledge is triggered through the process of the learner connecting to, and providing information into, the learning community. This initially takes place when individuals start to apply their personal knowledge to a common system and gained knowledge is then fed back into the same system. This cycle keeps on going and the individual's knowledge continues to grow through constant interactions with the cycle. The advantage of this is that learners can remain up-to-date on any topic through the connections created and can promote and organise the flow of knowledge to attain common goals (Siemens, 2004). According to Siemens (2004), 'community' is a cluster of similar areas of interest that allows interacting, sharing, dialoguing and thinking together. A learning community in the Connectivism model is defined by nodes which are part of a larger network (Downes, 2007). A node can refer to anything that can be connected to another node, such as organisations, groups, communities, fields, ideas, information/data, and emotions.

2.5.1 Characteristics of Connectivism

Connectivism considers learning as a process of creating connections between two entities and expanding the network (Siemens, 2006b). According to Downes (2007), knowledge is circulated across a network of connections, therefore the learning in Connectivism approach has the ability to construct and traverse those networks. In addition, he stressed that due to the distribution of knowledge and connected learning within the network, a change in one learning aspect can have an impact on the second learning aspect. In addition, he mentioned that the application of Connectivism includes the insight of the following characteristics: diversity, autonomy, openness and interactivity, as part of connective knowledge. According to Downes (2007), each of these aspects of Connectivism are important to develop to learn in a connected way.

Autonomy is about self-directed learning, which Mackness *et al* (2010, p.4) describe as "the learners' choice of where, when, how, with whom, and even what to learn". Interactivity, sometimes called as connectedness, is grounded in the networking aspects of Connectivism (Rafaeli 1988). This refers to the ability to connect with others. This principle of connectedness is discussed in communities of practice (Wenger, 2000) and personal learning networks (Richardson and Mancabelli, 2011). According to Downes (2010), the principle of diversity refers to the different availabilities of multiple perspectives for learning. Finally, the principle of openness focuses on the ability and willingness to share information. Saadatmand and Kumpulainen (2014), in an educational context, have highlighted the importance and benefits of openness in terms of building knowledge. Even though Connectivism has distinctive features, people's view of it differs according to their standpoint.

2.5.2 Global View of Connectivism

Previous learning paradigms such as behaviourism, cognitivism, and constructivism discuss how people learn, as shown in Table 2.7.

Theories	Perspectives of learning
Behaviourism	Learning as the creation of a habitual response in particular circumstances.
Cognitivism	Learning viewed as a process of inputs, managed in short-term memory, and coded for long-term recall.
Constructivism	Learning takes place with the creation and application of mental models or representations of the world.

Table 2.7: Different perspectives of learning

Behaviourism and cognitivism theories consider knowledge as external to the learner, whereas the learning process as the act of internalising knowledge. On the hand, constructivist principles believes that knowledge cannot be inserted within learners and that they need to be actively engaged to create meaning from their experiences. These theories have only focused on learning which takes place inside a person or group, but the situation has changed now due to digitalisation, and learning is no longer limited within certain boundaries. Instead, it is currently driven by the formation of connections in networks. Supporting this, Siemens (2004) through his intrapersonal view, argues that these earlier learning theories fail to address the learning that is located within technology and organisations. Moreover, he believes that Connectivism will help to share cognitive tasks between people and technology in order to cope with technological change.

Learning that is considered in Connectivism is focused on connecting learning related aspect in the learning environment. Although Connectivism is focusing on learning that is networked, some scholars still argue that is not sufficient to be a learning theory. Verhagen (2006) stated that Connectivism is no more than a pedagogical view and this is mainly because it has no inclusion of new learning principles or no exploration on people's learning process. Similarly, Chatti (2007) argues that Connectivism ignores some of the learning concepts such as reflection, learning from failure, error detection and correction, and inquiry, which are essential for learning. Supporting these arguments, Kop and Hill (2008) accepts that Connectivism is not solely a separate theory and it shifts the learning control from tutor to autonomous learner during the development and emergence of pedagogies. Slightly different to these arguments, Ally (2007) states that people have now shifted to networked world. Hence the old learning theories are now less relevant. But at the same time, similar to Kop and Hill (2008), he believes Connectivism is not a standalone theory, but instead it is a model that integrates different theories to guide the design of online learning materials. Converse to all the negative arguments, Foster (2007) believes that the concept of Connectivism needs to be introduced in learning to utilise the limitations and full range of connections within the learning environment. Even though there is a need for further refinement of the Connectivism concept, it is an appropriate and timely one in the increasingly digitalised world.

Intrapersonal views of learning in behaviourism, cognitivism and constructivism have failed to address the learning that takes place in digital environment and contribution towards knowldeg-rich environment. On the other hand, these learning theories also fails to learning occurs in(Siemens, 2004). Digital technology is now part of people's life in their communication and how they learn. Therefore, there is an urge for current learning needs to be transformed to enhance the digital transfration not only through acquisition of knowledge or adding on to the existing knowledge but also through connecting them. Learning, in Connectivism is not only the accumulation of knowledge but also the meaningful connection between the learning aspects in the learning environment. This is because social learning in Connectivism is networked where it connects people and information sources (Duke et al., 2013). Therefore, this research has adopted Connectivism to encourage more people to implement BIM in construction projects through mitigating the lack of skilled people and widening their existing knowledge.

2.5.3 Conceptualisation of the learning model

Workplace-based learning happens in day today activities and is somehow related to global challenges such as skills shortages, growth of new building methods, poor productivity and profitability, project performanace and sustainability concerns. These challenges need to be met and resolved both directly and indirectly from the top level employer to grass root level. Therefore, this study has focused on the fundamentals needed for workplace-based learning, the process involved in the learning environment, and finally learning outcomes to suggest a new way of learning to cope with ever-changing digital world. This is to allow people to engage in transformative and innovative processes through reproducing the learning strategies, encouraging networks and social learning instead of individual learning. Hence, to create a learning model for the workplace, it is important to realise the deep understanding on learning that takes place in the workplace.

Several numbers of learning models have been introduced in the workplace environment. Workplace-based learning is not just only about work-related learning, instead it is linked to the factors within and beyond the learning environment as discussed in the section above. Therefore, it is clear that there is a need for a suitable model for workplace-based learning. Jørgensen and Warring (2001) has developed a learning model for workplace learning as shown in the Figure 2.8.

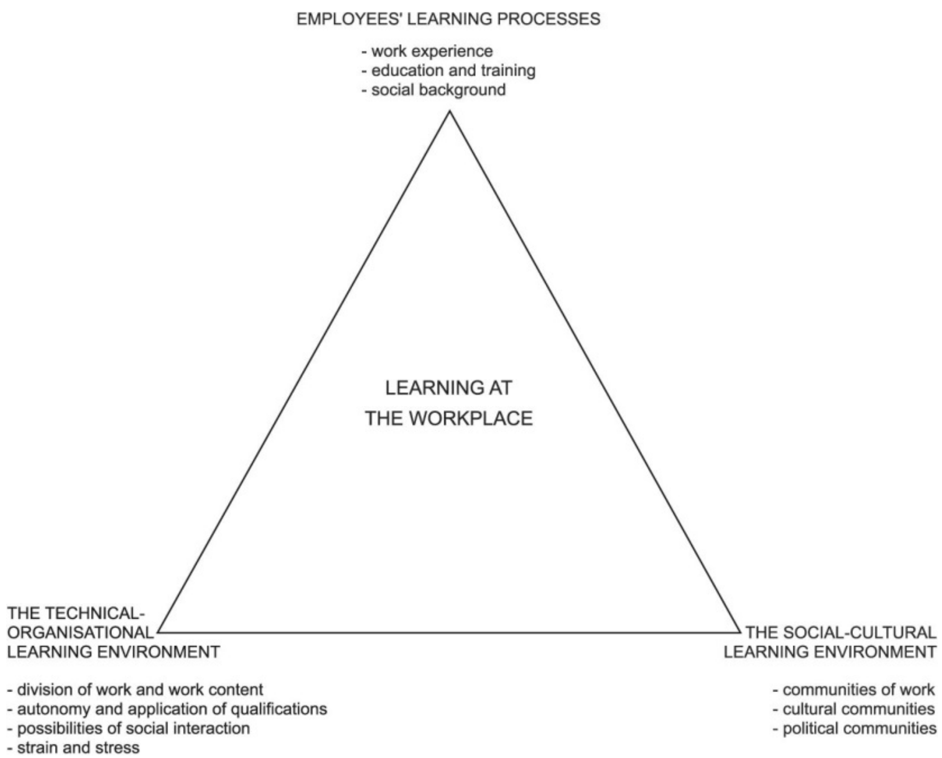

Figure 2.8: Learning Model for workplace (Jorgensen and Warring, 2011)

The idea of this model is that learning that takes place in the workplace encounters between the learning environment and learning processes. The concept of the learning environment introduced by Jørgensen and Warring (2001) includes the opportunities for learning contained within material and social surroundings. Whereas learning processes is about an understanding of an individual's life. This is considered as a continuous learning process, which is developed through past experiences that helps to look forward towards life plan and future perspectives. The learning process plays a major role for the readiness for learning through individuals and groups meeting together and exploiting the opportunities for learning that happens in learning environments. Jørgensen and Warring (2001) have considered learning happens through the dynamic relationship with employee's learning processes, the communities involved in the workplace and enterprise as technical-organisational system. Therefore, with this background, the triangular model for learning is built with three main aspects in workplace-based learning: the technical-organisational learning environment, the social learning environment, and the employees' work processes. The triangle's two sides are separated with two different learning environments because each of them is developed through different dynamics. The technical-organisational learning environment is fundamentally related to market and technological conditions, which determines the learning. In social learning condition, specific social and cultural matters are essential for learning possibilities. Nevertheless, the learning environment only includes the framework of learning, while the interaction between individuals and the learning environment also has an impact on learning. Therefore, employee's background, experience, and future perspectives were included in the model to understand the dynamism that take place between the learning environment and learning process. In this model, the individual elements chosen are interrelated to each other. For example, an individual's learning process is related with the social learning environment and can only be disconnected analytically. Three elements identified in this model have less features related to learning and how they are connected to societal context such as learning through individual's past experiences, position in the environment, and feature of they are being formed in societal environment. Jørgensen and Warring (2001) highlighted that to understand this model, it is important to consider two different interactions involved in this model. Firstly, it is about two different learning environments: technical and social mingle with each other. Secondly, vertical interaction refers to the connection between these mingled environments and the individual's learning process. The area where these interactions encounter is referred as learning work practice where workplace-based learning is developed. Learning in workplace can be direct or in-direct but it is necessary to organise the fundamental ways or work life and functions in the society.

Rylatt (1994) believed that, organisation need to develop their true capacity of its people through investigating the close relationship with existing policies, systems, and activities to decide whether they are supporting or inhibiting workplace-based learning. Introducing a new attitude to learning within the workplace is challenging due the acceptance and commitment of the individuals, teams, and organisations. Therefore, Rylatt (1994) has proposed a model for workplace-based learning which is built up on the belief that individuals and organisations should shift from their existing beliefs or mind-sets about the workplace. Moreover, he mentioned that a positive mind-set is essential because

''*Mind-sets have the capacity to transform the growth and performance of the workforce by providing much needed clarity and a sense of purpose to all actions, plans and strategies*" (Rylatt, 1994, p. 16).

Therefore, he has highlighted eight key mind-sets that are vital for workplace-based learning transformation:

1. Change should not be considered as a threat and learning that takes place in the workplace environment needs to higher that the change. Learning process should be also greater or in sophisticated level to generate an attitude of commitment and opportunity.
2. Workplace-based learning should be systematic, interactive, highly integrated and should incorporate with wide range of inputs into its design, delivery, and assessment.
3. Workplace-based learning should be geared towards business outcomes. For an example: Workplace environment which has the goals to " to bring about measureable improvements in performance, productivity, quality and potential" (Rylatt,1994, p. 19) needs to be connected with their short and long term organisational needs.
4. Workplace-based learning should generate a meaning, self-worth and sustainment for environment and should give more importance to address the person, incorporating compared to the development of technical and functional skills.
5. Workplace-based learning needs to be learner driven and flexible enough to satisfy the individual's needs.
6. Workplace-based learning needs to be competency based and programs should be connected to the achievement of particular competencies for the organisation to achieve the benefits. This is addressed in this study through focusing on "Learning conditions" especially the learning factors such as choosing appropriate skills and knowing the background knowledge.
7. Workplace are becoming more responsible for ''learning'' they provide therefore it need to be delivered in right timing.
8. Workplace-based learning needs to be developed with new frontiers of knowledge and organisation should have the ability to seek information from both internal and external sources to help them maintain a viable strategic intent.

Rylatt (1994) in his study has focused on workplace-based learning in relation to the individual learner, the business objectives and the future. Moreover, he considers workplace-based learning environment as a systematic and interactive processes, which includes several influential elements for improving business results, competencies, including satisfying the peoples and argues ignoring this might cause confusions to the individuals participate in the workplace. Even though Rylatt (1994) has proposed the necessity for systematic, integrated and national approach for workplace-based learning, Mathew (1999) has pointed out a number of limitations of Rylatt's work. Organisations, where individuals are involved, do not operate in a vacuum and learning is not totally rational. Therefore, more variety of influences need to be taken into account. Rylatt (1994) has only focused on the connection between inputs and specific outputs to direct the learning, which can also save financial resources. However, Mathew (1999) suggested that clear goals and objectives for workplace-based learning needs to be considered for positive learning. Moreover, Mathew (1999) suggested that the model created by the Rylatt (1994) explains the result of an integration of organisational strategies, policies, programs, and resources, nevertheless has no explanation of this interaction and type of workplace-based learning that results from it. Furthermore, although the model has identified several organisation activities, the mix of input essential to produce successful work learning is not shown or discussed in the model.

The third learning model is called the 3-P model of workplace-based learning (See Figiure 2.9) which is related with key main areas: nature of workplace-based learning, identities and agencies in workplace-based learning, development of professional practices, competence developed in education, communities of practice, and organisational earning. This model is considered as an analytical tool to understand the diversity of the workplace and is used as a map by the individual researchers to locate their key ideas and interests in broad field of research and to outline research designs for future studies (Tynjälä, 2013). The fundamentals for this 3-P model for workplace-based learning is derived from Briggs (1999) 3-P model for learning, which shows the complexity of the phenomenon and presents the relationship between different learning aspects.

3Ps in this learning model refers to three fundamental aspects of learning: presage, process and product. Brigg's model that has been created in a school context included two elements, which are student related factors (eg: prior knowledge and motivation) and factors related to teaching contexts (eg: teaching methods and assessments). In Brigg's model, the process aspect plays the cental part of the model and it relates to the way student's approach learning. Finally, the product part is about the results that are produced from the learning process (eg: knowledge, skills, and attitudes). Brigg's model has been generated for a school context and cannot be adapted to workplace-based learning. This is because sociocultural approach adopted in Brigg's model emphasises the contextual and situational nature of learning and assumes that the model described in one context (school) cannot be applied in another context (workplace). On the other hand, workplace-based learning is mostly related to informal learning without explicit teaching (Eraut 2004a), whereas the school context is focused on formal learning through explicit teaching. Therefore, Brigg's model, which has adopted a teaching context, does not suit the workplace environment. Following this, with the base of this model similar workplace-based learning model has been produced by Marsick *et al* (2011). The same three main aspects (presage, process and product) used in the Brigg's model has been adopted but the presage aspect has been referred to as inputs. On the other hand, they have included context as a framework aspect, rather than adding it in the presage aspect. The key addition of 'interpretation' in between presage and process aspect in the 3-P model is the key difference between Brigg's and Marsick *et al*'s model and explains the model slightly in broader terms.

Tynjälä (2013) has created a 3-P model for workplace-based learning through also making a few modifications (See Figure 2.9). In the original model, context is presented as a part of the presage aspect, while the modified workplace-based learning model has considered context as the attachment of surrounding frame, which refers to the sociocultural environment. This includes both opportunities and constraints of workplace-based learning, which creates an additional level of investigation. On the other hand, this model does not only consider the sociocultural environment but also the technical-organisational environment (Jørgensen and Warring, 2001; Illeris, 2011). This is because the author believed that the socio cultural context comprises a wider perspective with the addition of artefacts of human culture that includes organisations and technologies. Moreover, concepts of communities of practices (Wenger 1998), organisational learning (Argyris and Schön, 1996), and activity systems (Engeström, 2011), including the focus on power and politics in workplace-based learning (Fenwick 2008), were considered in this level of research on workplace-based learning. Furthermore, work experiences organised in different educational systems (Guile and Griffiths, 2001) were also considered in this model. Next, an alteration was the addition of 'interpretation' between presage and process into the model. Looking through the constructivist view, the presage aspect does not impact directly on the process aspect, therefore interpretation needs to act as mediator between them (Glasersfeld 1995; Prosser and Trigwell 1999). In other words, the way people see themselves as a worker and the way they perceive their workplace as a learning environment, determines the learning rather than previous knowledge and skills (Lantz and Andersson, 2008). A third alteration in the 3-P model is changing the terminologies in the model according to the workplace environment. The 'student factor' label has been replaced by 'learner's factor' and teaching context is changed to 'learning context'. This replacement has been made because learners in the work environment could be employees (part-time and full time workers), new comers, old-timers, managers, blue collar and white collar workers, apprentices, interns, and many others who are different from learners in a school environment. Furthermore, the teaching context is changed because teaching is not main in the workplace environment. Similar elements such as knowledge and skills in the presage factor is transformed to workplace-based learning model but at the same time additional factors such as agency and commitment (Lantz and Andersson, 2008), self-confidence and life situations (Sambrook, 2006) were added. The learning context includes factors connected to work organisations and their features for instance, structure of an organisation, work organisation, orientation toward learning and innovation, human resource improvement, collaborative environment and partnerships and networks (Fuller and Unwin 2004; Sambrook 2006). Next, the process aspect in the workplace model is also different from the school learning environment which focuses on different workplace activities where learning generally occurs through self-learning, self-reflection, collaboration and communication with others, by participating in network or formal learning activities and tackling new challenges (Eraut 2004b; Tynjälä 2008). Therefore, this does not involve deep and surface learning, which is followed by the students in the school environment. In other words, workplace-based learning is mostly involved in informal learning in nature (Eilström 2011; Eraut 2004a, 2004b), whereas the school learning environment is engaged with formal learning approaches. However, this model has characterised workplace-based learning through the combination of informal, non-formal, or formal learning (e.g. Billett 2002a; Cairns and Malloch 2011). Finally, the final product aspect represents diverse learning outcomes that can occur within the workplace-based learning environment. Moreover, scholars have argued that workplace-based learning is not restricted only to individual but also to the organisational development (Engeström et al., 2007; Salojärvi *et al*., 2010)

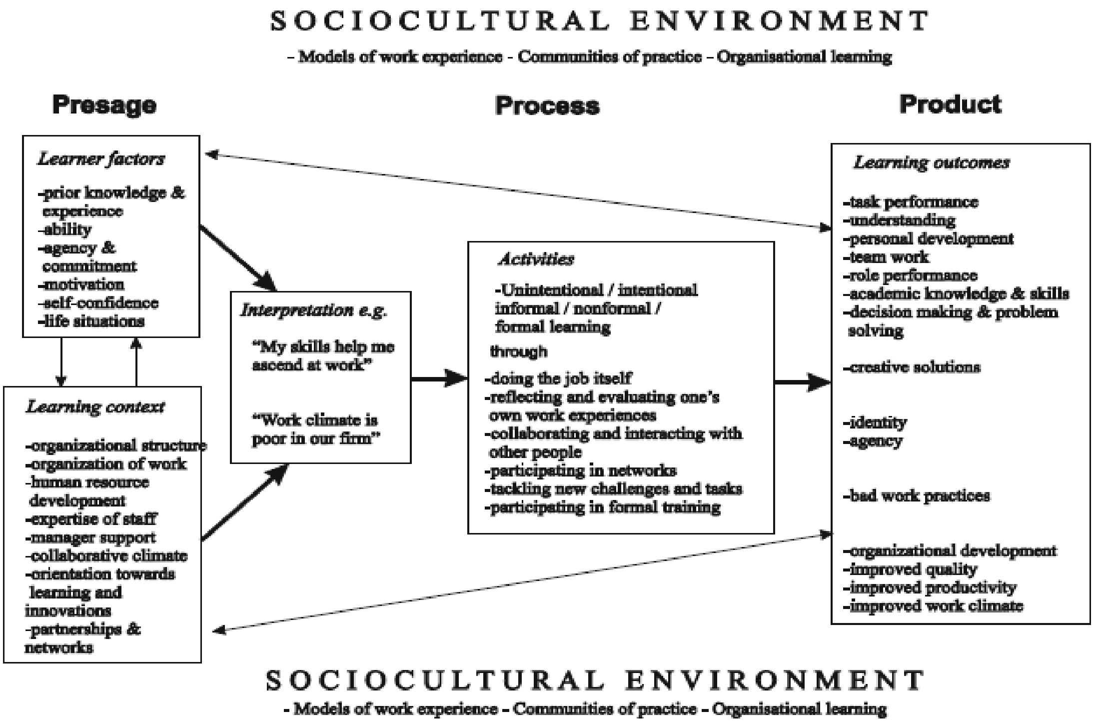

Figure 2.9: The 3P model for wrkplace-based learning (Tynjala, 2013)

In reference to Figure 2.9, the exploration of different learning aspects in the workplace environment shows it is explicit that learning as a process has certain conditions attached to presage stage, learning stage, and outcome stage. In the presage stage, learning aspects are more focused on people who are ready to be involved in the project and environment where learning is about to take place. Considering these learning aspects in the beginning of the learning process provides a strong base to deal with ad-hoc situations in workplace. Following this, the importance of interpretation in the learning stage is enormous in addition to the progress of task related activities. This plays a major role in identifying participant's own abilities and how things can be done differently. Learning outcomes is the stage where all the intended and unintended tasks are completed to achieve the desired goals. Effective workplace-based learning can be measured through the success of task completion in learning outcome stage.

Studies on workplace-based learning have helped to improve task performance through deepening worker's understanding, developing as a person, learning new roles, and improving problem solving abilities (Eraut, 2011). On the other hand, scholars have mentioned learning outcomes in the workplace environment comprises vocational and professional identity development (Billett *et al*. 2006; Brown *et al*., 2007; Virtanen A and Tynjälä , 2008) and supports the sense of agency (Hänninen and Eteläpelto 2008;Hökkä *et al*., 2008). However, studies have also pointed out some risks such as leading to bad practices or negative attitudes towards work (Virtanen and Tynjälä, 2008), errors at work performance which are related to learning (Bauer and Mulder 2008; Harteis *et al*., 2008). Therefore to overcome these issues it is important to recognise the interconnections and understand the patterns of connections in decision making to improve their learning to work in the digital age.

Digital technologies are rapidly evolving hence it is important to understand the current need and learning to tackle the digital changes in the world. The adaptation of Connectvism in this digital age helps to search for the current information and prioritise the most important information from the secondary information. Moreover, Connectivism concepts form the interconnections between the ideas, people and resources to create a specific set of information. This networking system in Connectivism approach encourage critical thinking and helps to constantly update and change the knowledge. Therefore, this can help to understand the new way of learning in digitally enabled environment to tackle the new digital world.

2.6 Summary

This chapter started with the influence of digitalisation in the construction industry. Later, it has discussed the level of BIM implementation in construction projects to move towards this digital world. Following this, the chapter explored skills deficiencies in BIM construction projects, which is one of the drawbacks for slow adaptation of emerging technologies in the construction industry. Consequently, the need for workplace-based learning for digitally enabled construction projects were also highlighted in the discussion. Construction projects are not only fragmented and complex but also connect with many influences such as people, information, and activities. Furthermore, to understand the connections within construction projects, Connectivism theory was discussed through looking at its charecteristcs, viewpoints and how it impacts on the current learning to face digital changes. Hence, this chapter also discussed Connectivism view which will be adopted in this study. Overall, this chapter has provided an idea of where the knowledge gap is and what steps needs to done in future to overcome this identified issue.

CHAPTER-03: RESEARCH METHODOLOGY

3.0 Introduction

Methodology is a logical and systematic process of investigating a study with the well organised research design, methods, and approaches to achieve a novel knowledge (Kivunja and Kuyini, 2017). Critical Realism has been used in the primary research of this study to investigate the learning that takes place in BIM-enabled construction projects and to understand the connection between learning aspects in a workplace context. This section focuses on justifying the selected research strategies/methodology, research design and methods adopted to accomplish the primary research. It starts with the discussion on research philosophy through exploring the philosophical and methodological issues. Then, the chapter moves onto the research process that explains the holistic picture of the methodology adopted for this study. Following that, research design is explained in three phases: literature review, semi-structured interviews and case study approach. Consequently, appropriate data collection methods and method of analysis adopted to conduct the study are discussed through reviewing the critiques and limitations. This chapter also explains how this research has made use of the strengths of these methods to overcome the limitations. Finally, ethical considerations related to the research topic is discussed. Figure 3.1 below demonstrates the research design of this study.

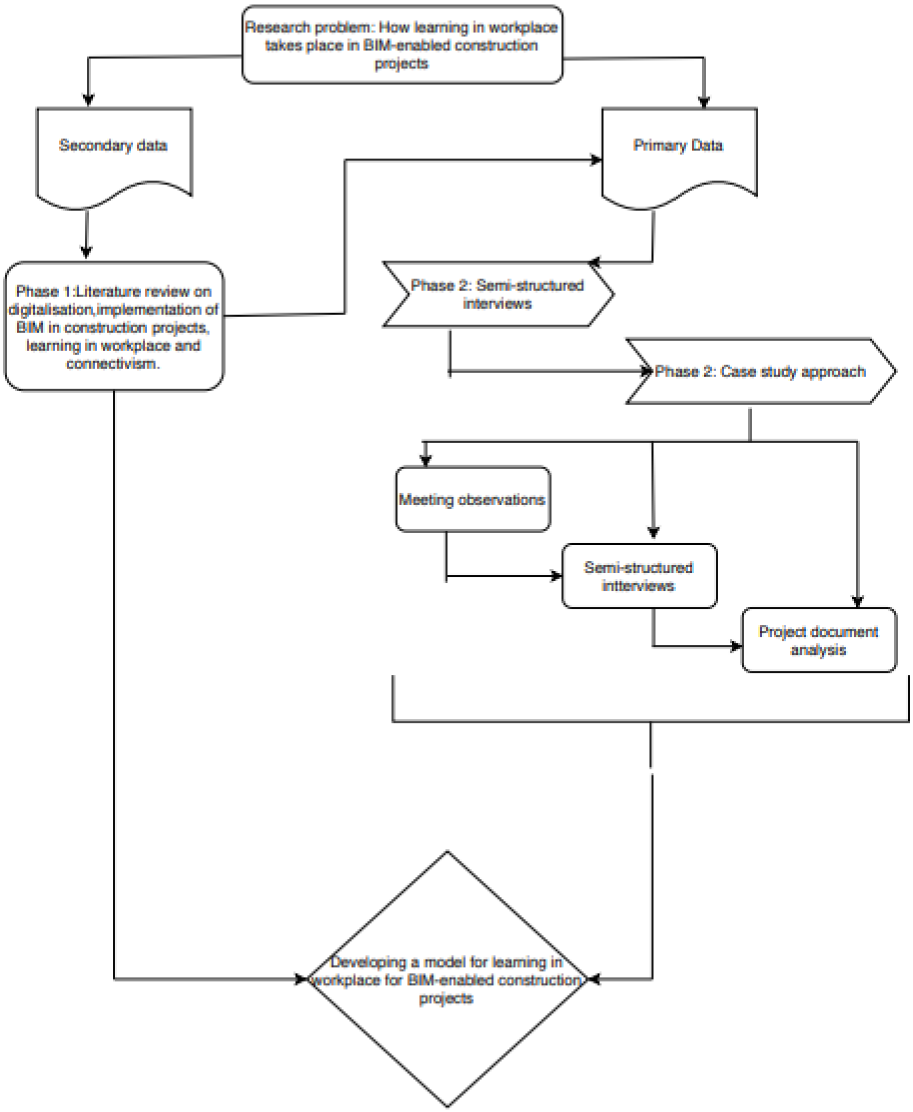

Figure 3.1: Research design of the study

3.1 Research philosophy

In general, philosophical worldviews are hidden in research, however it has a huge impact on research practice (Slife and Williams, 1995) hence, it is important to identify philosophical ideas that influence the research. According to Saunders et al (2009) philosopies can be divided into different categories: positivism, realism, interpretivism, objectivism, subjectivism, pragmatism, functionalist, interpretive, radical humanist and radical structuralism.

Positivism derives from scientific thinking and in this view social science reflects, as similar as possible, those of the natural sciences. Primarily the aim of positivism is to identify the fact of the study through choosing suitable techniques to observe and measure the phenomenon objectivity (Oates, 2006) and to apply scientific reasoning and law-like generalisations in the process of knowledge construction (Remenyi, 1998). This view assumes that the reality can be captured through the use of research instruments such as experiments and questionnaires (Blaxter, 2001). Later on in twentieth century social phenomenon was moving into scientific subject thus original version of positivism was transferred into a new version called post positivism which was developed by Corbetta (2003). The idea of post positivism is that reality could not be perfectly objective (Oates, 2006) and considers the potential uncertainty within the research context. On ther hand, Interpretivism focuses on the value, meaning and purpose of the research. Moreover, it considers that there is no single reality or truth and it needs to be interpreted through the connection of each factor which will vary case to case. In other words constructivism is the belief that social phenomena are in a constant state of change because they are completely reliant on social interactions as they take place (Walliman, 2006). The idea of pragmatism is that the reality is constantly renegotiated, debated and interpreted therefore there is no best method to resolve problem. In other words knowledge in pragmatism is a social phenomenon instead of introspective where the object must consider the conceivable effects upon the actions in order to conceive of the object society. According to Meesapawong (2013) single paradigm is not sufficient to solve the issues or could not direct to the right path to find the solutions for the problems. So pragmatism is a new paradigm developed to solve specific research problems. This paradigm is centred on research question which decides which philosophical approach is suitable for the study (Wicks and Freeman, 1998). In pragmatic paradigm the questions are applicable to view from positivism or interpretivism with the combination of all collected and analysed data to solve the issue (Saunders et al., 2009; Meesapawong, 2013).

The idea of realism is that whatever people believe for that moment is just an approximation of reality and every new observations added will closer to understand the reality. This ideas are ignored in positvisits, constrictivist and pragmantist. The primary focus of realism is to identify the underlying objects of research and secondly define the suitable approaches for the research. Realist believe that once the purpose of the research is known, any number of approaches can be adopted and applied in different, novel ways; the target is to extract the real structure and mechanism in a particular situation. In this PhD study, BIM technology used in BIM-enabled construction projects is considered as an existing independent which can be empirically experienced and interacted by people (objective knowledge). Meantime, workplace-based learning which is socially constructed and subject to change is considered as subjective knowledge. Scholars have used different philosophical approaches to investigate workplace-based learning in different situations. For an example, the nursing discipline uses a philosophy of clinical coaching with wide range of guidance and objectives to achieve their targets through focusing on their personal development (Faithfull-Byrne *et al*., 2017). However considering the nature, this research has adopted “critical realism” in specific.

The critical realistic view was developed by Bhaskar (1997) with the collaboration of a number of social theorists. They admit the existence of an objective (intransitive) world but believe this can never happen until it has access to the subjective knowledge (transitive) which constantly changes due to social construction. In other words, scientific theorising of critical realism is based on the assumptions grounded on an existence of a mind-independent reality (Wikgren, 2004).

This method best suits this study because challenges in both natural and social science regimes are equally considered in Critical Realism. Moreover, the characteristic of commitment to the ontology of Critical Realism has helped to focus this study on BIM technology through analysing the information system (part of natural science) to understand the workplace-based learning which is socially constructed by humans (part of social science). According to Sayer (2000), “observability may make us more confident about what we think exists, but existence itself is not dependent on it” (p. 12). Therefore, this study has combined observable events with unobservable entities to provide more information especially about understand how things work.

Critical realism states that the social world is very complex and various outcomes can be achieved with the same casual power due to constant change in the environment. Thus, the central idea of critical realism is that natural and social reality needs to be understood as an open stratified system of objects with casual powers (Morgan, 2006). This viewpoint suits this study well, in exploring how learning has been perceived in the real world to understand the learning that currently takes place in workplaces. To analyse this in detail, this study has adopted the Critical Realism view of Mingers and Willcock (2004) which layers Critical Realism into three different layers: *empirical* (observable experiences), *actual* (events that are generated through mechanisms) and *real* (mechanisms that have generated the actual events). In this study, identifying the key learning aspects within BIM context is considered as real. In other words, these learning aspects actually exist in the BIM- enabled construction projects. Therefore, these existing facts are actual rather than imaginery, idela or fictitious and there is no need to prove these aspects in the external world. Following this, understanding those learning aspects and finding the connection between them falls into the layers of actual and empirical, respectively. So, the idea is to study the social mechanism (connections between learning aspects in BIM context) that are not readily observable that have power to produce effects.

Exploration for this study begins with identifying the ontological insight within critical realism and it is introduced through BIM technology, which is a fixed, observable point in the real world where the meaning can be given by humans to a certain extent. This is because technology in this study is considered to be already existing in this external world which human can acquire knowledge. Hence, this starting point helps the researcher to understand the certainity of the nature and existence of the objects. The generative mechanism considered in this domain is 'workplace-based learning' which is at the level of the empirical. This study is centred on how people learn in BIM-enabled workplaces, therefore it falls into social science hence, and there is a necessity to explore beyond collecting and interpreting the underlying mechanism. Instead of focusing on why people think in that way and their understandings related to the mechanism should be realised (Danermark, 2002, p. 32). The study intends to achieve this through finding the connections between the learning aspects within the BIM context.

Although critical realism has its own way of viewing research problems, there are some related issues. One of the challenge is that critical realism does not guarantee the research methodology in the science (Isaksen, 2016). However, Bhaskar (2009) differentiates both philosophical and scientific ontologies. He claims that each science, guided by meta-theory should develop an ontology, epistemology and methodology in a specific domain or knowledge. In addition, he believes that categories of philosophical ontologies – open and close, emergence and stratification – are related to each other. However, this can be overcome by focusing on suitable meta-theory and ontological understanding (Hoddy, 2018; Ackroyd, 2004).

Workplace-based learning for this study is beyond the accumulation of knowledge which includes the meaningful connection between the aspects in the learning environment. However, learning becomes problematic when people give different meaning to it. Therefore, it is vital to understand the connection between the key learning aspects to make effective decisions and solve problems in BIM-enabled construction projects. To understand the theory behind the workplace-based learning and its learning aspects suitable research approaches are discussed in the next section.

3.2 Approaches to research: Abductive Approach

Reasoning in research is mainly divided into two different approaches, namely deductive and inductive (Fellow and Lui, 2008) and the combination of these approaches is refreed as "abductive". A deductive approach generally tends to develop the theory and hypotheses with the use of literature reviews and the subsequent research strategy is designed to examine the hypotheses. In other words, the deductive approach is related to a theory testing process, which begins with the established existing theory or generalisation and creating hypotheses and testing it to revise the theory (Locke, 2007; Nola and Sankey, 2007). On the other hand, in the inductive approach data is collected first and data analysis is used to build up on theories (Saunders *et al*., 2012). The inductive research approach commences with empirical facts and the collection of observations to move to broader generalisation to develop a theory

(Danermark, 2002; Spens and Kovacs, 2006). In other words, the inductive research approach develops through the consequences of data analysis (Saunders *et al*., 2012).

The abductive research begins with the understanding of the new phenomenon (Alvesson & Skoldberg, 2009) and propose a new theory based on application of new theory in the empirical settings (Andreewsky & Bourcier, 2000). Research question in abductive research question is often independent between method and theory development or testing, and the proposed knowledge is developed through the interaction between data and an amalgam of existing theories or propositions (Dubois & Araujo, 2004; Van Maanen et al., 2007). However, this is just the initial proposition or theoretical framework and evolves simultaneously with observations in terms of developing new knowledge. According to Dubois and Gadde (2002) connecting the suitable theories (rules) with the empirical observation (results) is referred as 'theory matching' or 'systematic combining'. During this process theory building and data collection happens simultaneously which implies a learning loop (Taylor et al., 2000), or back and forth direction between theory and empirical study (Spens & Kovacs 2006). Even though, iterative process are followed in this approach the generalisation of new theory is decided after the corroboration in theory-testing phase (Spens & Kovacs, 2006). Qualitative research methods such as case studies and action research are used in this approach which allows to simultaneously collect data and build theory (Dubios and Gadde, 2002). In these situations the researcher has the ability to revisit the phenomenon they study. According to Kilpinen (2009) revisiting researcher allows the researcher to re-evaluate and rethink the mundane experience to overcome habituation of perceptions and this is encouraged through qualitative data such as detailed field notes, transcriptions, and documentation analysis. The iterative approach between empirical observation and conceptual inquiry which leads to valuable empirical evidence and unorthodox theoretical insight is a biggest strength of this approach. On the other hand, explicit description of the research process including rigor concerning research ethics in order to increase the reliability of the research question needs further improvement for this approach (Timmermans & Tavory, 2012; Spens & Kovacs, 2006).

According to Saunders *et al.* (2012), even though both deductive and inductive are wholly distinct approaches, they can be used together in research. However, the effectiveness of such a joined approach depends on the experience of the researcher. Creswell (2018) has mentioned that when there is plenty of literature available, a theoretical framework and hypotheses can be defined through the process of deduction. Conversely, when the topic is new, there will be less literature and it is more appropriate to adopt an inductive approach through relevant data and analysis reflecting on the theoretical themes that the data is suggesting. Considering these views, the researcher has used abductive approach. The reason behind this is to explore the main two key areas related to this study, namely the learning in the workplace, and BIM implementation. As mentioned previously, a wealth of literature about BIM has made it possible to conduct deductive reasoning by identifying BIM usage, maturity levels, and benefits.

However, learning in a workplace is subject to change with new technologies, therefore learning elements related to the BIM environment specifically, are gathered through the inductive approach (See Figure 3.2). In this study, a combination of both deductive and inductive approaches is used to propose a model for workplace-based learning. A framework is a way of reprenting the empirical relations between every aspect of inquiry when considering a scientific theory or research. On the other hand, a model is initially used in research to outline the possible courses of action or represent the ideas/thoughts.

In this study, a deductive approach was initially used to develop a background understanding on three topics: Building Information Modelling, Workplace-based learning, and Connectivism. This approach began with the established existing generalisation around these topics. During this, the researcher has worked from more general information to specific (top-down approach) and concluded that there is a need to focus more on workplace-based learning in the digital world. In contrast to the general way of testing the assumed hypothesis or established theory, a deductive approach in this study was used to collect the theoretical arguments behind the above three topics. Collecting the background knowledge and understanding the problem have been a starting point to explore the learning that takes place in digitally enabled workplaces. Moreover, this study has adopted qualitative methods such as semi-structured interviews and a case study approach to investigate the problem in depth.

The inductive approach initially helped the researcher to understand the problem and the context in which it exists, and generated the facts through a specific case study. Although there is literature around these topics, workplace-based learning, which is socially constructed and understood, is still evolving to cope with new technologies. The inductive approach in this study commences with the subjective account of lived experiences. The steps similar to Interpretative Phenomenological Analysis (IPA) have been adopted in this study: reading and re-reading, identifying the themes, developing emergent themes, analysing across the cases, finding the connections. This bottom-to-top approach is based on collected qualitative approaches: meeting observations, semi-structured interviews, and project documents. However, it involves degrees of uncertainty. During the meeting observation, the activities that has occured on site as well as office are analysed and discussed. Whereas, during the semi-structured interviews, BIM professionals shared their experience working on BIM. These discussion and conversation during both meeting observations and semi-structured interviews within the case studies were supported by the project documents. Overall, all these information allowed the researcher to elicit the “lived experience”.

The overall idea of this approach is to explain the social phenomena and finally build a model for workplace-based learning for BIM-enabled construction projects with the aid of the findings from the context. The following sections in this chapter explained data collection and data analysis techniques in more detail.

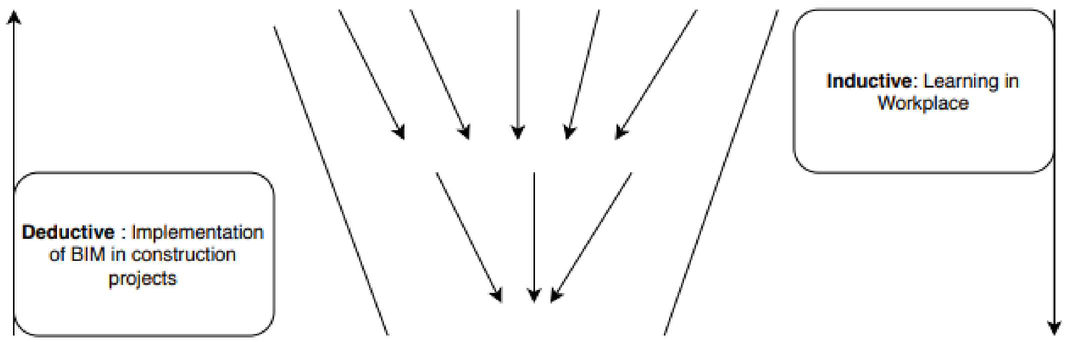

Figure 3.2: Inductive and deductive approach for the study

3.4 Research strategy and Research Method

Creswell (2018) claims that choice of research strategy in a study is centred on the research objectives. Agreeing on that statement the objectives of this research lead to an answer for how learning is taking place in the workplace. On the other hand, workplace-based learning in BIM-enabled construction projects is an evolving topic hence, there is lack of prior knowledge which would potentially create new theories. Therefore, to understand the best way to learn in learn in workplace the researcher has adopted the choice of an exploratory study. In this study, exploratory approach is used to investigate how learning is happening in BIM-enabled construction projects that has not been clearly defined in previous studies. Moreover, identifying and understanding the key learning aspects in BIM-enabled projects have allowed the researcher to develop a model for wprkplace-based learing especially for BIM-enabled construction projects.

The rationale of the research method selection was to accumulate an in-depth understanding of the chosen subject. Research methods are usually classified into three categories depending on the research question namely: qualitative, quantitative and mixed method (triangulation) approaches (Creswell, 2018). The major topics of BIM and workplace-based learning studies have generally been studied using qualitative analyses to maintain both reliability and validity. The literature has established that the topic of workplace-based learning in BIM construction projects is rarely explored and thus, an investigation was launched to study the learning that takes place in workplace especially in BIM-enabled construction projects. A qualitative research method is adopted in this study to gain the deeper understanding of how learning is taking place and how learning is perceived by the project participants in BIM-enabled construction projects. Moreover, this method is used to understand how these learning aspects are connected to solve issues and make decisions in BIM construction projects. This is perceived through observing the activities in BIM construction projects along with in-depth explanations from, and views of, professionals employed in those projects. This information is then used to identify the key learning aspects. Overall, this research is more subjective and needs more investigation on existing themes and theories related to learning in the workplace. Although, some of the learning aspects were gathered through the initial semi-structured interviews with BIM professionals the information collected were subjective and limited due to time constraint. Hence, this study has chosen case study approach among other qualitative methods such as action research, ethnographic research and grounded theory to further investigate this subject matter (Galliers, 1992) due to its flexibility and character of capturing the reality.

3.4. 1 Adopted Research Methodology - Case study Approach

Case studies are commonly used in studies where the research questions take the form of “how” and “why” and when there is no control on behavioural events or when the focus is on the contemporary issues (Yin, 2018). A case study can be defined as “an empirical inquiry that investigates a contemporary phenomenon with its real-life context when the boundaries between phenomenon and context may be clearly evident” (Yin, 2014, p. 16). Supporting this, Oates (2006) states that research that has closer connection with real-life context can be validated through empirical evidence through a case study approach. Therefore, this approach has been adopted for this study to explore the learning that takes place in BIM construction projects. A case study approach not only helps to understand the process but also the whole context. In this study, the researcher is interested to investigate workplace-based learning within a BIM environment, hence these key areas cannot be isolated.

Detailed qualitative methods within these case studies have not only helped to explore or describe the real-life situations, but to also explain the complexities of real-life situations, which is not possible in experimental and survey research. This study has used project documents, semi-structured interviews, and meeting observations within case studies to produce the evidence on how learning is taking place in BIM-enabled construction projects. Due to the involvement of extensive resources and replication process, results from multiple case studies are more compelling, robust, externally valid and powerful compared to the results produced by a single case design (Yin, 2018). Taking these points into consideration, this research has adopted a holistic multiple case study design for this study to address the research aim and objectives (See Figure 3.3). In this study, case studies are analysed in relation to the contextual conditions where workplace-based learning occurs. Case studies that are chosen from two BIM construction projects are considered as “different context”. Whereas each case studies which are considered as contexts is explaining the complex situations that takes place in chosen BIM construction projects. In this, chosen BIM projects are just wider context and the investigation is only taking place in the case study context. The purpose of chosing this holistic multiple case study is to analyse the learning that takes place in complex situations. Hence unit of analysis chosen here is "workplace-based learning". Although learning in each context happens differently, however by bringing them all together a commonality of workplace-based learning is identified. Contextual conditions in this study refers to a situation which involves specific professionals, communication methods to sort a particular problem raised in the project.

Yin (2018) states that the ability to conduct 6 to 10 case studies is sufficient to produce a reliable result; but workplace-based learning is connected with several aspects, hence a higher degree of certainty is essential. The researcher decided to stop with 20 case studies once the holistic picture of how learning is taking place in the workplace environment was understood. However, to complement phase one (literature review), which is more theoretical and phase two (semi-structure interview) which is highly practical, case study approach with 6 case studies from two BIM construction projects were chosen for this study (See Table 3.2). These chosen 6 scenarios have been defined as the case studies in this study whereas chosen two BIM projects have been considered just as a context. Moreover, number of case studies have been narrowed down to six among 20 in terms of the amount and clarity of data collected. In other words, the selection of 6 case studies were chosen interms of clarity,level of details, flexibility and level of access to the information.Among the chosen 6 case studies, 3 case studies were chosen from BIM project 1 and the remaining 3 were chosen from BIM project 2. Choosing the same amount of case studies helps to understand the learning that take place in both the BIM-enabled projects without any influences. Therefore, this will mainly avoid biased data. Although, case studies from both the BIM-enabled projects were chosen equally, the researcher had an opportunity to access the BIM project 2 from its initial stages whereas BIM project 1 was only accessed near to its completion stage. Although, this had no impact on the findings it allowed the researcher to understand the learning in project 2 in more detail. In this study, each individual case study reports how learning is taking place in the BIM construction project and the way in which learning aspects are connected with the BIM environment.

Case study approach includes three different stages to understand the learning that takes place in chosen complex situation (case studies). Intially, project meeting for each case studies were observered to understand how people are learning in complex situation (meeting obsercation).After understanding how learning is taking place in these comeplex situations, semi-structured interviews were conducted within the case studies with professionals who were involved in the meeting observation. This is to extend the understanding of workplace learning through clarifying the infrmation which were hard to capture during the meeting. Moreover, the researcher was also able to understand how professionals perceive learning in workplace while doing their day to day activities in construction projects. Finally, project document analysis helped to understand how organised and systemenatically people are working and learning in BIM-enabled construction projects. The logic behind this process is shown in Figure 3.3.

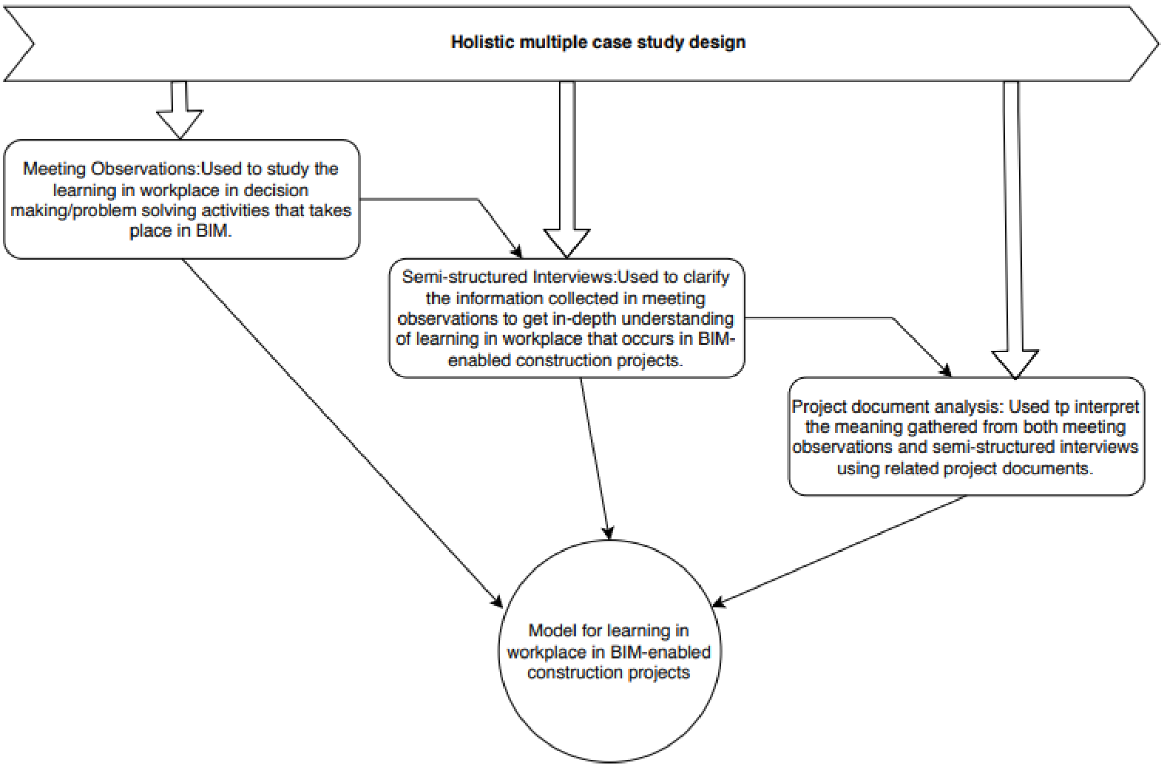

Figure 3.3: Holistic Multiple Case design for the study

Although, case studies present the data of a real-life situation and provide better insights of the subject of interest, the method has also received criticisms. According to Yin (2018), case studies are accused of lack of rigour. Moreover, he mentioned that case studies sometimes lead to equivocal evidence and biased views influence the direction of the findings. A common criticism of case study approach is reaching a generalised conclusion based on the findings of a single case (Tellis, 1997). Suporting this, Yin (2018) considered the case study methodology to be microscopic due to the limited sampling methods and focused more on parameter establishment and objective setting. The other disadvantage is that it is often critiqued as being too long, too difficult to conduct, and producing huge amount of documentation (Yin, 2018). Case studies of an ethnographic or a longitudinal nature can elicit a huge amount of data. However, this researcher has overcome these challenges of the case study approach through systematically organising the data collection process: chose the right case study, familiaries with the observation environment and people beforehand, practice to identify the key information and make note quickly, read the notes thoroughly after the observation, make the key learning aspects from the observation and finally see the commanility across the case studies.

Selecting multiple case studies and selecting a non-probability sampleing method have also minimised the disadvantages of the case study approach. In this study, non-probilbilty sampling involves with a collection of feedbacks without having any fixed selection process. To be more specific, this study has adopted purposive sampling where researcher has purely considered the purpose of the study and targeted specific audience such as BIM professionals. Although, a case study approach has its own challenges, in this study it has provides a much broader view on how learning is taking place in BIM construction projects and how learning aspects influence the real-life context. In addition, it offered an in-depth and comprehensive approach to understand the contemporary phenomena which is difficult to achieve through statistical representation.

3.5 Research Design

Research design is a conceptual blueprint that contains an action plan with the outline of data collection, measurement, and analysis to achieve the research aim (Akhtar, 2016). The purpose of this research design is to identify the appropriate empirical evidence for the study and to build a model to understand and explain workplace-based learning in the BIM context. The selection of the research design is influenced by a number of considerations such as research question(s), objectives, philosophical approach, established knowledge and accessibility of resources and materials (Saunders *et al.*, 2012). A three-phase research design is employed in this research to collect the relevant data to achieve the outcomes (Figure 3.4).

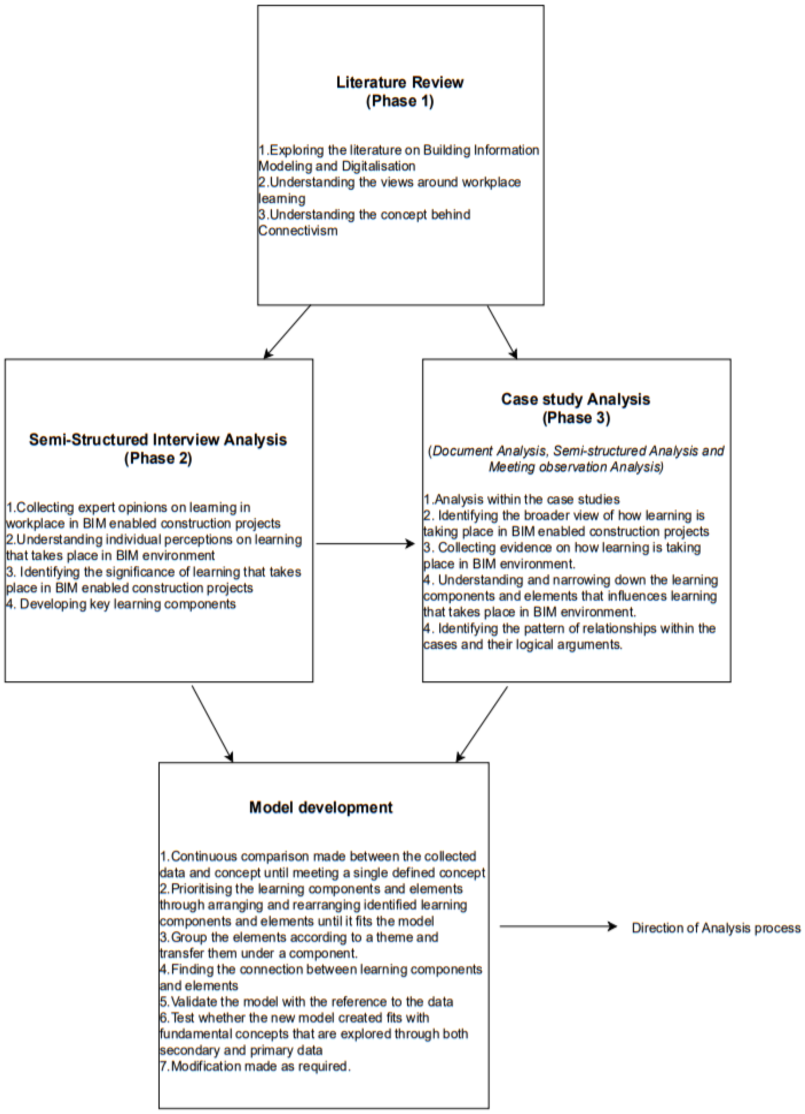

Figure 3.4: Analytical process for developing a model for workplace-based learning

3.5.1 Phase 1: Theoretical study (Literature Review)

The first phase of the research design explores the background knowledge on how BIM is implemented in practice and identifies the themes related to learning that takes place in the work environment. In addition to this, the Connectivism approach is also discussed in this section.

A literature review is a study on the selection of available documents, which contain information, ideas, data and evidence from specific standpoints to obtain predefined aims and objectives (Hart, 1998) to provide a description and critical analysis of the current state of knowledge in the subject area (Jankowicz, 2002; Saunders *et al*., 2012). Moreover, it provides justification of new research through coherent critics of what has done before and why new research is important (Gill and Johnson, 2002) and it is usually classed as "desktop research" which is a continuous process until the research is completed. According to Moore (2000), the research process is concerned with gathering data and processing it into information. Therefore, this study has commenced with the literature review to provide preliminary insights into a subject area, including identifying the gaps. Blaxter *et al*., (2001) believe that this will certainly identify the suitable area(s) where further research can be carried out (Blaxter *et al*, 2001) and bring clarity to the chosen methodology.

The literature review in this study has been carried out in two stages. Firstly, existing literature was analysed to form a background body of knowledge of the subject, especially to understand the learning that is a currently major barrier leading to the slow BIM implementation in the construction industry. This led to the formation of the research aim and objectives. After this a second detailed literature review was completed on the subject matter to form the knowledge on BIM and learning that takes place within the digitally enabled environment. This information was then used to identify the learning aspects that impact on BIM construction projects. According to Michalski (1987, p188), inductive interference is referred to as ''a process of generating descriptions that imply original facts in the context of background knowledge''. Therefore, the inductive approach in this study was obtained through the literature review, which helped to explore the background knowledge and related concepts, especially on workplace-based learning.

After establishing the research gap and relevant knowledge through the literature review, the next step is to identify the appropriate methods to collect the data. Semi-structured interviews and the case study approach were adopted as the most appropriate methods for this research to understand the social phenomena.

3.5.2 Phase 2: Semi-Structured Interviews

The second phase of this research comprised semi-structured interviews with professionals working in BIM construction projects in UK. This is a sequential process that takes after literature review and before conducting the case studies. Results achieved in this phase have confirmed that skills shortages in the BIM-enabled construction projects is still a significant problem and there is an urge for learning in workplace to tackle the technological changes. This then helped the reasearcher to investigate workplace-based learning more in detail through case study approach in phase 3.

According to Silverman (2006), the semi-structured interview technique explores individual perception of the subject matter. Therefore, this method is adopted to collect interviewees' opinions about the learning adopted to complete activities in BIM construction projects. In addition, this method is chosen to understand the in-depth experiences from professionals engaged with BIM construction projects. Accordingly, in this research these semi-structured interviews helped the researcher to understand the importance of learning in a BIM environment. Open-ended questions were employed to get the wider view of the situation (Kvale and Brinkmann, 2009). Two pilot interviews were conducted with construction professionals working with BIM to refine the questions. The interviews were recorded, then transcribed and coded using Nvivo, which was used to organise and interrogate the data. In addition, it has helped the data to link internally and externally to explore key themes in workplace-based learning. In this phase, a deductive approach was adopted to obtain more current information on learning in BIM construction projects which is still in its evolving stage.

3.5.2.1 Purpose of chosing Semi-structured interview

Kumar (2005) mentioned that interviews are conducted to collect in-depth information covering a wider area than is practicable with a questionnaire. To support this, Chadwick *et al.* (1984) have considered interviews as a conversation between two people, which is then manipulated by the researcher to obtain information to achieve specific research objectives. Moreover, semi-structured interviews help to understand an interviewee's experiences, knowledge, idea, and impressions (Alvesson, 2003) and provide an opportunity to uncover new clues and open new dimensions of a problem (Yin, 2018). Moore (2000) and Coombes (2001) suggested that semi-structured interviews allow much more scope for the discussion and recording of respondents' opinions and views. Understanding the importance and suitability of semi-structured interview has led the researcher to choose this method as an initial step to collect the primary data. The purpose of conducting the semi-structured interviews is to capture the view of professionals using BIM in construction projects. Questions sought to understand the process of learning in BIM construction environment and learning aspects related to the BIM environment. The list of semi-structured questions is attached in Appendix A

As Moore (2000) and Singleton et al (1993) mentioned, semi-structured interviews not only yield data quickly and in a greater quality but also provide an opportunity to refine or restate the questions when respondents are not clear what the researcher is asking. They also provided an opportunity for a face-to face meeting with respondents, obtaining a huge amount of data, and facilitating cooperation and collaboration (Greenfield, 1996). However, this was also time consuming, expensive and provided information that is difficult to analyse. In addition, it was subjective compared to questionnaires (Kumar, 2005; Moore, 2000). Some of the interviews led to misinterpretation due to cultural differences and some of the information gathered was difficult to relate to the topic due to lack of clarity. At the same time, accuracy of the information depends on the respondent's honesty and researcher's resourcefulness (Greenfield, 1996, Patton, 2005). However, the problems were overcome through setting up short and pre-determined open-ended questions (Robson, 2011) which were written in simple language. This allowed the interviewees to express their thoughts in a wider view and led the researcher to be flexible in exploring emerging issue in 'workplace-based learning'.

3.5.2.2 Selection of participants and semi-structured interview design

The participants for the semi-structured interviews were chosen to understand the significance of skills and learning to obtain the in-depth experience of professionals engaged in BIM construction projects. The researcher identified 30 BIM professionals working in the UK construction industry in various roles using LinkedIn and Birmingham City University contacts, whose location made face-to-face interviews practicable. However, only 20 agreed to participate due to their work schedule and commitments. Those interviewed included BIM co-ordinators, BIM managers, BIM consultants and BIM technicians (See Table 3.1). The initial criterion was to include only BIM professionals who had more than 1 year of experience because the researcher believed that at least a year's experience is vital to understand what is happening in BIM construction projects. However, all of the interviewees chosen had more than 2 years' experience in BIM construction projects. Experienced professionals were purposefully chosen to get their in-depth understanding of their BIM experience and the skills and learning they develop to work in BIM construction projects. Researcher, believed that experienced BIM professionals should have understood the learning that takes place in the workplace in more depth including knowing about different learning opportunities and learning challenges. The other criterion was the rile they played in the BIM projects as shown in Table 3.1. The professionals interviewed were from both public and private sectors and were chosen by considering their experience and involvement with activities using BIM in their construction projects.

The semi-structured interviews that took place in phase 2 were between 40-50 minutes, within the average interview lasting for 45 minutes. The interview questions were divided into three sections to address the skills deficiencies and the need for a new way of learning in BIM construction projects. The questions in part one was related to the interviewees' role and experience in handling and using BIM in their construction projects. Through the literature review several benefits of BIM were explored and this helped the researcher to understand how well construction professionals are utilising it in their construction projects. After establishing the interviewees' BIM knowledge, they were asked to relate their views and concerns about the acquisition of skills during the implementation and delivery of BIM in construction projects. The questions in part two were developed to address the significance of the skills deficiencies and learning in BIM construction projects highlighted in several construction reports. Finally, in part three they were also asked to share their views on their BIM learning experience in construction projects. This was to emphasise the importance of workplace-based learning to acquire knowledge and the need of new learning approach to make connections during the transition to digital construction.

During the interview process the researcher chose to explore the emerging issue through both closed and open ended questions. The open-ended questions in these semi-structured interviews allowed the interviewees to express their views openly which provided an in-depth information. Moreover, collected information along with the two-way communication has helped the researcher to conclude that workplace-based learning needs more focus. Initially, interviewees were provided with a brief about the purpose of the study and the time allocation for the interview. During this process the interviewer had some prepared questions and interviewees were free to mention their opinions in more depth when essential. The interviews were conducted in meeting rooms and the interviewer's office in a quiet, comfortable, and interruption free settings. All the interviews were transcribed precisely for the analysis. All the interviews were audio recorded to increase accuracy without disturbing the interviewee's concentration on the questions. The interviewer ensured that interviewees were comfortable and happy to audio record their conversation for ethical purposes. In addition, strategic and focused notes were also taken by the interviewer to stimulate early insight for subsequent interviews before transcribing, to facilitate detailed analysis and as a backup for audio recordings. Strategic notes taking in this case study observation involves listening, writing and understanding the information.It is believed this skills of strategic and focused notes taking skills should help tp understand the workplace-based learning in-depth.All the listed questions were asked on the interview day to get the accurate information from the interviewees. All the interview questions were kept short to make it easy for the interviewee to respond. The number of semi-structured interviews depends on the methodological aspects of the research and purpose of study, considering the issue of saturation point which is central to qualitative sampling (Baker, 2012). This research has adopted 'non-probability' sampling, which is suitable for qualitative data collection especially to gain a deeper understanding of social phenomena. The interviewees chosen for this study hold different backgrounds, positions and years of experiences in the project. Initially, 30 participants were selected however, 7 participants dropped out due to their work commitments and the time limitations. Although, there were 23 participants after 20 semi-structured interviews saturated point was reached and interviewee's responses merely started to replicate previous interview results. Following this step, the empirical data was collected through the case studies which adopted Level 2 BIM to complete their construction process.Although, Level 2 BIM has now superseded by UK BIM Framework /ISO 19650 during my research both the chosen projects have used to achieve BIM Level 2.

Names	Job Role	Experience
I1	BIM Coordinator	Creating and maintaining BIM Models for quantification, project planning, control and visualisation, assisting the creation and production of highly coordinated BIM 3D,4D &5D Models, with the ability to extract quantity take off, clashes, discrepancies and delivering B.O.Q's according to the latest international QS standards and assisting in preparation of documentation necessary for the distribution on RFIs (Request for Information).
I2	BIM Consultant	Expertise in BIM Software-Revit, Naviswork manage MS Office and Architectural Design and drawing software-AutoCAD, 3DX max, Sketch-up anD Photoshop.
I3	BIM Manager	Mainly involved in changing the leadership, interface management, innovation, systems and process engineering, business architecture, programme management, project management, estimating, communication and strategic orientation.
I4	BIM Coordinator	Mainly supporting BIM usage for coordinating the construction process, improving both the standard and flow information from when specifying a manufacturer product. Also, helps to manage the assets and resources and materials on-site and off-site.
I5	BIM Manager	Involved in project management, organising the training programmes and advising employee on using appropriate BIM software.
I6	BIM Manager	Mainly guides the employees on creating 3D models, utilising the software and updating on the BIM standards.
I7	BIM Technician	Specialised in teaching BIM applications for Architecture Technology and Construction Management.
I8	BIM Coordinator	Involved in creating 3D models, training other co-workers and advising on using correct BIM software and standards using his experience.
I9	BIM Technician	Creating BIM models using BIM, Sketch-ups and maintaining the BIM process through involving in clash detections
I10	BIM Coordinator	Expert in creating models showing site logistics, existing buildings and proposed building to produce rendered stills, animations and 4D timelines, using Sketch-ups and Naviswork. Also, involved in the implementation of BIM processes in the construction sector with the use of clash detection and time lining within Naviswork through a series of BIM workshops.

I11	BIM Manager	Overseeing the development and implementation of product training programmes for the client and employees through a variety of techniques including CPD, face to face, hands-on and e-learning.
I12	BIM Manager	Mainly involved in managing the BIM 360 field implementation and responsible for the maintenance and staff training.
I13	BIM Manager	Helps to provide BIM project through technical advice and assistance to projects, providing training and guidance in CAD and BIM software, creation and development of templates and protocols, introduce all aspects of BIM to all affected areas (contracts, procurements, programme, data as well as quantities etc). Internal and external project liaison: guidance, interpretation, requirements etc.
I14	BIM Consultant	Mainly involved in developing project protocols, managing the use of the improved electronic database and the production of 3D models for various projects.
115	BIM Manager	Provides guidance and advice on projects in terms of using the tools and information in BIM. Also, involves in creating 3D and extraction of the information out of the model.
116	BIM Manager	Involved in generating 3D models and creating higher integrated project delivery due to broad range of digital, technical and productive skills considering industry perception.
I17	BIM Technician	Mainly involved in 3D models and coordinating the specifications and standards for the project.
I18	BIM Consultant	Responsible for management and delivery of business change and communication work stream for the implementation of Information Modelling & Management Capability Programme. Also, involved in development and management of people change plan and communication.
I19	BIM Manager	Mainly managing the BIM process, guiding and advising the employees on using BIM tools. Also, involved in organising BIM training programme for employees.
I20	BIM Coordinator	Involved in design, detailing, BIM modelling and project management.

Table 3.1: List of Interviewees

Note: I refer to Interviewee. Example *I1* refers to Interviewee 1 (Cross-reference to section 3.9)

3.5.3 Case study design

The third phase of this study is the selection of 6 case studies from 20 case studies that have implemented BIM in their project whole life cycle. These 20 case studies are day to day work situations extracted from chosen two BIM projects. This research was selected in the project level becaue workplace-base learning has rarely discussed in previous studies. At the same time, the views and intricacies of the learning that occurs in these BIM construction projects can be easily applied to wider context such as organisational level. The following sections explain the level of unit of analysis and description of the selected BIM-enabled construction projects.

3.5.3.1 Level of Unit of Analysis

The unit of analysis in research is the major entity that a researcher wants to explore in the study. It includes sources of data that support the level of analysis (Yin, 2018; Baxter and Jack, 2008) such as individuals, roles, social artefacts, process models or relationships (Martin and Davidz, 2007; Valerdi and Davidz, 2009). ‘Workplace-based learning’ is chosen as unit of analysis and is studied in all the unique contexts adopted from the case studies.

3.5.3.2 Selection of Case Study BIM construction projects

The selection of two Level 2 BIM projects are based on 1) the level of BIM implementation within their construction projects and 2) geographical location. The BIM projects chosen for this study targeted to achieve BIM Level 2 even though the requirements were not fully satisfied. These projects have classified as BIM Level 2 through considering the followings: adaptation of Employer’s Information Requirements (EIR), Common Data Environment (CDE), BIM Execution Plan (BEP), creating a federated model and collaborative working environment and using International Foundation Class (IFC) for information exchange.

Considering the limitation on access and resources, it was decided to choose the BIM construction projects from the West Midlands, United Kingdom. The selection of BIM projects within Midlands did not have any impacts on the findings however, the access of the project information was easy during the research. Moreover, the researcher ensured that the BIM construction projects chosen for this research were recent projects (defined as being completed within the past 5 years). The workplace-based learning in this digital world is evolving even though the fundamentals still remain the same. Therefore, recent projects are chosen to understand how workplace-base learning is perceived currently in BIM-enabled construction projects.

Altogether four BIM construction projects were approached for this study. One project declined the invitation due to confidentiality, and a second project refused to participate due to current workload issues. There was no particular reason to restrict the selection of the construction projects to the educational sector, however the researcher easily obtained access to two BIM projects through the contacts of BCU employees. These two BIM projects were interested in participating in this research and, as well as, looking forward to the end results.

To develop a detailed understanding of learning in BIM construction projects, in-depth studies of BIM implementation approaches were observed through investigating case studies from these two projects. This was mainly achieved through project meeting obseravtaion where the BIM professionals discussed about the issues that took place during that project stage. Following that, solutions were discussed with other project project participants involved with that situation. The researcher was able to observe and understand where the workplace-based learning happening in this situation and how it is taking place. To further understand the workplace learning in these selected case studies, semi-structured interviews within these case studies and project documents were used.

This is mainly to address the third objective which is to establish the learning required by the project participants to work with BIM construction projects. These case studies within these two BIM projects are used to compliment both the results from phase one and two. A detailed description of the chosen BIM construction projects follows.

BIM enabled construction project- 1

The first project, 'BIM project 1, selected for this study is a 100,000-square foot extension to a building completed in 2015. This is a £31 million project which engages over 3,000 students and members of staff and features more than 650 rooms, a student hub and lecture theatres, a new library, teaching and IT spaces (See Figure 3.5). The main purpose of the building is to increase the provision of teaching and social learning. This high-tech university project has used Level 2 BIM for its delivery and detailed planning. The project was completed in January 2018. The main contracting company is an expert in Level 2 BIM and used across the entire construction, residential and interior activities. Therefore, it made the effort to contact and invested to create a network with BIM experts in each office. This is to provide the other co-workers with advice and guide the client to embrace the visualisation technology at the early stages of the project cycle. In this project, the client had access to a dedicated BIM Manager for a 'soft take-off' in the situation where those who are not familiar with the technologies used, which reduces risks, as well as, encouraging the multi-disciplinary collaboration during construction.

In this project the intention of implementing Level 2 BIM has allowed the design and construction team members to communicate with their co-workers and coordinate the information across different level of the project. In addition, it has also benefited in cost management, construction management, project management and facility operation. The project team that promoted Level 2 BIM has quickly coordinated design, predicted the planning beforehand, reduced CAPEX (Capital Expenditure), delivery and operational cost, reduced risk and errors in design and work on site, improved logistics through 4D time simulation, quick valuation of design changes theory 5D cost, quantity take off from the 3D model, generated more efficient site team through task management tools linked to the model and reduced site waste. From the project documentation it is clear that project participants were encouraged to develop their BIM knowledge and skills in many ways such as through training, short courses, meeting expertise, and accessing BIM related documents to successfully deliver this project.

Figure 3.5: Learning space generated through BIM models-BIM-enabled projet-1

BIM enabled construction project - 2

BIM project 2 is a £57 million project of 9,000 square metres designed for media and art students for teaching, rehearsal and state of the art performance space (See Figure 3.6). This building includes facilities such as a jazz club, 450 seat conference hall, intimate 150 seat recital hall, 100 seat practice and rehearsal hall, organ studio and complete AV digital interconnection. Five performance venues were constructed with a box-in-box method due to the high acoustic requirements. This is basically constructing a box that is sitting on a rubber acoustic pad and then constructing another box surrounding it both to contain the noise coming out and ensure that external noise does not break in and disturb the performance. This project has adopted Level 2 BIM and was completed in September 2017. In this project, value engineering with Mechanical and Electrical work (MandE) work was undertaken such as changes to plant and lighting settings.

Each room and floor in this project were designed in a unique way to ensure they all have different features. Therefore, much effort was involved in designing, planning, thinking and organising the work sequences. The main highlight of the project is teamwork maintained through the entire project. Project participants had a large office where the entire team were including client and sub-contractors at based. Closed communication within this environment made sure that entire team had the same understandings of the goals that they are trying to achieve. This project has used Level 2 BIM from the beginning of the project for coordination, collaboration, clash detection, and clear scheduling.

Figure 3.6: Spaces generated in BIM-enabled project 2

Both projects have been chosen for the study because of their focus on developing BIM knowledge and skills to efficiently achieve the goals, which has explicitly expressed the shift in learning in the new digital age. The clients in these construction projects were driving to introduce BIM to their project team members. There was also a clear intention to develop BIM capabilities from the contractor's side of the project team. Gatekeepers of these projects were flexible in terms of the accessibility of these projects. Overall, these projects had enthusiastic professionals who were willing to learn new digital technologies to make changes in the construction projects. These collaborative multi-disciplinary environments in both BIM construction projects were examined to see how learning is taking place in BIM-enabled construction projects.

3.6 Data collection technique for Case study approach

A key consideration in data collection depends on the nature of the request and context or settings in which it has been used (Naoum, 2013). Nevertheless, different techniques can be used according to inquiries involved in the research. However, data collection can use many techniques depending on the researcher's and participant's level of involvement.

The trangulations for a qualitatitive can be achieved through diferent methods: method triangulation, investigator triangulation, theory triangulation and data source triangulation (Patton, 2002)..Data source triangulation which used variety of sources to study the situation or phenomena is used in this research.This study has used multiple sources of evidence such as semi-structured interviews, meeting observations, project documents to establish the construct validity and reliability of the evidence and increase the quality. The researcher has carried out meeting observation however, not solely relied on the evidence. Instead, the results were also based on semi-structured interview and project documents such as project brief, project programme schedule, EIR, BEP, BIM standards (BS1192, BIM Protocol). The researcher commenced collecting empirical evidence through gathering the experiences of BIM professionals. According to Saunders *et al.* (2012), interviews, questionnaire, and observations are approaches used to generate data from people. In this study, taking the critical realism position suggests that the logical way to generate data is by interacting with experienced people in BIM project events, including analysing the project documents and meeting observations. Therefore, this research seeks to generate data from the project participants' experience from their past and current experiences, and existing available data. Consequently, the researcher has adopted three data collection techniques: meeting observations, semi-structured interviews, and document analysis. Semi-structured interviews in this study are conducted in two phases: in phase 2 and phase 3 (within the case study approach). Initially, after gaining the basic knowledge of BIM implementation in construction projects and workplace-based learning, semi-structured interviews were conducted with BIM professionals to explore and understand the significance of skills deficiencies and learning in BIM-enabled construction projects. Secondly, to complement both literature and semi-structured interview data, 6 case studies from two BIM construction projects were adopted to understand how learning is taking place in the workplace and to identify the connection between learning aspects within the workplace-based learning. This is to provide stronger substantiation of the phenomenon under investigation. The project meeting observations were carried out for each case study. Each meeting was observed roughly for an hour. During this, project participants mainly discussed about the issues they have faced during the project stage. Following that, critical discussion took place among the involved project participants in terms of resolving the situation. During this, the workplace-based learning took place by project participants teaching their colleagues using their expert knowledge. Moreover, learning opportunities such as training was also discussed in few meetings. The researcher collected all these information through taking notes because recording was not allowed due to maintaining the confidentiality.

This multiple sourcing of evidence in this study addresses a broader range of learning aspects that influences the workplace environment. Moreover, based on the intersection of different reference points through these multiple sources, the researcher was able to establish accurate and reliable findings. Developing convergent evidence, data triangulation in this study helped to strengthen the construct validity of the chosen case studies. However, this multiple sourcing of evidence imposes a greater burden on the researcher especially in designing and planning data collection methods. In addition, it is also time consuming. To overcome this, the researcher began designing and planning the interview questions, while collecting the literature. This has saved both time and effort.

3.6.1 Data Collection within Case study approach: Meeting observation, semi-structured interviews and project documents

Yin (2018) believes that the selection of data collection techniques will depend on the investigator's level of assessment of the prospective quantities where some of the evidence such as acquisition records could be confidential and willingness to share the information, which is beyond the researcher's control. Semi-structured interviews, meeting observations, and project document analysis within case studies were the main data collection method in this phase of the research. The importance of these data collection methods are discussed in the following section. The selected 6 case studies are listed in the table below:

Case study	**Event**
Case study 1	Mechanical and Electrical Installation issues
Case study 2	Vent above the door
Case study 3	Use of laser scanning
Case study 4	Pipe work installed in site
Case study 5	Light fittings for halo effect
Case study 6	iCloud scan training

Table 3.2: Selected case studys for data analysis

3.6.1.1 Meeting observation

Bryman and Bell (2011, p, 281) note that the aim of the observing meetings is

"to record in as much detail as possible the behaviour of participants with the aim of developing a narrative account of that behaviour."

Therefore, this method is adopted to have a unique access to events or behaviours in the workplace to capture that participant's learning. The observations chosen take place within the natural context of the occurrence; however, the researcher has not participated in any interaction during the observation. Therefore, the collected data is purely natural without any direct influence of the researcher. The purpose of these observations is to capture the data which are not recorded in semi-structured interviews. The meetings observed for this study were held in project participants' work sites. During these meetings, BIM-related problems were discussed among the professionals who are directly or indirectly associate with BIM for that specific project. Regular observations on BIM activities that took place in the selected BIM projects have provided an understanding of how learning is currently taking place in workplace in BIM construction projects.

Altogether, 20 project meetings were observed until the saturated of observationswas reached. After, observing 20 case studies the researcher has started to get similar results in terms of how the project participants are tackling the project issues and how project participants were learning in workplace environment in BIM-enabled projects. Thereore, the observations were stopped after observing 20 case studies. One single meeting is conducted for each case however, only 6 of them were used for the data analysis. The selection of 6 case studies was based on the amount and clarity of data collected, access to the project documents, and professionals involved in the meetings. Each meeting observation approximately lasted for an hour. Audio recording for these meetings was not permitted due to confidentiality, therefore, the meeting notes were handwritten. During these meeting the issues faced in the BIM construction projects, the way professionals deal with these issues, how the learning happens in that situation and the opportunities provided for workplace-based learning were observed in detail.The understanding gained through literature review and phase 2 semi-structured interviews have provided sufficient knowledge to the researcher on what to collect. Some of the key learning aspects have been already extracted from both literature review and phase 2 semi-structured interviews.This gave confidence to the researcher where to focus in the project meeting in terms of collecting the data.Meeting observations during this research have allowed the researcher to reflect on the theoretical interest and identified different learning aspects that influence workplace-based learning in BIM-enabled construction projects. To maintain the accuracy the collected data were further clarified through project dcuments analysis and 4 semi-structured interviews in total for all 6 case studies with the professionals involved in the project meetings. These semi-structured interviews were a second set of interview which were conducted within the case studies.

3.6.1.2 Semi-structured interviews within case studies

The case study approach used contains a further four semi-structured interviews with the professionals involved in the case studies. These 4 semi-structured interviews in total for 8 case studies is robust enough because the information has been already gathered from project meetings. At the same time, the reasearher also have some prior understanding about the workplace-based learning from literature review and phase 2 semi-structured interviews. Therefore, arranging semi-structured interviews with available professionals who participated in the meetings helped the researcher to clarify the information that were hard to capture in the project meetings. As mentioned previously, in the meeting observations the researcher had no opportunity to communicate with any of the professionals involved or contribute to the meeting discussions. Although, the researcher is focused on what information to collect, there were several discussions took place in that short period of time. These interviews lasted between 50-60 minutes. During the interviews different ways of learning that are implemented in the project and the learning opportunities provided for the project participants were discussed in more detail. The interviews were conducted in the site offices of the projects. These discussions with BIM professionals helped the researcher to gain wider knowledge on how learning is taking place in BIM- enabled construction projects.

3.6.1.3 Project documentation

Reed-Scott (1999) highlighted that the integrity of documents or ‘‘text’’ should not be taken for granted and this is mainly because the textual approach is based on the assumptions that the creator has embedded on them (Knorr-Cetina, 1981). The other assumption is that meaning is “inter-textual’’ (Culler, 1976), which means that a given text is constructed from, and acquired meaning through, its embeddedness in a multiplicity of discourses. Furthermore, the intrinsic properties of embedded interpretations of the authors of texts are used to provide substantiation and clarification of data obtained through semi-structured interviews and observations. According to Gephart (1993), sources of documentary data such as text allow the researcher to interpret the meanings of events and generate understanding of both document and events as contextually mediated. Taking these points into consideration, project documents are chosen to provide an opportunity to expand the empirical depth and robustness of the research. The analysis of documents in this research involves the examination of soft and hard copies of project details such as BIM implementation strategy, project descriptions, mission statement, project file, and company brochures. Furthermore, Employee’s Information requirement (EIR), BIM execution plan, BS1192 and BIM Protocol were also incorporated during document analysis. EIR in these BIM projects were used to establish the information related to the management requirements to achieve the project scope. On the other hand, PAS1192 provides information that were essential for delivery phase.

Overall, the analysis of these documents has supported the researcher to interpret the data collected from meeting observations, project documents, and semi-structured interviews (Table 3.3). Furthermore, it is used to understand how BIM technology has been implemented in the construction projects and how project participants have designed, specified, and planned to achieve the project outcomes. Although other documents such as meeting minutes, BIM protocols and contracts were available, issues of confidentiality made their use less appropriate. However, the key findings from the document analysis were integrated with the observations and interview data.

Source of Evidence	Examples	Strengths	Weaknesses
Project Documentation	Project Brief, Project Programme schedule, Employer's Information requirement, BIM Execution Plan, BIM standards (BS1192,BIM Protocol)	Can be referred more than once, Concrete information, Broad coverage	Biased in terms of author's perspective, favourable to the project team, access blocked for some documents
Semi-structured interview	Closed ended questions, Open ended questions	Insightful and able to interfere, targeted interviewees	Biased due to misunderstanding of questions, incomplete answers, favourable answers to the interviewer
Meeting observation	Field notes, Access to BIM models	Covers real life events, Contextual, Got to know current issues	Time consuming, Meetings were selectively attended, influence of observer's perspective

Table 3.3: Evaluation of case study evidence

3.7 Data Analysis techniques

Data analysis techniques involve examination, categorisation, tabulation, or combining the evidence to address the research problem of the study (Yin, 2018). This study is predominantly qualitative in nature. Therefore, the researcher has relied on participants' experience and literature to analyse the evidence in various ways to come to a conclusion. This is possible in qualitative data analysis because statistical representations are not used in these methods. Consequently, there is a challenge in qualitative research to make sense of a huge amount of data, reducing the volume of information, identifying the important patterns, and construct a framework for communicating to essence of what the data revealed (Patton, 2005). According to De Vos (1998), data analysis begins when data collection is started in the research: however, the process makes sense when the research starts to make sense (Morse and Field, 1996). Furthermore, a stage of compression is achieved when the researcher has sufficient data to write coherent and rich description.

The study has adopted a coding technique identified from the literature which is commonly used to analyse qualitative data (Robson, 2011). Number of data analysis techniques such as thematic analysis, content analysis and IP but the intention of this research is to identify the key learning aspects and finding the relatuinshiop between them. Hence, coding procedure id adopted for this study. Strauss and Corbin (1998) state that the coding procedure includes conceptualising data, elaborating it in terms of its different properties, and relating the concepts that emerges to build theory. However, in this study, these steps are followed to build a model for workplace-based learning in BIM-enabled construction projects.

3.7.1 Coding process

Data analysis in this research uses verbatim data which was audio recorded from the semi-structured interviews, field notes collected from the case study observations, and project documents. These were first transcribed by the researcher into text before starting the analysis. Observation data which was already maintained in the form of text were elaborated using the researcher's background knowledge gained from the existing literature. Then this was processed using Nvivo 11, a qualitative data analysis software tool. The coding process involves child node (sub-themes) and Parent node (Main theme emerges from the sub-themes) (See Figure 3.7). Transcribed texts were thoroughly read and then identified learning factors were categorised into groups under a child code according to the pattern observed. Following that, related child codes were grouped together under the parent node and this process concluded the micro analysis process. Information from parent nodes was completed from the set of data coded under each code (child node), and finally all these codes are merged together to achieve key learning aspects in the BIM working environment. This type of extraction is referred to as 'induction' (Alvesson and Skoldberg, 2009; Flick, 2009).

Coding is done through a step-by-step process (Figure 3.7). The following steps are explained below in detail:

Step 1: Firstly, 'open coding' is proceeded to identify the relevant aspects related to learning. This is then categorised as sub-categorises (child nodes) according to their themes (Neuman, 2005; Strauss and Corbin, 1998).

Step2: The next step is 'axial coding' which connected the categories to sub-categories based on discovered properties and concepts (Strauss and Corbin, 1998). According to Hunter and Kelly (2008) and Coffey and Atkinson (1996), this stage is vital to start reassembling data fractured during open coding to generate more accurate and complete explanation about phenomena. In addition, both open and axial coding involved with line-by-line examination of data before moving to further analysis (Strauss andCorbin, 1998). This procedure is also called 'Micro analysis' (Strauss and Corbin, 1998). During this stage, all the sub-categories are grouped into main categories (parent node).

Step 3: After obtaining a conclusion from the micro analysis the data analysis moves to the next step, which is selective coding. This has integrated all the categories developed in the micro analysis process to form a theory (Silvester, 2004; Strauss and Corbin, 1998). In this study, this step has helped t develop a workplace-based learning model. The reliability of this coding process depends on the 'ingenuity and insight' along the process of selecting concepts and category tests (Guetzkow, 1950). Figure 3.8 depicts the coding process used for this research.

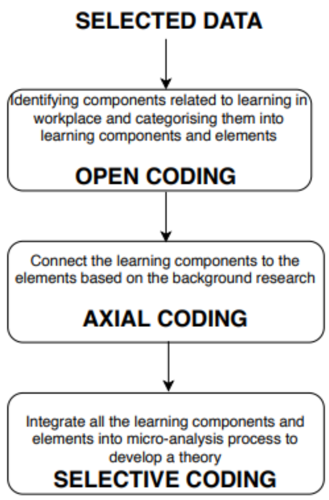

Figure 3.7: The Coding Process

3.7.1.1 Coding of Interview data

The purpose of the interviews is to gain the understanding of BIM, skills, and learning in construction projects. Therefore, the open coding in this involved mainly reading through the transcripts to find the main categories related to learning in BIM construction projects. In other words, factors that helped people to learn in the workplace environment were categoried as a learning aspects. These identified factors should be either a fundamental need to learn in workplace, factor encourages learning or any outcome of learning. Following that, axial coding helped to sort out the key learning aspects that influence the BIM environment in construction projects. After micro analysis of the interview data, the effectiveness of each aspect was analysed by the researcher.

3.7.1.2 Coding for meeting observation data

The analysis of meeting observation data yield information on 'workplace-based learning' in BIM construction projects. Since the meeting observations were conducted to investigate how learning is taking place in the BIM construction projects, the field notes have identified the learning aspects that are involved in BIM activities. These learning aspects are captured through analysing the influences of those aspects in the learning process that takes place in workplace environment. During the open and axial coding stages the identified aspects are sorted into various categories according to their themes.The sub-categories and categories were formed in open and axial coding through finding the commanalities and the inputs those learning aspects have in the learning process. The researcher also paid attention to the barriers and issues related to learning in the BIM construction project environment. This is to ascertain whether they have any impact on the learning that takes place in BIM construction projects. Initially, open coding from both the semi-structured interviews and meeting observations has produced a number of learning aspects in the workplace environment. Axial coding has reduced the coding and identified a number of categories and sub-categories and placed them under the main entities (See Figure 3.8). Finally, through this micro analysis, the selection of coding was further reduced and the main aspects were then put under the relevant learning aspects after relating back to the theory. Finally, the conclusions were derived from the project map generated in Nvivo 11. The project map was achieved through grouping the sub-categories into main categories through identifying the common characters of the learning aspects and the influences it has on the learning process. This helped to identify the sub-categories and categories and to map the connections between key learning aspects in BIM construction projects.

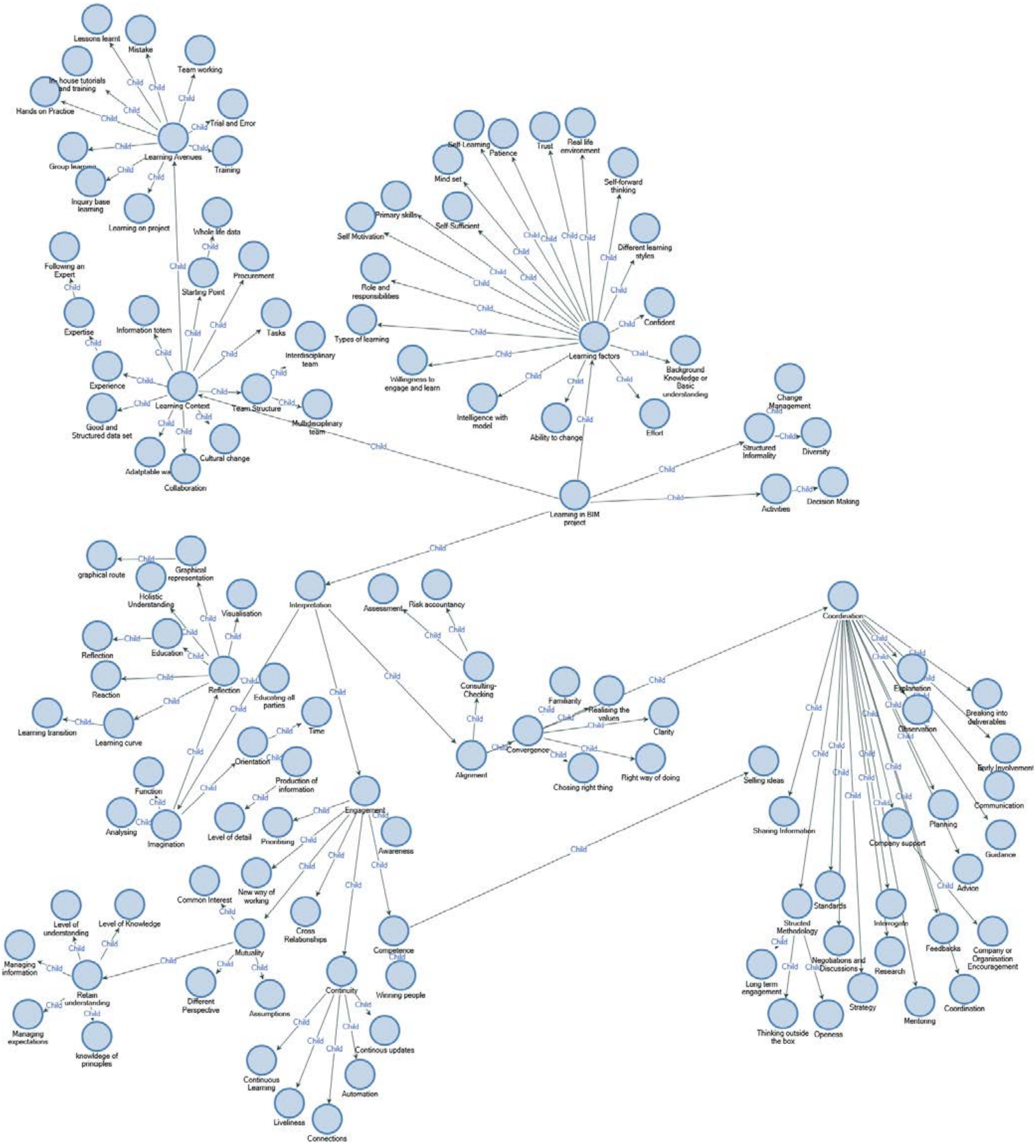

Figure 3.8: Learning aspects after Axial Coding

3.8 Validity and Reliability

Morse *et al* (2002) mentioned that any elimination of validity and reliability in qualitative study will make the research worthless through losing its rigour and utility description. According to Saunders *et al.* (2012), validity is the degree of accuracy of research results whereas reliability refers to the accessibility of the results. Gibbs (2007) states that validity in qualitative research refers to the verification process of the findings employed by the researcher and it can be divided into two categories: internal and external validity (Yin, 2018).

Validity in research was tested in four different types: construct validity, internal validity, external validity, and reliability. In this research, construct validity is maintained through identifying multiple sources of evidence such as existing literature, project documents, semi-structured interviews, and meeting observations. The semi-structured questions were validated through two pilot interviews with BIM professionals. In this study, all the interviews and case studies were verbatim manually and were checked to ensure that transcripts do not contain any noticeable mistakes. The process of transcribing was also cross-checked by the supervisory team and BIM professionals involved in the case studies through face-to-face meetings and conversations via email. Internal validity during the data analysis was cross checked with existing learning models. Moreover, it was also confirmed that codes created for this study do not drift the workplace-based learning to a different definition, thus generating a different meaning. This was achieved through writing memos, while coding and continuously comparing with other related research. Memos includes explanations, insights and comments around the terminologies.

Subsequently, external validity for this research was established through generalising the results to a wider context. Even though this research focuses on BIM-enabled construction projects, its results can be generalised to any digitally enabled construction projects. In other words, these findings can be applied in any workplace environment during while using other technologies such as drones, 3D printing and Artificial intelligence. Finally, rather than choosing one single case, the research has involved 6 case studies to draw the conclusion for the identified knowledge gap. Therefore, this replication process in this research helped to confirm the reliability of the study. Moreover, this has also helped to diminish the biases and errors in the study.

3.9 Ethical considerations

Ethics in research is related to obligation, rights, duty, right and wrong, conscience, justice, choice, intention, and responsibility (Burns and Grove, 2008). According to Polit and Beck (2004), ethics obey professional, legal, and including social obligations to the research participants. Meesapawong (2013) has considered the ethical issues in three stages which are before the field work, during data collection process, and during data analysis process. Considering the large number of interactions with the construction projects, informed consent was sought and obtained from the companies and individuals involved in the research. Prior to data collection, the research proposal was scrutinised by the Faculty ethics committee. This approval allowed the researcher to collect data from BIM professionals in construction projects through semi-structured interviews and observations.

Patton (2005) has summarised a checklist for potential ethical issues: explaining the purpose, informed consent, confidentiality, and advice. This research involved participants for the purposes of data collection. The subjects were made aware of their rights of refusal and rights of privacy and anonymity before contributing to the research. This is done through sending an invitation letter including stating the purpose of the research to the potential participants via email. This letter clearly states that the participants have rights to choose not to participate or withdraw from the participation at any time, and their personal information and data given would be kept confidential and will be only used for Birmingham City University research purposes. Moreover, at this stage they were also made aware of the formal assurance over any concerns about the privacy of their identities and those of their projects or organisations. In terms of informed consent, an appropriate consent form was developed to rights and what to ask from the participant during the data collection procedure. During this first set of semi-structured interviews the confidentiality was maintained and the results was agreed to be shared with project staffs upon completion of the study.

Maximum effort was made to ensure that inquiries via interviews and observations were only used to obtain the information that was being sourced. Direct interactions between the researcher and the interviewees were encouraged rather than in an inferred manner to reduce the inaccuracy of data interpretation. The data collected from both the semi-structured interviews and observations were confidentially maintained through password protected computers, private, locked compartments and areas of interaction. The researcher also ensured that the BIM related case studies were picked for meeting observations. This is to avoid unnecessary involvement that can adversely affect on the outcome of the operation. The researcher did not contribute in the meetings and all the information collected from the meetings is independent from the researcher. Furthermore, data collected during this stage is a collection of how learning is happening in the workplace and interconnections between the learning aspects within the learning environment in BIM construction projects.

3.10 Summary

This chapter has discussed the methodology adopted for this research. This covers the philosophical position, research process, research approach, research methods, research design, and data collection and research analysis techniques. After gaining the background knowledge on BIM implementation in construction projects and workplace-based learning, the study has adopted a qualitative approach to collecting the primary data for the study. Primary data for this research is initially collected through semi-structure interviews. Following that two ongoing construction projects implementing BIM Level 2 were chosen for in-depth exploration. During this, 6 case studies were selected and data was collected through meeting observations, semi-structured interviews, and document analysis within the case studies. The main purpose of this is to thoroughly investigate how learning takes place in BIM construction projects. The next chapter focuses on findings that are derived from phase one, two and three.

CHAPTER 4: DATA ANALYSIS AND FINDINGS

4.0 Introduction

This chapter presents the findings derived from both phase two and phase three data analysis. Semi-structured interviews with BIM professionals were conducted in phase two of this study.

Consequently, phase three includes the data collected from 20 case studies chosen from 2 BIM-enabled construction projects. This data is gathered through meetings observations, semi-structured interviews within the BIM projects, and project documents. In these BIM projects, altogether 20 case studies were observed however, 6 of these case studies were presented in detail in this chapter to show how learning is currently taking place in BIM-enabled construction projects. The purpose of this discussion is to demonstrate an understanding of how people learn in the workplace, especially in BIM construction project environment. The combination of phase two and three have helped the researcher to identify the key learning aspects (themes) and elements (sub-themes) that impact on learning in the workplace.

This chapter discusses phase 2 semi-structured interview findings in section 4.1. Findings are discussed under How learning is perceived in BIM workplace (section 4.1.1), opportunities provided in BIM projects (section 4.1.2) and learning factors related to individuals/team (section 4.1.3). Next, section 4.2 includes phase 2 semi-structured interview data analysis. Follwing that case study data analysis and findings and summary were discussed through investigating each case study that contains a unique context which focus on how learning in the workplace is taking place in BIM-enabled construction projects (Section 4.3.1 to section 4.3.6. Lastly, section 4.4 summaries the chapter. The analysis and findings are triangulated in the chapte

4.1 Semi-Stuctured Interview findings (Phase 2)

After exploring the literature on BIM in construction projects and learning in the workplace in phase-1, semi-structured interviews were conducted in phase 2. These interview findings describe how learning is perceived in BIM-enabled construction projects, opportunities provided to learn in BIM-enabled construction projects, and identified the key drivers that influence learning in these projects (See Figure 4.1). These divisions were made after collecting the data and finding the commonalities between the information collected. The researcher has used his background knowledge from the literature and his personal experienceto categorise the data under the chosen headings. This is mainly viewed in three major areas: how learning is perceived in the workplace in BIM-enabled construction projects, what are the learning opportunities provided, and the learning factors related to individuals and teams in the workplace. Understanding the current status of learning in BIM-enabled construction projects has led the research to further investigate how learning is currently taking place in the workplace in the digital world.

BIM professionals' views, beliefs, understanding and experiences on learning in BIM-enabled projects allowed identifying the learning aspects (both learning aspects) that influence the learning that takes place in BIM practices. Although a number of learning aspects have been discussed by the interviewees, the interesting, insightful and most frequently discussed aspects are adopted in this research. The most significant and meaningful verbatim quotations, which supports the learning aspect in a clear manner are also adopted across the semi-structured interviews and case study approach to stergthen the arguments. The learning aspects are written in non-italic, whereas quotations are presented in italic format. The number presented next to each quotation represents the interviewee who has made that statement (eg: *I1* –Interviewee 1). Understanding the importance of learning in the workplace through BIM experts has led the research to identify more drivers influencing learning in the workplace. This is because interviews with BIM experts has taken the discussion into more depth where they shared information about how they learnt and learning BIM in workplaces, what opportunities are available in workplace, how learning is taking place and how learning helps to solve the issues in workplace environment.

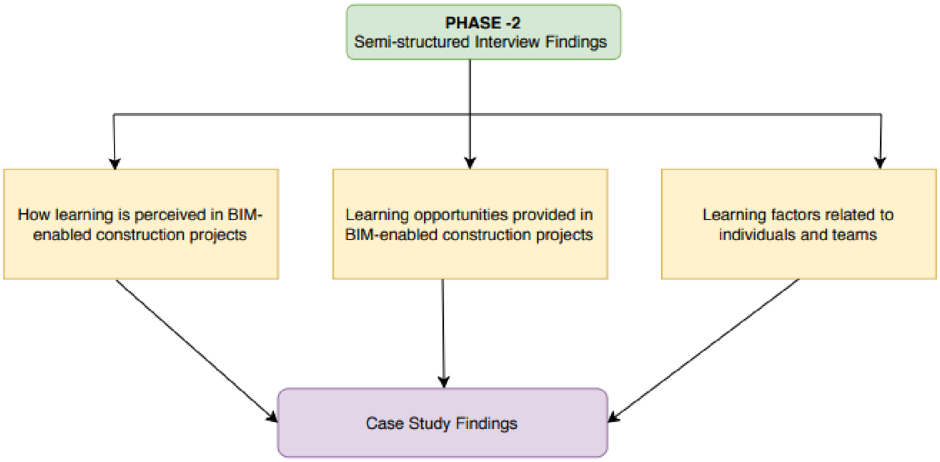

Figure 4.1: Three main areasin semi-structured interviews

4.1.1 How learning is perceived in the workplace in BIM-enabled construction projects

One of the key areas investigated in the semi-structured interviews was about the different ways of learning that is perceived in BIM-enabled construction projects. The main categories (themes) for this section have emerged through axial coding. During this process, the researcher connected all the child nodes (sub-themes/sub-categories identified through open coding) related to learning in workplace. Some of the child nodes developed in these sections were from open coding which were derived from the literature and some others were new which were developed based on other nodes. These child nodes (sub-themes/sub-categories) are grouped into 5 parent nodes (theme/main categories): Human response, Adopting technology, Interaction, Work culture and Evaluation. Human responses were originally derived from the phase 2 semi-structured interviews. This shows the characteristics of a person to perceive learning in workplace environment. This is supported by statedment provided by *I19*:

''I am not sure whether there are any skills necessary and I think it is an approach but there should be willingness to think outside the box and try new things. Also challenging the norm and challenging the usual deliverables and trying to find a linear way of going from conception to completion is vital''

Use of technology is part of skills however, the usage of technology in workplace allows project participants to perform their task in an efficient way. Hashim et al., (2013) from the literature mentioned that technology adaptation in construction projects not only enhance the quality but also provides satisfaction to the clients. This is again illustrated in verbatim quote stated by *I6:*

''It is very easy to just place objects in the line it exists. And it is also an understanding how to put the data into the object and to extracting it most efficiently and tagging out the drawings or scheduling and knowing how to structure on a model so that it helps other people to handle it better''

Interaction theme is purely emerged through the phase 2 semi-structured interviews. During the interviews participants mentioned seeing familiarised professionals frequently and having weekly updates including sharing their knowledge and experience help to learn quickly and efficiently in workplace environment. This is supported by *I13* stating:

''The people who I worked are the same people involved in the new project as well so I kind of started to develop the relationship between them. So, we know what we are trying to do''.

Cooke-Davies (1996) argues that work culture is one of the reasons for lack of learning in workplace environment. Furthermore, Harris (2002) believes that project participants are used to an existing routine pattern for working in a certain work culture hence, workplace learning to adopt new technologies is difficult. This is again supported by *I2* stating as below:

''Process implemented after detail design stage to deliver information to modelling teams were done through ACAD drawings, PDF's and excel sheets or 3D geometry and to convert it into a 3D Informative model to check and resolve the coordination errors'' (I2).

Finally, evaluation is a theme that has emerged from phase 2 semi-structured interviews. Evaluation in a workplace helps to check whether the given tasks have been achieved in the required standards. On the other, self-evaluation of a person in a workplace helps to identify whether the person is capable with required competencies to successfully complete the given task. This is again supported by the quote stated by *I8*:

''We have like a checklist so it will be like 20 in the list and colour then that one deliverable using BIM through Revit''

More verbatim quotations to support the identified themes are listed in Table 4.1

How learning is perceived in BIM construction projects	***Quotations***
Human response	*''I am not sure whether there are any skills necessary and I think it is an approach but there should be willingness to think outside the box and try new things. Also challenging the norm and challenging the usual deliverables and trying to find a linear way of going from conception to completion is vital''(I19)* *''Don't be afraid to ask, there is always organisation that spent the whole day in solving problems'' (I6).*
AdoptingTechnology	*''It is very easy to just place objects in the line it exists. And it is also an understanding how to put the data into the object and to extracting it most efficiently and tagging out the drawings or scheduling and knowing how to structure on a model so that it helps other people to handle it better'' (I6)* *''models are very important because it gives you a graphical route map to the information'' (I4).*
Interaction	*''The people who I worked are the same people involved in the new project as well so I kind of started to develop the relationship between them. So, we know what we are trying to do'' (I13).* *''We have BIM weekly catch-up meeting to share our knowledge and ideas with the other team members. Every week people who are specialised in certain areas share their knowledge with others'' (I12).*

Work culture	*''Process implemented after detail design stage to deliver information to modelling teams were done through ACAD drawings, PDF's and excel sheets or 3D geometry and to convert it into a 3D Informative model to check and resolve the coordination errors'' (I2).* *''From what I experience it is a new way of working together for instance with the structural engineers, engaging with them on a much easier platform and way to do it through integrated models to take it a step forward would be then to do the clash detection which is going to change the lot of the way that traditionally where we use to working and it is kind of pulling out all those design flows already at the earlier design stages which means that we are bound to speak to the civil engineers at that point'' . (I7)*
Evaluation	*''We have like a checklist so it will be like 20 in the list and colour then that one deliverables using BIM through Revit'' (I8)* *''So, we did an initial test assessment where we then ranked on our skills and that way the consultant that providing the training would find out who would go into certain groups and trained up in certain areas'' (I7).*

Table 4.1: Ways learning is perceived in BIM construction projects

4.1.2 Learning opportunities provided in BIM-enabled construction projects

In BIM projects, a number of learning opportunities were provided for the individuals and team to learn and achieve their tasks. Collected child nodes in this section are grouped into 4 parent node: learning avenues, human influences, learning environmentand communication.

Learning avenues is originally generated from the literature. Several scholars have mentioned that learning in workplace can happen through number of different ways. According to Eraut et al (2004b) learning in workplace can occur through books, protocols, documentation, intranet, training and apprenticeship programmes. This is also demonstrated in phase 2 semi-structured interviews. For example, *I7* stated:

''So I learnt mostly by myself and asking lot of questions from my colleagues in workplace''

Human influences is again promoted in literature and the study by Eraut et al., (2004b) noted that some people in the workplace are proactive to improve their knowledge with wider networks whereas some do not have much interest in it. They also highlighted that receiving short term and long term feedback is vital for the learning process where the learning process is mostly occupied with short term feedback, which provides confidence to workers. This is also supported in phase 2 semi-structued interviews. For example, *I14* stated:

''initial training sort of helped me to use Revit face and Revit modelling techniques and playing around with it is the one really helped me be after to embraces sort of really the effectiveness of it. So also using the other software such as Naviswork, 360 glues in the projects and playing around with the tools''.

Next theme is learning enviroment which has a great impact on perceiving learning in workplace. In literature this is been discussed by several authors. For example, Kakavelakis and Edwards (2011) learning in organisation or project is related to specific learning environment. Supporting this interview participants strongly believed that group learning has a huge benefit in learning in workplace environment. *I11* in semi-structured interviews stated:

''we are now sitting round the table and talking with people we have never expected to talk with before''.

Learning without communication is impossible. Styhre et al (2006) from literature mentioned that meaning is formed in different ways: written communication (eg: documents and protocols) and verbal communication. However, they highlighted verbal communication is more common between co-workers during learning in a workplace. At the same time, this theme is highlighted in semi-structured interview where *I3* stated:

''Chatting with that person about what software they use and getting support from them in telephone or Skype to get over the challenges'' and in addition he also mentioned that ''we try to use things like social Medias in terms of getting the communication to help''.

The clear and concise quotations to express themes are listed below in the Table 4.2.

Learning Opportunities	**Quotations**
Learning Avenues	*''So I learnt mostly by myself and asking lot of questions from my colleagues in workplace''(I7)* *''I think unless you use the tools you never be able to soon after the training and use tend to forget it. That's the danger in it if you are learning it'' (I6)''So, our BIM knowledge came out of our experience of we have already gleaned from the process power marine market and we just put some links together really and realise that the term that the government BIM agenda or something we actually have some experience with in terms of process and practice because of the works we have done for process power marine but it's just called in two different things which is 3D specification or BIM'' (I11)*
Human influences	*''initial training sort of helped me to use Revit face and Revit modelling techniques and playing around with it is the one really helped me be after to embraces sort of really the effectiveness of it. So also using the other software such as Naviswork, 360 glues in the projects and playing around with the tools'' (I14).*
Learning environment	*''we are now sitting round the table and talking with people we have never expected to talk with before'' (I11).*
Communication	*''Chatting with that person about what software they use and getting support from them in telephone or Skype to get over the challenges'' and in addition he also mentioned that ''we try to use things like social Medias in terms of getting the communication to help'' (I3)*

Table 4.2: Learning opportunities provided in BIM construction projects

4.1.3 Learning factors related to individuals/team

Learning factors that influence individuals and teams also have a high impact on learning in BIM construction project environment. The identified child nodes are grouped into main two parent node: human behaviour and person skills.

Literature has considered human behaviours within people has been considered in learning has been discussed for many years (Shuell, 1986) along with attitutes and actions by individuals and groups (Valli, 1996). This is also supported by *I12* where he has stated as below:*''You need to be very quick learner. Because it is always a new piece of software, tools and technology. So, you should be able to pick it up quick automatically through following the experts''*.Eraut (2004b) has claimed that skills is an essential factor to perceive learning in a workplace environment. Supporting this, I9 from phase 2 semi-structured interview stated:

''Having said that from the individuals I see who are part of people willing to get over the humps and all the problems in terms of exports, imports, how do we manage this, how do we manage that, how to do end up with sensible set of clashes and how do we manage information in this way. Those people I would say as a champion in the organisation''.

These are listed below in Table 4.3 with the precise quotations extracted from the interviews.

Learning factors that influence individual/team	**Quotations**
Human behaviours	*''You need to be very quick learner. Because it is always a new piece of software, tools and technology. So, you should be able to pick it up quick automatically through following the experts''(I12)* *''If I want to step into a change program now I am in far better position that I was before. But it was the practice element that has given me the confident''(I3)*
Person's skills	*''for me it was all because of myself motivation in my case and strive to learn that something that would help my personal development'' (I9).* *''Having said that from the individuals I see who are part of people willing to get over the humps and all the problems in terms of exports, imports, how do we manage this, how do we manage that, how to do end up with sensible set of clashes and how do we manage information in this way. Those people I would say as a champion in the organisation'' (I3)* *''In my opinion I would say that there must be some holistic understanding in BIM overall process. I am not saying that every single detail should be understood but there must be some holistic understanding and that means right from the beginning towards the end that opportunities for the stakeholders to interact with each other and share information but the important level is that each stakeholders' involvement in BIM and what they contribute to BIM''. (I9)*

Table 4.3: Learning factors that influence individual/team impact on learning in BIM construction projects

4.2 Semi-Structured Data Analysis

At the end of the semi-structured interview a number of child nodes were created answering the key questions related to learning in workplace. Connecting the collected child nodes individually in each section has developed the parental nodes that directly links to learning in the workplace.

How learning is perceived in workplace in BIM-enabled construction projects

A number of child nodes emerged, and similar child nodes are grouped under a parent node. In other words, child nodes categorised under a parent node is interlinked between that specific child node and parent node. All the collected child nodes are grouped into 5 parent node: Human response, adopting technology, interaction, work culture and evaluation. Each parent node (themes) in this section has been developed through number of child nodes (sub-themes). The openness in tackling the works, awareness of what is going on project, observing how things are taking place and whose been involved and thinking outside the comfort zone are key sub-themes that developed the theme "human response". Following that, handing structured data, working with graphical representations, having knowledge of modelcreated the theme "adopting technology". These sub-themes shows that learning is difficult without adopting suitable technolog(y) ies to learn efficiently in a workplace. Consequently, engaging with people as well as information, working in a multi-disciplinary teamwork and sharing information are the sub-themes that generated the theme "interaction". Next, adopting certain process to achieve the targets and continuous learning are some of the key sub-themes helped to create the theme "work culture". At last, assessment and research that took place in BIM-enabled construction projects to enhance the workplace learning has developed the theme "evaluation".

To discuss these themes and sub-themes in more detail firstly, human response in this illustrates the human actions that takes place to learn in work environment. These actions help the learners to add more knowledge to the existing knowledge and to gain new knowledge. Awareness, openness, reflection, observation, thinking outside the box and visualising are some of the key human actions acknowledged in the semi-structured interviews. Secondly, adopting technology is another main theme that influence learning in the workplace. Technology is a combination of both human and machinery effort applied together to complete the tasks in workplace. Structured data, graphical representation and knowledge of the model are key child nodes identified under technology. Third important theme develop was interaction. Interaction in this research is an exchange among different individuals or teams. In this study, long term engagement, multidisciplinary teamwork and sharing information are reported as most frequent ways professionals interact with others. Next, work culture also played an important role in learning that occurred in work environment. Culture is the mentality of the employers working in the project. Interviewees mentioned following certain process, continuous learning and adopting new ways of learning are some of culture followed in their project. This shows that culture differs to each construction projects however, it has a great impact on learning in the workplace. Finally, even though the above 4 parent nodes are important evaluation is added as the final key theme to this list. Evaluation in this indicates making sure whether learning is happening in the workplace. Assessments and research are some of the examples of how it is evaluated in the workplace. Overall, this section clearly states that different themes influence the learning that takes place in BIM-enabled construction. This shows that learning in workplace does not solely depend on the human aspect. Instead, social interaction and technology are important to understand the learning. On the other hand, culture also influence the learning process to achieve the desired goals. However, learning in the workplace is incomplete without the evaluation. So, altogether the combination of all these main themes (parent nodes) are vital to perceive the learning that occurs in the workplace.

Learning opportunities provided in BIM-enabled construction projects

The semi-structured interview results have revealed that there is a range of learning opportunities available in BIM-enabled projects to complete the tasks. These collected child nodes under this section have grouped into 4 parent nodes: learning avenues, human influences, learning environment, and communication. Learning avenues is an approach to learn something. In other words, learning avenues is the where actual learning is taking place. This either means developing a new knowledge or adding new to an existing knowledge. BIM projects involve multidisciplinary teams, hence there are a variety of learning avenues available for the employers to get involved in the project. Inquiry-based learning, hands on practice, qualification and education, group learning, self-learning, learning on projects, learning from mistakes, collaborating, trial and error, and past experiences are the most common learning avenues mentioned by the interviewees. Following this, Human influences such as advice, mentoring, support, guidance, training, feedbacks and cross-relationships also influence the learning that happens in work environment. Along with these themes, interviewees' emphasised that the learning environment is also another one which is essential to perceive the learning in workplace. Sub-themes such as company support, company strategies, collbarative work, structured information and work coordination helped to develop the theme "learning environment". Finally, the theme "communication" which plays a margor role in BIM-enabled construction projects is emerged through sub-themes such as verbal communication, documentation and email conversations. Interestingly, this results show without effective communication and suitable learning environment learning in workplace is difficult to achieve.

Learning factors related to individuals/team

Results from 4.1.1 and 4.1.2 already indicates human factors play a major role in learning in the workplace. However, this section further highlights the importance of learning factors that are related to individuals and teams. The child nodes collected under this section are grouped into two major parent nodes: human behaviour and person's skills. Human behaviour in this study indicates how people act or react in the process of learning. Ability to change, effort, confidence and trust are some of the human behaviours highlighted by the interviewees. On the other hand, a person's skill that is embedded in each individual/team also has a huge impact on learning in the workplace. Prioritising, self-motivated, patience, adaptation, holistic understanding, mid-set, background knowledge, and role and responsibilities are a few person's skills mentioned in the semi-structured interviews. This shows that these intangible qualities of humans gives the encouragement to learn in the work environment.

In conclusion, the semi-structured interview results have highlighted that internal factors such as human influences and external factors such as technology, environment, and culture are vital for effective learning in the workplace. However, results point out that learning avenues and social interactions are the place where learning actually takes place. At the same time, evaluation is essential to ensure whether the learning is happening in workplace. In whole, the impact of all these parent nodes identified leads towards effective learning in workplace.

4.3 Case study Analysis and Findings

Following the semi-structured interviews, case studies were conducted for the in-depth analysis of learning in the workplace in BIM-enabled construction projects. Case studies from BIM construction projects context were chosen for the investigation. This is achieved through meeting observations, semi-structured interviews, and project documents within the chosen BIM construction projects. Among the 20 observed case studies, more complex and detailed 6 case study contexts were presented in this chapter for the data analysis (Figure 4.2). In this SC refers to the complex scenarios chosen for case studies. These chosen case studies were more open and provided an easy access to the relevant materials. The contexts presented in this study are reporting the conflicts and challenges professionals faced in the project along with how learning is taking place in BIM-enabled construction projects. Therefore, this information is sensitive personally and emotionally from an organisational point of view. Nevertheless, the reference to the project type is shared whereas other details were kept confidential. These meetings covered people's view on learning, learning opportunities in the workplace and a broad range of factors that influence learning in the workplace. This gave the researcher the opportunity to listen to in-depth discussions which helped to analyse the learning in the workplace in more depth. In addition, analysing these contexts in detail provides an overall idea of how learning takes place in BIM projects. A number of views were expressed by the professionals within both meetings and through the semi-structured interviews within the case studies. Statements made by professionals were represented as verbatim quotations and written in italic format. Selection of the quotation were based on explicit and clear quotations.

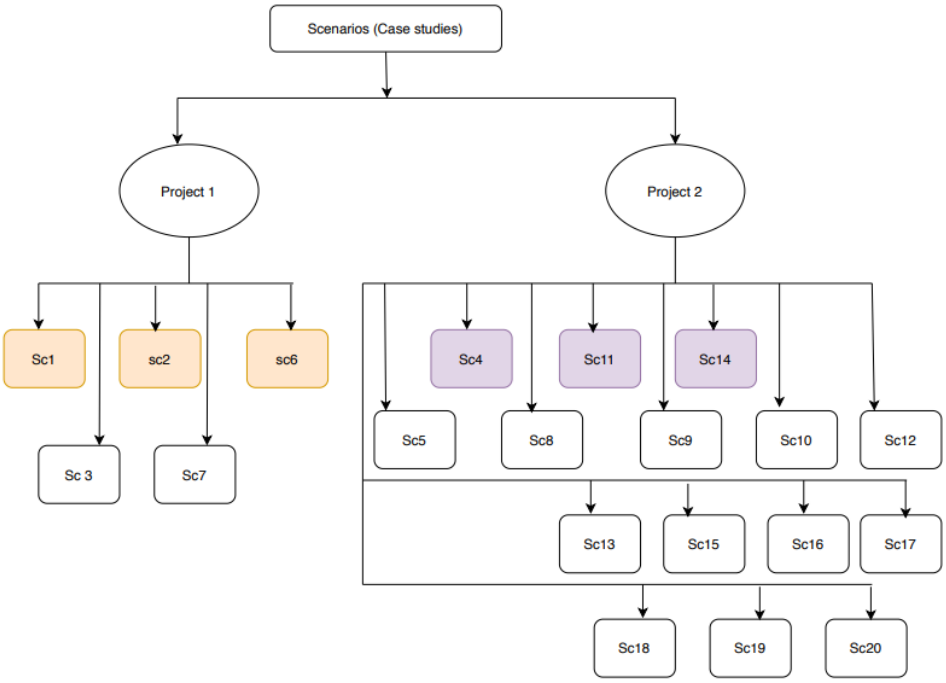

Figure 4.2: Case study selection

4.3.1 Mechanical and Electrical Installation issues

OVERALL LEARNING MODEL
The case study started with the clash detection process. However, BIM coordinator with his prior knowledge with the model has helped to spot the problem in MandE installation. Furthermore, looking at the duct work installed in the site with the connection to 3D model has provided the understanding of duct that causes the clashes. During this project team member's ability to change, awareness has helped to get quality information and to avoid errors. Process of coordination, communication, explanation, planning, research and exploration carried out in this situation shows how information and activities are aligned to make decisions. Moreover team members have advised, shared information, prioritised and visualised to understand the project and project goals. Different learning avenues discussed in the situation shows that learning occurs in many ways in this collaborative environment. Prioritisation, openness, assumptions, good structured data, clarity and trust also plays a role in making decisions in this multidisciplinary team.

Case study context

This context focused on Mechanical and Electrical (M and E) installation issue identified in the clash detection process. The BIM coordinator mentioned that the main cause of this problem is due to installing the electrical fixtures in a different way in on-site rather than what is contained within the model. This has caused the cable trays to clash with the duct passing near the cable trays. The Service engineer mentioned that they have gone through lots of difficulties while modelling the duct with mark ups given to them due to number of services passing them. In addition, he added that he has tried a number of ways to design the duct where most of them did not work. Finally, the BIM coordinator, working with the Service engineer, has found a suitable duct design solution. During this, the BIM coordinator highlighted that there are also number of other clashes with the duct works and are currently waiting for the revised mark ups and photographic evidence to confirm. He also stated that he has no trust in the old mark ups provided to them earlier and this is because the early mark ups clashed with lots of other building elements in that area. The BIM engineer from the building service team said, from his experience these clashes could be mainly due to the different positions of the ducts and trays. Therefore, he emphasised that getting correct mark ups is important. In addition, the Service engineer added that even though their team has promised to provide the mark ups, Civil engineers working on-site have not release it yet. Moreover, they have also reported that the duct work is installed slightly differently to how it is mentioned in the model and specification. However, the Service Engineer highlighted that their mark ups for all other services such as pipelines, cable trays are correct, but it is just the duct work for some reason clashing with so many things. This shows the level of accuracy and coordination between the teams. The BIM coordinator at the end of this discussion suggested that if they still have difficulties with the new mark ups, point cloud scanning would be an option. However, the Building service team mentioned that they have already tried to use the point cloud scanning, but it did not work due to difficulties in capturing the full picture. Therefore, they said they have dropped using it after suspecting that it would create more clashes at the end. During this BIM coordinator also highlighted that MandE installation on-site is lacking behind the project schedule. To overcome this issue, the Service team has agreed to get new mark ups and use the point cloud with additional training.

Analysis

It is noticed that prior knowledge and experience of BIM coordinator was used in the beginning of the meeting. Even though the clash between Mechanical and Electrical issue was identified through the clash detection process, his knowledge with the model and experience spotted that this issue was because of electrical fixtures installed in different ways than what is specified in the model. This then allowed the team members to investigate further to find the cause and impact for this issue. Discovering the duct installation on-site and comparing it with the model allows the team members to change the focus and minimise the errors in the early stage. For example, in this context, identifying slightly differently installed duct work on-site has helped the team members to focus on duct work design and installation, rather than focusing on cable trays or other Mand E services. Moreover, the BIM engineer sharing his experience about the difficulties on modelling the duct and mark ups has turned the team members to focus on mark ups and design of duct which clashed with the cable trays. This shows that other project participants not only learn from what BIM engineer has gone through but also they directed to learn outside the box. In addition, the Service engineer's statement about his awareness about the other clashes shows that he is open minded, rather than focusing just only in this specific problem. Moreover, revised mark ups and photographic evidence by the Service engineer depicts their level of trust on the mark ups that are collected by other project members working on-site. For example as stated by Service engineer (Observation 13)

''I have not got trust in old mark ups provided by them earlier''.

This shows that the BIM engineer is expecting good structured data for the analysis to avoid unwanted confusions among the project team members. Supporting this, the BIM Engineer also mentioned that having correct mark ups are vital to analyse the situation. Similarly, Interviewee 13 during the semi-structured interview stated about trust but in terms of information in the model

''So, you have to understand how the models are put together and some of them you can rip to pieces in order to understand what the numbers are inside it and whether you trust it is hugely important …'' (Interviewee 13)

Also, from his experience he assumed that these clashes could be due to the different positions of the duct and trays.

Involvement and discussion between more than one team members in this situation shows the collaborative environment in this BIM project. In this collaborative environment, project team members shared their experiences and ideas as shown below to build up their understanding of the situation and related actions at that occurrence.

- Verbal conversation
- 2D drawing explanations (eg: Duct work drawings)
- 3D BIM model (clash detection and 3D models)
- Project specification documents

In this situation, the multidisciplinary team structure is also exposed where different disciplines contribute to achieve the solutions for this situation. This discussion between the multidisciplinary team triggers how duct was designed and installed in the site. Service engineer's experience in modelling the duct shows the opportunity to learn on project through trial and error method.

''…have gone through lots of difficulties while modelling the duct with mark ups given…'' (Service engineer, observation 13)

As much as design detailing and its documentation moved forward along with the discussion, project team member's ability to change according to the situation was explicit. Members actively participated in exploring the situation including sharing their views in the middle of the discussion. However, in terms of alignment of collected information and understanding, time was an issue. This is evident through Service engineer stating:

''…even though their team has promised to provide the mark ups, they haven't release it yet'' (Service engineer, observation 13)

After exploring and reacting to this problem team members started to coordinate all the documents and understanding to find the solution. During this planning stage, the Service engineer has validated the other mark ups for all the other services such as pipe lines, cable trays to ensure the level of accuracy. An explanation regarding duct work installation with the aid of 2D drawings and 3D models were carried out during the discussion. Visualisation of 3D BIM model shown by the BIM coordinator in the meeting has allowed the team members to reflect quickly to the situation. Insight, in this situation was generated through the documents and 3D models that are used. In addition, visualisation through 3D models helps the team members to appropriately reflect on the situation. The explanation provided by the Service engineer shows his participation and how he is interpreting the situation. Overall, as a team there is a learning taking place in this specific situation. During the discussion, information was shared from project documents, 2D drawings, and 3D models. However, team members did not only rely on the data they see or hear, instead they researched before using or implying it to make decisions. For an example, 2D drawings only shows the design of the duct work. However, the team looked at the federated 3D BIM model to see what the other services are going around that area and to see the cable tray routes. Collecting the information from different sources shows the the importance of coordination process during workplace learning. After exploring the situation team members at this stage identified and prioritised on the issue which they are mainly going to focus on, in this case the duct work installation. This depicts that planning and prioritising are taking place when workplace learning is occuring. The BIM Coordinator stated that there is still a problem in the linkage of installing on site, which is lacking behind the project schedule. In other words, there is a gap between what is installed on-site and what is agreed on project schedule. Therefore, for this reason this issue was re-visited in this project before making the conclusion. This again demonstrates the importance of continuous update and research to perceive the learning in work environment.

Later, in this meeting the BIM Coordinator advised the team members to adopt point cloud scanning if they still have a problem in using the new mark ups. This shows that the project team is ready to learn alternative ways to achieve the targets. However, the service team mentioned that they were not able to use point cloud scanning because of an improper way of using it. Moreover, members who were using point cloud scanning assumed that this system was causing more clashes, therefore they decided not to use it. While sorting this issue, the building service team communicated and interacted with the other team members to know more about point cloud scanning and how it works. Other team members spending some spare time after the discussion explained the way point cloud scanning works and helped the building service team to start using it. Finally, at the end of this discussion the building service team has agreed to adopt the new mark ups and use point cloud to check the accuracy. This has not only solved the problem but also helped to make effective decisions within a short period of time. This shows how learning in workplace is happening through interactions with other work colleagues and sharing their experiences. On the other hand, this situation also confirms the importance of accuracy in learning process. Key learning aspects from this case study-1 are summarised in Table 4.4. The learning aspects: learning conditions, learning progress and learning outcomes are derived from the literature. On the other hand, themes dicussed in the table 4.4 are derived from the case study analysis. Although, all these themes are not presented under the same name the idea behind the themes are embedded within the chosen final themes. For example, learning opportunities can come under learning context where is learning factors are common in both phase 2 semi-structured interviews and case study approach.

STRUCTURE	NODES	EVIDENCE
LEARNING CONDITIONS		
Learner's Factors	**Awareness: Having consciousness of what is happening**	*Service engineer was aware of number of other clashes with the duct works while resolving this situation*
	Prior knowledge and experience	*BIM Engineer from the building service team said, from his experience these clashes could be mainly due to the different position of the duct and trays*
	Trust: Quality to maintain relational stability	*Service engineer mentioned he is currently waiting for the revised mark ups and photographic evidences because they have not got any trust in old mark ups provided to them earlier*
	Ability to change :Capacity to act physically and mentally for the change	*Service team members even didn't know how to use point cloud scanning they were able to adopt and change with aid other team members*
	Knowledge with the model: Sufficient knowledge to use the model	*BIM coordinator through understand the clash detection and connecting the information in the model spotted that this issue was because of electrical fixtures installed in different ways than mentioned in the model and specification*
	Real Life situation: What is happening on construction site	*BIM coordinator concerns about the duct is installed in the site and its linkage with the model*
Learning Context	**Collaborative climate: Involvement of more than one team member**	*Involvement of more than one person such as Service engineer, BIM engineer and BIM coordinator to find a solution for the problem.*
	Learning on project	*Service engineer response to this situation, mentioned that they have gone through lots of difficulties while modelling the duct with mark ups given to them due to number of services passing them*
	Trial and Error	*Service engineer mentioned he has tried number of ways to design the duct where most of them did not work.*
	Good structured data: Information that make sense without errors	*Service engineer is expecting revised mark-up that make sense which does not make any clashes with other adjacent building elements near duct.*
	Team structure: Multidisciplinary team : Community of different disciplines from the same field	*Involvement of different disciplines (BIM engineer, BIM coordinator and Service engineer) from the construction field got together to solve this issue*
LEARNING PROGRESS		
Activities	**Doing the work it self**	*Service engineer trying different ways of designing the duct*
	Reflecting from one's own experience	*Service engineer from his experience mentioned that duct work design is complex*
	Collaborating and Interacting with other people	*BIM coordinator, Service engineer and BIM engineer shared information, communicated and discussed several ideas to solve this issue.*

	Participating in the networks	*Building service team participating in a network where other team members were involved to learn to use point cloud scanning*
	Tackling new challenges	*Learning point cloud scanning is new for building service team*
PARTICIPATION AND INTERPRETATION		
Alignment	**Clarity**	*Service engineer asking for photographic evidence other than the revised mark ups for more clarification*
	Coordination	*Team members organising all the information collected from the model, people's experience and verbal discussion to solve the issue.*
	Communication	*Building service team interacting with other members to understand more about point cloud scanning*
	Advice	*BIM coordinator advised the team members to use point cloud scanning if they still have difficulties with revised mark ups provided to them.*
	Explanation	*Explanation regarding duct work installation with the aid of 2D drawings and 3D models were carried out during the discussion.*
	Research	*Team members without believing what they hear from other team members they research whether it is correct from 3D models ,2D drawings and documentation before making decisions*
	Planning	*At the end building service team has planned to use both revised mark ups and point cloud scanning to resolve the clash between duct work and cable trays*
	Sharing Information	*During the discussion BIM coordinator shared the information that he has extracted from the model whereas Service engineer shared information of duct design from both 2D drawings and project documents*
Insight	**Orientation :Time**	*Service engineer team has promised to provide the mark ups, they haven't release it yet*
	Accuracy	*During this planning stage Service engineer has validated the other mark ups for all the other services such as pipe lines, cable trays to ensure the level of accuracy*
	Reflection: Reaction	*Visualisation of 3D BIM model shown by BIM coordinator in the meeting has allowed the team members to react to the problem and reflect quickly to the situation*
	Visualisation	*BIM models were used to see images in 3 dimensional rather seeing it 2D drawings*
	Exploration/Analysing	*This issue was explored through considering different team members opinions, experience and also collecting information from various sources(Eg: 3D BIM model)*
Engagement	**Mutuality : Assumption**	*Building service team without knowing how to use the point cloud assumes that this system is causing more clashes than doing it with the aid of mark ups*

	Continuity: Continuous updates	*Need for revised mark ups for duct work where old mark ups are causing clash between cable trays and duct work*
	Competence: Effort	*Members from building service team took the effort to learn point cloud scanning from other team members involved in the discussion*
	Prioritising : Preference for most important activity	*After exploring the situation team members at this stage identified and prioritised on the issue which they are mainly going to focus, in this case duct work installation*
LEARNING OUTCOMES		
Learning outcomes	**Team work**	*Solving the issue with different disciplines involved in the project*
	Decision making and Problem solving	*To use both revised mark ups and point cloud scanning to redesign the duct work clashing with the cable trays and electrical services*

Table 4.4: Learning aspects from case study-1

4.3.2 Designing the vent above the door

OVERALL LEARNING MODEL
This case study about the vent above the door has initially influent by professional's prior knowledge and experience and their commitment to solve the problem. This issue was tackled through looking the real situation about what is happening on site with the use of resources. 3D visualisation and openness in the collaborative environment has moved the discussion forward to the next stage. Team members involved shared information for the purpose of exploration, explanation, negotiation, discussion and communication. Level of details about the building element and advising were provided at the right time. Professional were aware about the other building elements and also considered the continuity within the project. Multidisciplinary team through collaborating and doing the task itself with the aid of team working has concluded with the effective decision to improve the vent design.

Case study context

In this project review meeting the Architect reported about a vent above the door in the canal side of the building. This meeting was selected through considering ease of access, flexibility of gathering the information, having enough time to take notes and level of details of gathered information. He pinpointed that the vent has changed both in its size and shape (now changed it to very thin) from the original design. The project team members present at the meeting started to refer to the initial 2D drawings and specification to investigate this problem. To further explore, the BIM coordinator used the 3D BIM model to clearly visualise the vent and to check the dimensions and its position above the door. After viewing both 2D drawings and the 3D model, the Architect found that the information about the grills in the schedule were different from the model. To clarify the dimensions, he requested the team members working on-site to confirm the grill size because he was expecting two 400mm grills and a 300mm wide grill installed to position the vent. During this discussion, the Service engineer discovered that some of the other adjacent vents were coming through the door and also coming from the other side of the door. So, he raised a question regarding the space to fit these vents. The Architect for this issue suggested that they need a taller narrow vent, which does come out with a full width louver internally, but at the same time he was concerned about the two cladding panels in terms of its fittings, which stayed in between either side of the central fittings. Therefore, he asked the Service engineer to provide the size of the louver in terms of volume to find out the correct dimension and location of louver to coordinate them with the cladding. On the other hand, the Architect also requested for the information on the 300mm height metal planks and how many of them need to be exchanged for the revision. During this discussion, the Architect mentioned that he also found many of the exit signs clashed with the doors (i.e door to the corridor, near the toilet area) because there is not enough space on top of the door leaf and ceiling to insert the exit sign. Following this, the BIM coordinator reported he has also found a few exit signs inside the ceilings in the model and requested the Service engineer to alter by placing it in the right positions. After the discussion, to overcome this issue, the Service engineer agreed to post the sign on the side of the wall if it can point in the right direction. The Architect agreed with the decision, however he advised the project team that this might sometimes change the type of sign and change the fittings.

Analysis

The Architect has identified that the size and shape of the vent has changed from the original design using his prior knowledge about vent designs and his experiences in positioning them within the building (Prior knowledge and Experience). To investigate this problem, usage of a number of specifications documents on vent design, 2D drawings, and 3D BIM model show that project team members relied on number of resources (Number of resources). In this exploration, using 3D models has helped the team to visualise the vent where dimensions and position were clearly presented to the team members (Visualisation). In addition, exploration of this problem using different resources has helped other team members to completely understand the problem and follow the solutions which architect was discussing in the meeting (Holistic Understanding).

BIM coordinator in relation to this situation mentioned that:

''I think it is more of an understanding of an overall construction process and experience in working in a multidisciplinary team. Because you are producing an isolated drawing for part of an overall model and lots of people feed into''.

The Architect's interaction with the on-site project team members to confirm the accuracy of the grill sizes demonstrates the collaboration that takes place with various professionals (Interaction and Collaboration). Furthermore, this situation illustrates that understanding what is happening on-site is also important to consider, while making decisions especially when the project involves digital technologies (Legitimate situation).

On the other hand, discovering the positions about the adjacent vents shows the Service engineer's openness to consider the other related issues while focusing on problem related to vent (Openness). This exploration about the vents has made project team members to think about how to fit those vents within the limited space (Exploration). While discussing this problem there was also questions regarding positions of exist sign boards. The Architect with the knowledge of the model and using his prior knowledge explained this could be resolved through designing a taller narrow vent which does not come out with a full width louver internally (Prior knowledge and Explanation). However, with his past experience he said that he is concerned about the two cladding panels which stay either side of the central fittings (Past Experience). This indicates that the Architect's prior knowledge, experience, and knowledge with the model have great influence in making decisions. During this situation the level of details about the louvers were considered carefully which is about how big the louver is in terms of volume and their coordination with the cladding (Level of details). In addition, the Architect's request in collecting information on metal planks demonstrates the importance of sharing information during the coordination process (Sharing information). Furthermore, this also shows that the level of details of each element plays an important role in decision making.

Identifying the positions of the exit board sign and fitting them in right places show the awareness on how models are used in the project (Awareness). On the other hand, this also illustrates that the communication between the team members is key to avoid these problems (Communication). Furthermore, negotiating and discussing about the position of the exit sign, demonstrates the significance of negotiation and communication. This has helped to bring project team members to the same place and to an agreed decision to overcome this issue. The Architect's advice on placing the exit sign board on the side wall has guided the project team to prepare for the challenges that can be faced (Advice). The Architect's continuous in-depth investigation on the vent design and positioning shows his commitment in resolving this issue (Continuity and Commitment). In this context, teamwork has been explicitly expressed through the collaboration among the BIM Coordinator, Architect and Service engineer which has finally helped to learn efficiently and make decision to improve the design. This situation shows being aware of what is happening in the learning environment along with continuous communication and commitment are essential to learn in workplace. Key learning aspects from this case study-2 are summarised in Table 4.5.

STRUCTURE	NODES	EVIDENCE
LEARNING CONDITIONS		
Learner's Factors	**Prior Knowledge and Experience**	*Architect identified that the size and shape of the vent has changed from the original design that was provided in the beginning of the project. He spotted that vent has become thin than previous design*
	Commitment	*Architect's continuous in depth investigation on the vent design and positioning shows his commitment in resolving this issue.*
	Real life situation	*Workers in the site were contacted to get the information on grills installed on site*
Learning Context	**Resources**	*Therefore, in this situation number of specifications on vent design, 2D drawings and 3D BIM model were used to understand the way vent has been designed and positioned in the building.*
	Visualisation	*Especially for this, 3D model was pulled out by the BIM coordinator in this situation to visualise the vent where dimensions and position were clearly visible to the team members.*
	Experience	*After exploring the 3D model for vent architect requested the team members in the site to confirm the sizes of the grills where he expected two 400mm and 300mm grills to be installed in that position of the vent*
	Collaborative Climate	*Discussion has not only stopped within certain team members attended the meeting but also beyond that where workers in the site were contacted to get the information on grills installed on site*
LEARNING PROGRESS		
Activities	**Doing the job itself**	*Architect's continuous in depth investigation on the vent design and positioning.*
	Collaborating and Interacting with other people	*After analysing about this situation with the team members, architect explained this could be resolved through designing a taller narrow vent which doesn't come out with a full width louver internally.*
PARTICIPATION AND INTERPRETATION		
Alignment	**Explanation**	*Architect explained this could be resolved through designing a taller narrow vent which doesn't come out with a full width louver internally*
	Sharing Information	*Architect also requested information on 300mm height metal planks and how many of them need to be swop out for the revision.*
	Communication	*BIM coordinator communicating with the Service engineer about the exit signs hitting the doors and indicating about the exit sign in ceilings.*
	Negotiating and discussing	*Negotiating and discussing about the position of the exit sign, he has finally decided to stick the sign on the side of the wall to position it in the right direction,*

	Advice	*Architect also warned and advised the team that it might sometimes change the type of sign and change the fittings due to the continuous design changes occurring in the project.*
Insight	**Exploration**	*Analysing with the team members to about how to fit those other vents where space are much limited.*
	Level of detail	*Level of details about the louvers were considered carefully which is about how big the louver is in terms of volume and their coordination with the claddings.*
Engagement	**Awareness**	*BIM coordinator was concerned about the two cladding panels which stays either side of the central fits while designing the taller narrow vent.*
	Continuity	*Architect also warned and advised the team that it might sometimes change the type of sign and change the fittings due to the continuous design changes occurring in the project*
	Team structure: Multidisciplinary team	*Involvement BIM coordinator, Service engineer and architect to make decisions and solve problems.*
LEARNING OUTCOMES		
Learning outcomes	**Team work**	*In this situation relationships between the team members such as BIM coordinator, Architect and Service engineer indicates the team work to make an effective decision and improve the design.*
	Decision making and problem solving	*After analysing about this situation with the team members, architect explained this could be resolved through designing a taller narrow vent which doesn't come out with a full width louver internally*

Table 4.5: Learning aspects from case study-2

4.3.3 Use of laser scanning

OVERALL LEARNING MODEL
This case study regarding the usage of laser scanning in the project started with the awareness about what is happening around the project. Most of the team members had the mind-set and ability to change according to situation. However in this case the Project Engineer's negative opinion shows that people have different perspectives. The combination of self-learning and indirect group learning has helped the team member to think outside the box and do the task in a new way. Moreover this also gave the opportunity to realise the value of laser scanning. Acceptance of a laser scanning method shows the cultural shift where project team members were ready to learn new things in this collaborative environment. Multidisciplinary team organising/planning, communicating, exploring including sharing information with others have motivated and helped the team members to holistically understand the situation and to know more about level of details on building elements. Moreover, continuity of information including the accuracy and meaning production was easy through these actions, while tackling new challenges and tasks, collaborating with other people and participating in informal learning. Effective team work among the members has led to make decisions and solve the problem in this situation.

Case study context

This meeting focused on the issue regarding laser scanning. This issue has been raised due to queries on what has been scanned. The professionals started to investigate this issue through looking at the initial scan of completed parts of constructed building. In this meeting the BIM Coordinator arranged a walkthrough to understand BS standards and ISO standards adopted in the site especially to show the details on upper floor and boarding. In other words, during the walkthrough the places these standards adopted were clearly shown. Therefore, team members are aware about where and when to use these standards in BIM-enabled projects. As an initial step, the BIM Auditor sent the laser scanning format to the BIM coordinator via email. This is a capture of 3D data in the form of a point cloud.This is to understand how laser scanning is completed on site and what is being scanned before the walkthrough session. Then a comparison between the raw data and the laser scanning results helped the team members to find the clashes.

Once the walkthrough is completed most of the professionals agreed that laser scanning is effective to capture the images of several project elements. However, in contrast, the Site Engineer believed it can only be well suited to scan wall positions, which has about 100mm tolerance. This view contradicts from other team members where they argued laser scanning can provide positive results which can be used to scan wall areas, soffits and absolutely everything. Furthermore, team members strongly preferred the laser scanning due to exposed corridors, which pushes much of the equipment through the corridors and doors. Project team members stated that understanding the positions of each MEP connection will allow to identify the location of MEPs and build up the holistic understanding of building design. After understanding BIM model and physical constructed building, the Client mentioned that he wanted to make a few alterations in his design. Minor changes were discussed and agreed in this meeting, but the discussion on major design changes was put off to another meeting. This confirms the researh su-themes which is vital to learn in workplace. However, at the end of the meeting the BIM Coordinator stated that there will not be any considerable major design changes. The BIM Auditor in this meeting mentioned that any design changes in future needs to be reported to the BIM Coordinator to avoid clashes in the BIM model.

Analysis

This context mainly focused on the laser scanning that has been used in the project. Confusion on what has been scanned through using laser scanning in this context shows people's awareness about what is happening around them and to see how effective it is to the project.

Supporting this, the BIM Manager during the semi-structured interview within the case study mentioned that

‘‘The only way is to give them the tool and explain how to use it and they need to understand that this tool is useful and simplify the work and improve the work’’

The investigation on the initial scans helped the team members to understand the connection between what is happening on site and BIM model. Moreover, this walkthrough organised by BIM Coordinator helps the team members to understand the details on the upper floor and boarding used. The gathered scanning images has also been used to check whether the BS standards are followed on-site during construction process. Explicitly showing the usage of these standards help the team members to learn about these new standards and gives clear picture on when and where to use it in BIM-enabled construction projects.

Moreover, the BIM Coordinator’s initiative to arrange a walkthrough shows how organised he is in terms of completing the tasks without any mistakes (Planning). The project team members’ view on Laser scanning and its benefits indicates there is a continuous communication taking place within the project team to learn how to utilise the laser scanning in BIM-enabled construction projects. Moreover, acceptance of the project team members to use laser scanning shows that people are ready to move towards the most effective way to learn new things. In other words, it shows that there are different learning avenues to learn in workplace. This further indicates the cultural shift towards most comfortable and beneficial methods using new technologies has an impact on learnimg in workplace. On the other hand, the Project Engineer’s contrasting view on Laser scanning shows that people are free to express and share their views with other team members. This shows that he is limiting his thinking to a certain boundary and struggling to think outside the box. This entire discussion indicates Laser scanning is fairly a new thing to the project members and that is one of the reasons to have different viewpoints about this subject in a single project (different perspective).

Project team members’ continuous investigation on finding the positions of the MEP with the aid of Laser scanning shows their mind-set to know about the complexity in the project. They believe finding these issues in the first place will reduce the number of errors. In this meeting it is clear that project team members are using different ways to share the project information. For example, in this context, the BIM Auditor has used email to send the laser scanning format to the BIM Coordinator. Moreover, exploring how laser scanning is done on-site and what is being scanned shows their desire on doing the right things in the right way. On the other hand, this also indicates that the different ways of learning within this project, in this case the BIM Coordinator will download the laser scanning and learn it by him (self-learning) through following the instruction. This situation also depicts the motivation provided to the other team members where in this situation the BIM Auditor has motivated the BIM Coordinator to learn laser scanning, which has helped him to compare the results between raw data and laser scanning results and find the clashes. However, the Architect during the semi-structured interview mentioned it is important

‘‘to know how to use the software and therefore you need training and should know how to use the software efficiently and effectively’’.

Changing the client’s minor changes through critical discussion with the project team members in the meeting shows the power of the teamwork. At the same time, arranging a meeting to discuss further on major changes shows the importance of collaborative environment, while making decisions. The BIM Coordinator’s statement on not having any major changes in the model depicts his confidence and holistic understanding of the model and the project. Finally, the BIM Auditor’s suggestion to report the changes identified to be informed to the BIM Coordinator shows the multidisciplinary team handling. This is vital to understand the connections between the activities and information that are embedded within the project, especially to make a meaning. The key learning aspects from this case study-3 are summarised in Table 4.6.

STRUCTURE	NODES	EVIDENCE
LEARNING CONDITIONS		
Learner's Factors	**Awareness**	*Confusion on what is been scanned through using laser scanning in this case study shows the people's awareness about what is happening around them and to see how effective it is to the project*
	Ability to change	*Acceptance of the project team members to use laser scanning shows that people are ready to change to the effective way of doing things*
	Mind-set	*Project team members attended the meeting suggested that due to this complicated MEPs there is a need for them to know the positions of each of the connection for the holistic understanding of the building design.*
Learning Context	**Cultural shift**	*Acceptance of the project team members to use laser scanning shows that the culture is shifting towards most comfortable and beneficial methods through the use of new technologies*
	Group learning	*As an initial step BIM auditor in this project has sent the laser scanning format to the BIM coordinator via email to understand how laser scanning is done on site and what is actually getting scanned before the walkthrough session*
	Multidisciplinary team	*In addition BIM auditor mentioned that the changes identified will straight away informed to the BIM coordinator because what moves in the model will have an effect on the clash detection*
	Collaborative Environment	*Client has decided to make the minor changes straight away in the model whereas requested to arrange a meeting before making major changes in the model*
	Self-learning	*BIM coordinator downloads the laser scanning and learn it by himself through following the instruction.*
LEARNING PROGRESS		
Activities	**Participating in in-formal learning**	*BIM coordinator downloads the laser scanning and learn it by himself (self-learning) through following the instruction*
	Tackling new challenges and tasks	*Introduction of laser scanning and using it to understand the level of details through scanning building elements such as wall areas, soffits and absolutely everything*
	Collaborating and interacting with other people	*Client requesting the team members to arrange a meeting before making major changes in the model.*
PARTICIPATION AND INTERPRETATION		
Alignment	**Organising/Planning**	*BIM coordinator's initiative to arrange walkthrough indicate organisation work context in the project.*
	Communication	*Communication regarding laser scanning all project team members agreed that laser scanning is beneficial to understand the level of details through scanning building elements such as wall areas, soffits and absolutely everything*
	Sharing information	*As an initial step BIM auditor in this project has sent the laser scanning format to the BIM coordinator via email to understand how laser scanning is done on site and what is actually getting scanned before the walkthrough session*

	Motivating others	*BIM auditor has motivated BIM coordinator to learn laser scanning which has helped him to compare the results between raw data and laser scanning results and find the clashes.*
	Exploration	*In the discussion team members analysed about the initial scanning to understand what has actually happened on-site especially through the walkthrough organised by the BIM coordinator to know and understand the details about upper floors, secondly about the boarding.*
Insight	**Level of details**	*In the discussion team members analysed about the initial scanning to understand what has actually happened on-site especially through the walkthrough organised by the BIM coordinator to know and understand the details about upper floors, secondly about the boarding .*
	Holistic understanding	*Project team members attended the meeting suggested that due to this complicated MEPs there is a need for them to know the positions of each of the connection for the holistic understanding of the building design.*
	Consulting-checking	*In other words scanning has used to check the information against as built information to see whether they both match or contradict.*
Engagement	**Continuity**	*In other words scanning has used to check the information against as built information to see whether they both match or contradict.*
	Different perspective	*Project engineer reacted negatively and argued that it can be only well suited to scan positions which was about 100mm tolerance.*
	Meaning production	*Multidisciplinary team handling the connections between the activities and information that are embedded within the project to make the meaning out of it.*
LEARNING OUTCOMES		
Learning outcomes	**Team work**	*BIM auditor has motivated BIM coordinator to learn laser scanning which has helped him to compare the results between raw data and laser scanning results and find the clashes*
	Decision making and problem solving	*Team member's together before making major changes in the model.*

Table 4.6: Learning aspects from case study-3

4.3.4: Pipe work installed on-site

OVERALL LEARNING MODEL
This case study was about the pipe works installed in the building. In this, the pipe works were different from what had been designed in the model. This is identified while comparing the situation in construction site with the model designed. The BIM coordinator's commitment and knowledge of the 3D model has helped to spot this issue which was made aware to the team members.2D drawings, 3D model, and specification utilised in this situation shows the good structure of the data and organisation of the work followed in the project. Multidisciplinary team working in a new way through communicating, explaining, clarifying, researching, sharing information, exploring, planning and visualising helped the team members to share their experience and provide a holistic understanding of the problem. Even though team members have the mind-set to listen to others and look around other problems related to project they were made aware to check the information and continuity of the project. Finally, with all of this team members spotted the real cause of the problem, a clash due to positions of the anchors on the route of pipe works.

<u>Case study context</u>

In this meeting, the issue regarding pipe works is brought forward to the attention of project team members. The issue was the pipe work installed on site was different from what has been designed in the model. This was identified during the site investigation process by the BIM Coordinator. During the meeting, the BIM Coordinator confirmed this through point cloud scanning that shows the scan of setting out confirms the different positions of pipe works. Moreover, 2D drawings, 3D models and specifications of pipe work were also presented in the situation for the members attended the meeting. The Site Engineer in this situation stated they have designed the model as per the instruction given by the design team and have not changed anything in the design. Therefore, the BIM Coordinator decided to contact the Site manager to know about this issue. While talking with the Site Manager, the team got to know that the pipe works have been designed the same as instructed, however installed in a different way on site by sitting on the pedestals. Furthermore, the BIM Coordinator contacted the project manager quickly to further analyse and discuss about this issue. The BIM Coordinator from his model showed the Project Manager how the pipes are clashing with the wall rather than going straight through. The Project Manager explained this clashes is purely due to the position of pedestals but he said he will look at how it will go across and come back. In addition, another area where the pipes are turning over, and the cable trays have moved by the single line was also considered during this investigation. From looking at the model, using his experience in this field suggested that the thick pipe in the model needs to be moved a little bit more to the right even though it is in the right lane. The Service engineer from his engagement with the project believed this difference is due to mark-ups provided to them. At the end of the meeting the Project Manager, after referring to his panoramic views and site photos, mentioned that these changes happened due to the positions of anchors on the route of pipe works. Moreover, another reason he stated was not having the pedestals layout before start modelling the pipe works.

<u>Analysis</u>

This case study particularly focused on the issue related to pipe works in the building. Different pipe works installed on site identified by the BIM Coordinator shows his awareness of what is happening in a real life situation, in this case what is happening on site (Awareness and Real life situation). On the other hand, identifying these issues during his site visit shows his dedication and commitment to the work that is allocated to him. Furthermore, this issue was confirmed through the point cloud scanning where setting out positions are confirmed that pipe work positions are different than it is designed, which shows his knowledge of the model. This shows that team members’ clarify the collected information to make sure they have gathered the right information. Moreover, this also indicates that different technologies have been adopted such as point cloud scanning to complete the work tasks.The usage of 2D drawing, 3D model and specifications for the investigation shows that relevant information about the pipe works were extracted from various artefacts. The model with all the relevant information in this situation was beneficial to spot the problem without further delay (referring to good and structured data). In other words, learning is more efficient and quick when the project data is well structured. The Site Engineer's statement on designing the pipework according to the instructions provided shows the organisation that has been maintained in the team (organisation of work). During this meeting the importance of real life situation was highlighted again when the BIM Coordinator decided to contact the Site Manager to know the real situation about this problem. This has helped to analyse the problem in more depth. During the conversation between the Site Manager and BIM Coordinator, the Site Manager shared information about the pipework that has been installed on-site (Shared Information). He clearly explained that even though the pipework has been designed in the way it has been instructed but it is installed in a different way. This demonstrates the importance of communication between project team members (Communication). To further investigate this issue the Project Manager along with the BIM Coordinator sat together with other team members to view the models extracted from the federated model. This discussion in front of the project team members created an in-depth understanding about the identified issue. Visualisation and clear representation of the data in this situation encourages the team members to learn efficiently in workplace environment. During this, the BIM Coordinator pinpointed the Project Manager how the pipes were clashing the wall. The Project Manager to solve this issue said that this actually happened due to pedestals, however he said he will do his own research and cross check with the BIM Coordinator once he have a clear idea about what is going on (Consulting-checking). During this discussion, even though the BIM Coordinator and Project manager had different level of understanding about the problem, they both were focusing on getting this pipe works in the right positions (common interest).

In addition, another area where the pipes are turning over and the cable trays have moved by the single line was also considered during this investigation (awareness). This shows that BIM Coordinator has not only focused on one single issue instead he has considered the wider perspective of the identified problem (mind-set)

Supporting this the BIM coordinator mentioned that

''You need to have that understanding about the people and have that mind-set for information''

The Project Manager's suggestion on moving the thick pipe in the model to the right shows his experience in this field (Experience of staff). Following that, the Service engineer believed that this difference is due to mark-ups provided to them. This indicates his holistic understanding about the problem. At the end of the meeting, the positions of anchors on the route of pipe works were discussed by the Project Manager showing the continuity of tracking the issue is missing. At last, his identification of modelling the pipework before having pedestals shows the lack of planning in the team. These deficiencies were mainly due to lack of engagement between the team members This lack of engagement and planning will have a negative impact on learning in workplace. Key learning aspects from this case study-4 are summarised in Table 4.7.

STRUCTURE	NODES	EVIDENCE
LEARNING CONDITIONS		
Learner's Factors	**Real life situation**	*The issue was the pipe work installed in the site was different from what has been designed in the model*
	Commitment	*This was identified during the site investigation process by BIM coordinator.*
	Intelligence with the model	*BIM coordinator further confirmed this through point cloud scanning that shows the scan of setting out confirms the different positions of pipe works*
Learning Context	**Resources**	*During this investigation 2D drawing, 3D model and specifications are also used by the team*
	Awareness	*An issue regarding pipe works is brought forward to the attention of team members*
	Good structured data	*Moreover 2D drawings, 3D model and specifications of pipe work were also presented in the situation for the members attended the meeting*
	Organisation of work	*Site engineer in this situation stated they have designed the model as per the instruction given by the design team and from his concern they have not changed anything in the design.*
	Multidisciplinary team	*While talking with the site manager the team got to know that pipe works have designed same as instructed however installed in a different way in the site by sitting on the pedestals*
	Collaborative climate	*Involvement of survive engineer, BIM coordinator and site manager to solve this problem.*
LEARNING PROGRESS		
Activities	**Collaborating and interacting with others**	*While talking with the site manager the team got to know that pipe works have designed same as instructed however installed in a different way in the site by sitting on the pedestals*
	Participating in networks	*Furthermore, BIM coordinator grabbed the project manager quickly to further analyse and discuss about this issue*
	Reflecting and evaluating on own experience	*From looking at the model, using his experience in this field suggested that the thick pipe in the model needs to be moved a little bit more to the right even though it is in the right lane.*
	Doing job itself	*This was identified during the site investigation process by BIM coordinator.*
PARTICIPATION AND INTERPRETATION		
Alignment	**Clarify**	*BIM coordinator further confirmed this through point cloud scanning that shows the scan of setting out confirms the different positions of pipe works*
	Communication	*While talking with the site manager the team got to know that pipe works have designed same as instructed however installed in a different way in the site by sitting on the pedestals*

	Explanation	*BIM coordinator from his model showed the project manager how the pipes are kicking the wall rather than going straight. Project manager explained that it is purely because pedestals but he said he will look at how it will go across and come back*
	Sharing information	*Project manager explained that it is purely because pedestals but he said he will look at how it will go across and come back*
	Research	*BIM coordinator from his model showed the project manager how the pipes are kicking the wall rather than going straight*
	Level of understanding	*BIM coordinator and project have different level of understanding about the problem they both were focusing on getting this pipe works in the right positions*
	Planning	*Moreover, another reason he stated was not having the pedestals layout before start modelling the pipe works (lack of planning*
Insight	**Exploration**	*Therefore, BIM coordinator decided to contact the site manager to know about this issue.*
	Visualisation: Graphical representation	*During this pipe works models were pulled out from the BIM federated model to create in depth understanding about the problem*
Engagement	**Mind-set**	*Project manager explained that it is purely because pedestals but he said he will look at how it will go across and come back*
	Consulting- checking	*Project manager explained that it is purely because pedestals but he said he will look at how it will go across and come back*
	Common interest	*BIM coordinator and project have different level of understanding about the problem they both were focusing on getting this pipe works in the right positions*
	Awareness	*In addition another area where the pipes are turning over and the cable trays have moved by the single line was also considered during this investigation*
	Staff experience	*From looking at the model, using his experience in this field suggested that the thick pipe in the model needs to be moved a little bit more to the right even though it is in the right lane*
	Holistic understanding	*Service engineer from his engagement with the project believed this difference is due to mark-ups provided to them.*
	Continuity	*At the end of the meeting project manager after referring back to his panoramic views and site photos mentioned that these changes happened due to the positions of anchors on the route of pipe works.*
LEARNING OUTCOMES		
Learning outcomes	**Team work**	*During the further analysis project manager and BIM coordinator sat together with the other people attended the meeting*

	Decision making and problem solving	*At the end of the meeting project manager after referring back to his panoramic views and site photos mentioned that these changes happened due to the positions of anchors on the route of pipe works.*

Table 4.7: Learning aspects from case study-4

4.3.5 Fittings of Lights for halo effect

OVERALL LEARNING MODEL
The BIM Coordinator while conducting the design checks in the 3D model has discovered that the current lighting does not work without leaving dark-spots. This has been identified using the BIM Coordinator's prior knowledge and experience along with his intelligence with the model. Visualising this issue with involving in the process of explaining, discussing, exploring and clarifying has helped the team members be aware of what is happening regarding the current lighting. Moreover, team members providing advice and guidance with utilising the staff experience tackled this issue. In this situation level of details on length of the walls, prioritisation such as colour difference in Passive Infrared Sensor (PIR) was concerned. Finally, through interacting with people and reflecting on their experience, team members requested another meeting to decide the number of lighting fittings and the way it is going to be fixed in the ceiling.

Case Study Context

The BIM Coordinator reported that the current light fittings were not working properly due to the dark spots it is creating while design checks in the 3D model. After analysing the issue, the Project Manager ordered the building service team to correct the light fittings in the ceiling panels in the 'Egg Theatre' to achieve the lighting levels and to give a continuous strip of light. Moreover, he mentioned it needs to be incorporated into the design of the triangular panels. However, project team members presented in the meeting suggested the building service team to consider supplementing with LED's or sourcing different fittings and analysing what to discuss with the lighting suppliers in terms of supplier information. During this situation, Service engineer stated that they are concerned about the length of the wall mounted 'Jubliee' lighting fittings in the staircase. This is because the legths of wall mounted lights does not satisfy the requirements. The design team in this situation was offered with circular fittings, however the members in the design team were highly concerned about the colour difference of Passive Infrared Sensor (PIR). In addition, they mentioned they still prefer the original 'short' vertical fitting if the building service team can demonstrate that overall, Part L compliance is not compromised. On the other hand, the BIM Coordinator suggested using small 'Thorulux' lightings, however he as requested the Service engineer to confirm the changes in the setting-out prior to the design team issue stair core setting-out information. In this meeting, the project team members present questioned about the length of the wall mounted with light. Although the team members' weare aware of the fittings used in the project, they mentioned that they are still waiting for the client's approval on the fittings that comply with Part L and LED fittings. In addition, the project engineer asked that ''does these fitting change the number?'' and requested the design team to confirm the total number of lightings after the changes. After discussing the number of lighting fittings and the way it is going to be fixed in the ceiling, the project team members requested another meeting with the same group to clarify the information and methods before execution stage.

Analysis

The use of 3D model in identifying the lighting issue shows that information resources are key and the starting point to identify the problem. Collecting the right information in workplace helps to perceive learning in workplace in a right way. Supporting this, visualisation presented in the model with the BIM Coordinator's knowledge of the model has made the project team members to realise that current lighting does not work without leaving dark-spots. Visualisation shows that there is different ways to learnin in BIM-enabled projects. After the team members have realised (awareness) the problem, the Project Manager has directed the building service team to change the light fittings in order to achieve the lighting levels and to give a continuous strip of light. This shows the collaborative working environment and the teamwork maintained in this project to learn new things. On the other hand, the multidisciplinary team structure is also explicit in this situation through project team members suggesting other team members being involved in this situation. Multi-disciplinary team shared ideas and provides helps to learn in workplace. The Project Manager's explanation about the reason to change the lighting fittings and the guidance to incorporate that with the design of the triangular panels show the guidance given to the other team members to learn new process especially to successfully achieve the task. The Architect suggesting the building service team consider supplementing with LEDs or sourcing a different fitting shows his previous experience. What to discuss with lighting suppliers in terms of supplier information demonstrates the level of detail the project teams' members are expecting in each situation. Previous experience and level of details of information promotes learning that takes place in work environment.

The Service engineer's concern about the length of the wall mounted 'Jubliee' lighting fittings in the staircase indicates the clarity that he is expecting from the project team members. Various queries arose in this meeting shows that different team members have different prioritisation in their work. The offer made for circular fittings and design team's concern about colour difference of LED demonstrates the prioritisation of the design team. The discussion about the offer between service team and design team in terms of using circular fitting depicts the negotiation between teams where the service team were trying to persuade the Architects to use those circular fittings. Consideration of both the Service engineer's and design team's setting-out on lighting shows the importance of collaborative environment and teamwork.

During this, several questions regarding the length of the wall mounted with light shows the interrogation among the team members. Furthermore, the project engineer asked ''do these fitting change the number?'' and requested the design team to confirm the total number of lightings after the changes. This indicated the project team members are aware of the continuous updates that are happening around the project (continuity). In this meeting, inquiry-based learning shows the importance given to the opinions of all project team members. After discussing the number of lighting fittings and the way it is going to be fixed in the ceiling, team members requested for another meeting. This shows the importance of clarification and cross-checking in construction projects especially when dealing with a huge amount of data.

In relation to this, the BIM Coordinator claimed that although new effective ways are taught to professionals in the industry, they still fail to adopt these new ways of doing things. Following that he stated that:

''We have got QA/QS checklist to measure the quality of work and to see the best way of doing it''.

The key learning aspects from this case study-5 are summarised in Table 4.8.

STRUCTURE	NODES	EVIDENCE
LEARNING CONDITIONS		
Learner's Factors	**Intelligence with the model**	*BIM coordinator while design checks in the 3D model discovered that current lighting fitting does not work without leaving dark-spots*
	Prior knowledge and experience	*BIM coordinator while design checks in the 3D model discovered that current lighting fitting does not work without leaving dark-spots*
Learning Context	**Resources**	*BIM coordinator while conducting the design checks in 3D model has discovered that current lighting does not work without leaving dark-spots*
	Manager support	*Therefore, project manager in a meeting mentioned that building service team has to correct the light fittings to the feature ceiling panels in the 'Egg Theatre' to achieve the lighting levels and to give a continuous strip of light. He then said that it needs to be incorporated into the design of the triangular panels*
	Multidisciplinary team	*Team members present in the meeting suggested the building service team to consider supplementing with LED's or sourcing a different fitting and analyse what to discuss with lighting suppliers in terms of supplier information.*
	Collaborative climate	*During this several questions regarding the length of the wall mounted with light which the team is going with fitting comply with Part L and about LED fittings which the client needs to agree. In addition, project engineer asked that ''does these fitting change the number?'' and requested the design team to confirm the total number of lightings after the changes*
LEARNING PROGRESS		
Activities	**Collaborating and interacting with others**	*In addition the project engineer asked that ''does these fitting change the number?'' and requested the design team to confirm the total number of lightings after the changes.*
	Reflecting and evaluation on own experience	*The Architect from his previous experience suggested the building service team to consider supplementing with LED's or sourcing a different fittings*
PARTICIPATION AND INTERPRETATION		
Alignment	**Visualisation**	*BIM coordinator while design checks in the 3D model discovered that current lighting fitting does not work without leaving dark-spots*
	Awareness	*Therefore, the project manager in a meeting mentioned that building service team has to correct the light fittings to the feature ceiling panels in the 'Egg Theatre' to achieve the lighting levels and to give a continuous strip of light.*
	Explanation	*Therefore the project manager in a meeting mentioned that the building service team has to correct the light fittings to the feature ceiling panels in the 'Egg Theatre' to achieve the lighting levels and to give a continuous strip of light. He then said that it needs to be incorporated into the design of the triangular panels*

	Guidance	*He then said that it needs to be incorporated into the design of the triangular panels.*
	Discussion and negotiation	*The discussion about the offer between service team and design team in terms of using circular fitting and trying to persuade architects to use those circular fittings*
	Advice	*On the other hand, the BIM coordinator suggested to use small thorulux lightings, however the Service engineer needs to confirm the changes in the setting out prior to design team issue stair core setting out information.*
	Clarify	*At the end after discussing about the number of lighting fittings and the way it is going to be fixed in the ceiling team members have requested for another meeting with the same group to clarify the information and methods before execution stage*
	Exploration	*Team members presented in the meeting suggested the building service team to consider to supplementing with LED's or sourcing a different fittings and analyse what to discuss with lighting suppliers in terms of supplier information.*
Insight	**Level of details**	*At the same time Service engineer mentioned that they are concerned about the length of the wall mounted Jubliee lighting fittings in the staircase.*
Engagement	**Staff experience**	*The Architect from his previous experience suggested the building service team to consider supplementing with LED's or sourcing a different fitting*
	Prioritisation	*During this situation circular fittings were offered to design team but they were highly concerned about the colour difference of Passive Infrared Sensor (PIR) and would prefer the origin 'short' vertical fitting if building service team can demonstrate that overall Part L compliance is compromised.*
	Inquiry-based learning	*The project engineer asked that ''does these fitting change the number?'' and requested the design team to confirm the total number of lightings after the changes*
	Consulting-checking	*At the end, after discussing about the number of lighting fittings and the way it is going to be fixed in the ceiling, the team members have requested for another meeting with the same group*
LEARNING OUTCOMES		
Learning outcomes	**Team work**	*Team members present in the meeting suggested the building service team to consider supplementing with LED's or sourcing a different fitting and analyse what to discuss with lighting suppliers in terms of supplier information*
	Decision making and problem solving	*At the end after discussing about the number of lighting fittings and the way it is going to be fixed in the ceiling team members have requested for another meeting with the same group to clarify the information and methods before execution stage*

Table 4.8: Learning aspects from case study-5

4.3.6 Point cloud scan training

OVERALL LEARNING MODEL
This case study was about the usage of point cloud scanning and mark-ups done by the team members. The BIM Coordinator from his prior experience and knowledge identified that mark-ups and point cloud scanning dimensions are different. Therefore, point cloud scanning was encouraged among the team members. Project team members have common interest and were open to adopt new things, therefore processes such as communication, interrogation, explanation, exploration, visualisation were done to understand how to use the point cloud scanning. Professional's confidence levels were increased through the other team member's motivation, however accuracy and level of details on information were taken into consideration. Even though team members were not familiar before about this working method, they were provided with different learning avenues. Finally, collaborating with others and reflecting on people's experience, project team members agreed to use the point cloud scanning results in their work.

<u>Case Study Context</u>

The BIM Coordinator in this meeting reported about the positions building elements which differed in the point cloud scan and mark-ups taken by the team members working on site. In the meeting, the BIM Coordinator questioned the team members

''if you have got the scan results and mark-ups which one would you use to model your elements?''

The Service engineer responding to this question mentioned.

''we haven't used point cloud scan that much and we have purely depended on mark-ups provided to us''.

After this, the BIM Coordinator asked all the project team members to use point cloud scanning and explained to the team members how accurate the results would be. In addition, he described how it helps to get into the individual building sections/elements in the model to see the details, especially when they are built or building elements are installed. Furthermore, he showed how it has been used to identify the missing cable tray in certain areas and emphasised that this is one of the best ways of working. After the explanation, the Service engineer requested the contractors' team to train them to use the point cloud scan to complete their tasks. At the end of the meeting the BIM Coordinator shared all of his scanned documents with the building service team for them to use in their models. However, he asked to check how it is installed on site before using the information. On the other hand, the BIM Coordinator mentioned in the point cloud scan that the elements may also look different sometimes such as the wooden bridge to the sample room in the model might look like duct work, but it is just the ramp. Following this, the BIM Coordinator also shared the 360 panoramic pictures with the team members present in the meeting. The BIM Coordinator, after discussing the usage and benefits of the panoramic view, asked the team members to adopt this new technology, especially while modelling and scheduling. However, for this, the Service engineer mentioned

''We are currently using BIM link to upload everything that is tested into an excel sheet which is easier to use''.

To further explain, the Service engineer said

''We normally provide the excel sheet to the building service team to fill in the details. This will then be returned to me to feed the information in the model. However, the key challenge in this method is to find the location''

In this situation, he said they are still in the process of finding the location of pipeworks. Moreover, he mentioned when an item is split into different places, the team is not sure about the level of details that needs to be filled in the excel sheet (eg. bulbs and fittings). After this discussion, the BIM Coordinator explained that the 360 panoramic view technology is the same process with advanced technologies and assured that adopting this will give more confidence in phase 2 of the project.

Analysis

The discussion on different position of building elements in the point cloud scanning and mark-ups shows the team members are not entirely relient on the model, but instead they are aware of what is happening on site. Both mark-up taken by the team members and point cloud scanning indicate different resources such as human resources and artifacts are employed to solve this issue. Artifact in this case study means any object made by human being. The question raised by the BIM Coordinator about the information used for the building elements demonstrates the reassurance of using the right information. The Service engineer's response for using mark-ups or point cloud scanning shows that team is not open to other related project team members instead trying to do things in different or new ways. From the observation it had a negative on learning in workplace. On the other hand, this also made the learning in workplace complex and slow. The Service engineer accepting that they are relient on mark-ups indicates that they are comfortable with the methods they use and resist to change to new methods without any support. The BIM coordinator persuading and encouraging the project team members to adopt point cloud scanning indicates his thinking 'out of the box'. In this meeting, the BIM Coordinator sharing the benefits and challenges of using point cloud scanning shows his wiliness to share his knowledge with his colleagues. Moreover, this also indicates the guidance, motivation, and support he provides to his team to learn this new technology. The Service engineer requesting the contractor's team to get training on point cloud scanning to complete their tasks indicates team members have number of learning avenues available to learn new technologies. Moreover, the BIM Coordinator sharing his scanned documents with the service team depicts how team members share the information among the project team. However, the BIM Coordinator, asking the service team to check how the collected information is used on site, shows that the BIM Coordinator is aware of what is happening in real life situation and checking it before executing their plans. Highlighting the challenges faced in point cloud scanning demonstrates the awareness of using the technology in the right way. The BIM Coordinator sharing the panoramic view helped the team members to visualise things. In addition, this also shows various resources are used in this project to resolve the issues and make decisions. The BIM Coordinator recommending the team members to adopt point cloud scanning in modelling and scheduling shows the encouragement and motivation provided to the project team members. Supporting this, the BIM Coordinator also highlighted that the communication is better among the BIM team compared to the entire the project team. The effective communication in workplace environment helps to learn quicker but maintaining effective communication is a challenge. BIM Coordinator stated:

''BIM team is very active and they interact with other in regular basis but communication is less among the entire project team members''

Service engineer explaining about the process of using BIM Link shows that team members are happy to share information, which they have experience on. During this, his indication on the challenges faced in using BIM Link shows that he still has concerns with the technology that he has adopted for this project. At lLastly, the BIM Coordinator, persuading the team on using 360 panoramic, depicts how well information is shared among the team members and the motivation provided to them to try the new technologies in completing their tasks. The key learning aspects from this case study-6 are summarised in Table 4.9.

STRUCTURE	NODES	EVIDENCE
LEARNING CONDITIONS		
Learner's Factors	**Real life situation**	*In the meeting the BIM coordinator raised a question which is ‘‘if you got the scan results and mark-ups, which one would you use to model your elements?’’. The Service engineer for this question answered that they haven’t used point cloud scan that much and purely depend on mark-ups provided to them.*
	Prior knowledge and experience	*The BIM coordinator started to discuss about the positions which differed in the point cloud scan and mark-ups taken by the team members working on site.*
Learning Context	**Resources**	*The BIM coordinator started to discuss about the positions, which differed in the point cloud scan and mark-ups taken by the team members working on site*
	Multidisciplinary team	*Involvement of the BIM coordinator, Service engineer, and other team members during learning about point cloud scanning.*
	Collaborative climate	*Moreover, he showed how it is useful to identify the missing cable tray in certain areas and emphasised that this is one of the best way of working. After the explanation, Service engineer asked the contractors team to train them to use point cloud scan to complete their tasks*
LEARNING PROGRESS		
Activities	**Tackling new challenges or tasks**	*The BIM coordinator started to discuss about the positions which differed in the point cloud scan and mark-ups taken by the team members working on site*
	Doing the job itself	*Moreover, he showed how it is useful to identify the missing cable tray in certain areas and emphasised that this is one of the best way of working*
	Collaborating and interacting with others	*In the meeting, the BIM coordinator raised a question which is ‘‘if you got the scan results and mark-ups, which one would you use to model your elements?’’. The Service engineer for this question answered that they haven’t used point cloud scan that much and purely depend on mark ups provided to them.*
PARTICIPATION AND INTERPRETATION		
Alignment	**Awareness**	*In the meeting, the BIM coordinator raised a question which is ‘‘if you got the scan results and mark-ups, which one would you use to model your elements?’’.*
	Interrogation	*In the meeting, the BIM coordinator raised a question, which is ‘‘if you got the scan results and mark-ups, which one would you use to model your elements?’’.*
	Communication	*In the meeting, the BIM coordinator raised a question, which is ‘‘if you got the scan results and mark-ups which one would you use to model your elements?’’. The Service engineer for this question answered that they haven’t used point cloud scan that much and purely depend on mark ups provided to them.*
	Familiarity	*The Service engineer for this question answered that they haven’t used point cloud scan that much and purely depend on mark ups provided to them.*
	Sharing information	*The BIM coordinator shared all of his scanned documents with the building service team for them to use in their models*

	Explanation	*BIM Coordinator explained how it helps to go through into the sections and see the details such as when was these installed.*
	Motivation	*BIM Coordinator explained how it helps to go through into the sections and see the details such as when was these installed. Moreover, he showed how it is useful to identify the missing cable tray in certain areas and emphasised that this is one of the best way of working*
	Advice	*The Service engineer said they normally give the excel sheet to the building service team to fill in the details and after that they will return back to them and then it will be fed in to the model. This is how they do it without using the new systems*
Insight	**Exploration**	*So far, the Service engineer said he is still analysing to find a space for pipework*
Engagement	**Mutuality : common interest**	*Moreover, at the end of the meeting, the BIM coordinator shared all of his scanned documents with the building service team for them to use in their models*
	Learning avenues	*Moreover, at the end of the meeting the BIM coordinator shared all of his scanned documents with the building service team for them to use in their models*
	Consulting-checking	*But the BIM coordinator emphasised to check how it is actually installed in the site before using the information*
	Awareness	*In addition, BIM Coordinator said in point cloud scan the elements may also look different sometimes such as the wooden bridge to the sample room in the model might look like duct work but it is just the ramp*
	Visualisation	*On top of that, the BIM coordinator also shared the 360 panoramic pictures for clear visualizations, and he explained the photographic view.*
	Confidence	*During this, the Service engineering team mentioned they are currently using BIM link through putting everything that is tested into an excel sheet which is more easy to use. The BIM coordinator mentioned that it is exactly the same process in phase 2*
	Accuracy	*The only issue Service engineer highlighted was about the location. So far, he said he hasn't found to assign space for pipework to a space*
	Level of details	*When a particular time is split into different places he said they are not quite sure what level of details needs to be filled in the excel sheet (eg.bulbs and fittings).*
LEARNING OUTCOMES		
Learning outcomes	**Team work**	*In the meeting, the BIM coordinator raised a question, which is ''if you got the scan results and mark-ups which one would you use to model your elements?''. The Service engineer for this question answered that they haven't used point cloud scan that much and purely depend on mark-ups provided to them.*
	Decision making and problem solving	*Moreover, at the end of the meeting the BIM coordinator shared all of his scanned documents with the building service team for them to use in their models to start using point cloud scanning.*

Table 4.9: Learning aspects from case study-6

4.4 Summary

This chapter has provided information on how learning is perceived in BIM construction projects, what are the opportunities provided in BIM construction projects, and the learning factors that influence individuals/teams those impacts on learning in BIM construction projects which is achieve thirough data analysis and findings. The findings from this analysis shows that currently there is no structured way of learning in BIM construction projects. Instead, it is learned through a number of learning opportunities. The findings from the case studies explain how project participants learn in BIM-enabled construction projects. This indicates that learning in the workplace initially needs factors related to individual/team along with suitable learning context. Consequently, learning in the workplace has been developed through participation of project team members. During this project, participants have journeyed through the process of learning to interpret the message or action in the right manner. From the insignt of the results, alignment and engagement plays an important part in learning process that occurs in the workplace. Overall, this data analysis and finding chapter helped to finalise the themes and sub-themes that are essential to develop a workplace- base model for BIM-enabled construction projects.The detail explanation on how learning took place and the connection between the nodes are discussed in the next chapter.

CHAPTER 5: DISCUSSION AND DEVELOPEMNT OF THE MODEL

5.0 Introduction

The overall findings presented in chapter 4 provides a holistic understanding on how learning is taking place in BIM-enabled construction projects. This shows that learning in the workplace is a by-product that occurs in day to day life. This means rather than occurring by itself learning is a result of different influences.The overall findings indicated that the current learning that happens in work environments is a social process and is a combination of learning new things and expanding existing knowledge related to work. These findings also showed that the learning approach in the workplace is influenced by several learning aspects that are related to individuals, environment, process, and outcomes. On the other hand, these findings show that there is an urge to focus on the key learning aspects, especially in the workplace to cope with the digitally-driven environment. Therefore, through using these findings, this chapter will discuss the learning aspects that influences the different stages of learning that occurs in the workplace. This will then lead to the development of the conceptual model for learning in the workplace.The purpose of this model is to understand the learning process in workplace and to identify how workplace-based learning is used in workplace context.

Firstly, the chapter discusses the importance of learning in the workplace which is derived from ananlsis and findings. Subsequently, this chapter also evaluates the concept of Connectivism through looking at the shift in how learning activities are conventionally perceived. This is to highlight the connected learning that accommodates the learning aspects within the working environment. Next, it focuses on the learning in the workplace model that has been built with three key stages: ***Learning Conditions***, ***Learning Progress,*** and ***Learning Outcomes***. These themes are related to these stages through considering how those themes are impacting on learning process. The themes of **Learning Conditions** is focused on learners and the context where learning occurs. **Learning progress** is related to how project participants approach the learning in the work environment. In this section, the key learning themes '***Participation***' and '***Interpretation***' are discussed in detail to show how they contribute to create the connected learning in the workplace Furthermore, the combination of ***Participation*** and ***Interpretation*** is formed with three main learning modes: ***Alignment***, ***Insight*** and ***Engagement*** to explore what triggers, imposes, encourages or limits the learning that takes place in the workplace. Then the chapter returns to discuss the **Learning outcomes** that directly depends on **Learning Conditions** and **Learning Progress**. These findings are merged to develop a model for learning in the workplace in relation to BIM-enabled construction projects by conducting a cross analysis and cross referencing with the findings and literature sources. Overall, this chapter contributes to the connected learning in the workplace, especially to respond the changes that take place in BIM-enabled construction projects.

5.1 Need for Learning in workplace

Learning in the workplace, which is beyond acquiring and assimilating knowledge and skills, is currently evolving due to rapidly changing technologies. This learning transformation has led to the provision of better services and high-value products to the customers (CEEMET, 2016). In addition, recent reports have showed that this new way of learning in the workplace has helped to shape the strategic directions, reskill and upskill employees, and open up innovative opportunities to engage and monitor business performance (LinkedIn Learning, 2020). Similarly, OECD (2016) reported that this has also reduced the demand for routine and manual tasks. These arguments are supported through the quotations adopted from the interviews conducted in phase 2 of the research. For an example *I4* states:

''The client wanted and had the vision of managing the entire estate using BIM. They only wanted to use Revit in order keep everything up-to-dated rather than using other software such as AutoCAD and others.. .''

On the other hand, *I6* mentioned*:*

''It gives two benefits at the same times which is visualizing and modelling. So it is quick, cost effective and saves time. On the other hand, because of templates and Revit families it is automated as well. This is a greater way of controlling what we are output''.

According to Ernst and Young LLP (2011), this learning transformation in the physical world is replicated through digital communities that include several digital platforms and tools. Berger (2016) argued that digital maturity is predominantly about understanding the technology, but also what this digital transformation means for the business. According to World Economic Forum (2021), implementing digital technologies in each stage and processes of construction projects add value to the overall achievement. Therefore, it is vital to rethink and redesign the construction environment to deliver successful projects. Besné et al, (2021) believe one of the key causes for poor performance in construction projects is due to not having effective learning approach and flexible learning environment adopted in the industry. Likewise, Poell (2013) and Tynjälä (2008) believed learning in the workplace is predominantly determined by complex social practices and is highly connected to the efficiency of types of learning. Therefore, there is a need for learning in the workplace to create a social, material, and informational environment through key figures, agents of labour organisation, and employees to facilitate learning within the team. The importance of learning in practice has been highlighted by a number of interviewees. For an example *I3* stated:

''But it was the practice element that has given me the confident. There is always different interpersonal skills you can always work on and adopt different styles and approaches to get the people in the right space. So again, I think you have to learn and practice those elements in your working environment''.

An Economic Forum report (2021) reported that workplaces are now forced to progress towards digitalisation. However, growing digital dependency, increasing automation, information suppression and manipulation, outdated regulations, and lack of right skills and capabilities are identified as barriers of the digital gap. Fenwick (2010) mentioned that learning and knowledge are interrelated in an iterative, mutually reinforcing process within a project environment. Supporting this, Eraut (2004) and Illeris (2004) argue that the concept of learning has shifted from traditional learning, which only focuses on formal education, and now has extended to the idea of 'Learning in the workplace'. Findings from the semi-structured interviews (sections 4.1.1 to 4.1.3) and case study findings (sections 4.3.1 to 4.3.6) shows that digitalisation is connected with different learning aspects. Understanding these learning aspects shows how it influences the learning outputs such as decision making, task performance, enhancing skills and capabilities, improving the quality, personal development and problem solving. Moreover, McKinsey and Company (2020) claimed that the construction industry has developed optimistic ways of dealing with these issues related to digitalisation through concentrating on networked social learning. To cope with this digital transformation, participants should not limit themselves with knowledge accumulation: instead, they need to start making meaning out of the suitable learning aspects in their working environment through participation and knowledge creation. The awareness, understanding and readiness for learning in the workplace will lead towards better outcomes. The findings from the semi-structured interviews (4.1.1 to 4.1.3) and case study findings (4.3.1 to 4.3.6) show that learning in the workplace among the project participants is essential to deliver successful construction projects. Morever, this data analysis and findings have identified the learning themes and sub-themes that influences the workplace- base learning in BIM-enabled construction projects.

For example, *I10* mentioned:

''I learnt BIM through 2 day course from Exactal on Revit. Also when I came across to BAM it gave me the opportunity to play with the software and watch you tube videos and just make 100s and 100s of mistakes''.

Likewise, the case study findings have depicted that learning in workplaces happens in various ways. For example, the finding in Mechanical and Electrical installation issues (Section 4.3.1) shows that learning in that situation happens through collaboration, communication, using prior knowledge, and research. This has helped the project participants to solve problems and make quick decisions through connecting different project participants and information within and outside the project. On the other hand, case study findings also revealed that having a common interest and common space are important to work collectively as a team to achieve the project goals. The case study findings show the concept of common interest highlighted in the idea of the Community of Practice (Wenger, 1998) has a greater influence in learning in the workplace. According to the findings, learners' common interest in learning new things and developing existing knowledge depend on how project participants participate and interact in work environment to understand the situation and relevant information. Furthermore, learners' common interest in learning in the workplace also helped to analyse the problem in more detail before finding a solution. In the semi-structured interview *I19* has clearly stated that:

''So everything was fully coordinated and it was fully collaborative team where everyone had pain shared and gain shared within the design and the delivery. With the team contracting everybody had the long term engagement with the client, everybody had the common interest to get a common goal and it just works.. .''

In relation to this, it is noticed that all these events in BIM construction projects are centred on the BIM federated model, which is considered as a common space for all project participants involved in the project. In this BIM-enabled consctrucion project, as Nonaka and Konno (1998) mentioned, this common space in BIM-enabled construction projects is used to build up relationships among physical, virtual, and mental spaces to form a forum develop individual or collective knowledge. For example, in case study 4 (4.3.4), the issue regarding pipework installation is analysed through using the BIM federated model along with the 2D drawings and specifications. During this, it is noticed that project participants express their views and problems in the meeting referring to this BIM model. This demonstrates that the BIM federated model is acting as a common space for project participants and also establish a shared understanding of the project among the project team members. Furthermore, as Engeström and Engeström, (1999) stated, project participants have utilised this common space to solve the complex activities, which are difficult to resolve as an individual. For example, again in case study 4 (4.3.4), the BIM Coordinator contacted the project manager to discuss the pipes clashing with the wall rather than going straight through. In this, the BIM model has acted as a common space between the BIM Coordinator and project manager allowing them to discuss this issue in detail.

Interestingly in this study, the overall findings from semi-structured interviews and case study findings show that the learning that takes place in the work environment makes meaning through understanding the connection between several learning aspects related to the specific situations. Findings revealed that this connected approach along with project participants' implicit and explicit knowledge has not only supported to accomplish the tasks in the digitally-driven project environment, but also to take effective decisions and solve unexpected problems. To understand the connection between the themes and sub-themes identified from the data analysis and findings the researcher in this study has adopted Connectivism concept. The end purpose of this is to develop a model for workplace-based learning for BIM- enabled construction projects.

5.2 Learning in the workplace through the lens of Connectivism

The BIM-enabled construction projects chosen for this study have indicated that learning in the workplace is more than the acquisition of knowledge. Complexities in BIM construction projects are more often observed due to different levels of understanding and backgrounds. Hence, there is a necessity to understand complex events and learn from them. According to the findings, these confusions and misunderstandings are resolved during the collaborative discussion among the project participants (section 4.2). However, complexity of learning has been experienced through the challenges (eg information overloaded, ignorance, misconception) faced during learning in the workplace (section 4.2). Therefore, this study has intended to examine the learning that takes place in BIM construction projects in a novel way of using the lens of Connectivism. The main purpose of viewing the learning network in this way is to understand the learning aspects that influence the learning that takes place in BIM construction projects and to understand how learning can take place in digitally enabled projects. In addition, this study has adopted Connectivism to explore how learning themes and sub-themes in the workplace are meaningfully connected to allow more interactions to reach relevant information within the network. Understanding the connections how these themes and sub-themes are dependent on each other helps the researcher to understand the workplace-based learning that happens in BIM construction projects. Moreover, this will allow to undersand the skills that are essential to work with BIM environment and how learning needs to develop to overcome the issues faced in BIM construction project environment.

This study shows that learning in the BIM environment is mainly achieved through creating a network with people, information, context, and other learning elements. Project participants in the BIM workplace have dealt with unexpected issues at all stages of projects. To tackle these situations, different coordination and interaction techniques were used. Heylighen (2008) states that linking the connections and understanding the patterns between the connections within a network help to learn something new. Therefore, focusing more on how these learning themes and sub-themes connect might be beneficial to make progress in the ever-changing digital era.

The case study findings (4.3.1 to 4.3.6) show that learning is moving towards a connected world due to the development of digital technologies. Diverse learning avenues and approaches adopted while learning in the workplace in BIM-enabled projects show that there is no specific way or restriction to develop the knowledge. For example, in case study 4.3.1 the discussion among BIM coordinators shows that a combination of mark-ups, photographic evidence, and a 3D model are used to design the complex duct that is associated with a number of services.

In this study, as Downes (2010) mentioned, maintaining the openness has promoted the connected learning through sharing knowledge and experiences among the project participants. In other words, this refers to willingness to share the information. This has then led them to build up their knowledge (Saadatmand and Kumpulainen, 2014) through developing from their current state of knowledge or learning new things from other participants. The characteristic of openness is observed in case study finding 4.3.2. In this, an architect was advised to resolve the position of the vent above the door. Using his prior experience, he suggested designing a taller, narrower vent. This shows the openness of the architect to share the knowledge and understanding that he had gained from the model and previous projects.

On the other hand, being open in the collaborative environment has led to making quick decisions and learning new things in a short period of time. The case studies (4.3.1 to 4.3.6) demonstrate that project participants in BIM-enabled construction projects work efficiently in a collaborative environment. This is because each task involves a number of elements of information. Hence, considering different project participants' views and opinions is useful in making appropriate decisions. For example, in case study 4.3.2 discussion about a vent was not limited among the team members present in the meeting. Instead, they also consulted the project participants working on site to gather more detailed information before making a decision. Working as a team in the collaborative environment not only helped to make a quick and effective decision, but also built project participants' confidence in making judgments in this issue.

Project participants in the BIM-enabled workplace are centred on the federated BIM model. Therefore, most of the activities in BIM-enabled construction projects are achieved through interacting with the model and project participants. This agrees with Rafaeli's definition of interactivity ". . . an expression of the extent that in each series of communication exchanges, any third (or later) transmission (or message) is related to the degree to which previous exchanges referred to even earlier transmissions" (Rafaeli 1988: 111). The interaction, which represents the connectedness, can be observed in almost all of the case studies (4.3.1 to 4.3.6). In other words, on of the purpose of digital transformation is about creating more connected project team, industry through team working and true collaboration BIM-enabled construction projects.

One example is, in case study 4.3.5, while fitting the lights in the halo effect, a number of questions were raised regarding the length of the wall with wall-mounted lights and the number of lighting units by both design and project team members. This highlights the importance of interaction among the related project participants in resolving an issue within the workplace. In addition, interaction is a way of keeping project participants within the loop and it also keeps them up-to-date. This ability to connect with others is sometimes referred to as 'true collaboration', which is grounded in the networking aspects of Connectivism (Bannister, 2016). As Wenger (1998) mentioned, this principle has been widely seen in the community involved in BIM-enabled construction projects, while sharing information, learning new things, tacking new issues, and making important decisions. However, as Richardson and Mancabelli (2011) indicated, interactivity is also observed among the personal network mainly during the interaction between the models and project participants (section 4.2). Interactivity in this project indicates the process of more than one person working together to achieve a task. From the observations, interactivity seems to be the key factor for the interaction between two or more people.

Another important principle, Autonomy, is highlighted in the semi-structured interviews. Autonomy, which is about self-directed learning, is mainly incorporated in the initial stage of learning BIM technology. According to Mackness *et al* (2010), autonomy allows the learner to choose where, when, how, with whom, and even what to learn. The following quotations from *I3* and *I12*, respectively from the semi-structured interviews shows self-directed learning is part and partial of learning in the workplace.

''But from the pure training perspective there is so much free information out there (YouTube in BIM). This is the real time to make the strategic image changes but there are too many silo process, self-interest going around.''

''Other than that everything is been really self-taught, try to learn from error and I think this is where lot of people got to learn from really.''

Although, these self-directed learning is essential having formal training provided within/by organisation fulfils the workplace-based learning in BIM projects. Learning in Connectivism concepts starts with an individual learning hence autonomy in this view is about being their self.

Even though Connectivism is still in the development stage and needs further refinement, this study has adopted it to examine learning in the workplace from a different viewpoint beyond personal boundaries. This is targeted through understanding the formation of connections in a digital network. The principles discussed above in this section have played an important role in meaningfully connecting the learning aspects that are essential for learning in workplace. This has not only helped to understand the structure of knowledge in the workplace, but also helped to recognise the learning patterns suitable for these situations. Moreover, these principles of Connectivism have encouraged project participants in BIM environments to learn and complete the construction process in a short period of time. Case study findings show that the connectedness in the BIM-enabled projects is strengthened by project participants' interpretation of the information and actions along with active participation in learning networks (4.3.1 to 4.3.6). The above discussion indicates the urge for the consideration of connected view in technology-driven workplaces. Therefore, the next section discusses the model for learning in the workplace that includes learning themes and sub-themes that influence learning in BIM-enabled construction projects.

5.3 A Model for Learning in the workplace

Information on how learning is happening in the workplace in BIM-enabled construction projects was collected during this research. Findings of this study have identified the key learning aspects that influences learning in the workplace. These learning themes and sub-themes have been categorised into three different stages which were originally derived from literature. The final model has been presented in Figure 5.1 along with the connections between the three stages which is obtained through the data analysis and findings of this study. The development of the model is discussed in following sections mainly focusing on '***Participation***' and '***Interpretation***' that influence learning that takes place in the workplace. Combination of these themes is given more important in this study because the findings of this research show these themes which are dependent to each other mainly drives the workplace-based learning in BIM-enabled construction projects. Different aspects of learning that affect learning in the workplace have been identified during both the semi-structured interviews and case study observations. Project participants highlighted that there is an urgent need for a connected approach for learning to cope with the digitalising world. This study has developed a learning model for workplaces with key learning themes and sub-themes which helps to understand connected learning environment. Moreover, this characteristic of a connected approach would be beneficial to improve knowledge and skills, capabilities and the competencies of professionals to adopt and work with technology-enabled projects (NBS,2021). Moreover, having these appropriate skills and competencies will encourage more professionals to adopt new technologies such as BIM in the construction projects.

5.3.1 Transition for the Learning Model for workplace practice in digitally-enabled projects

Established learning themes and sub-themes identified from the surroundings of the learning environment have explicitly showed that learning in the workplace needed more than the formal learning that is taught in universities and the informal learning that takes place in the work environment. Instead of connecting these learning themes and sub-themes in a meaningful way it is vital to understand how learning is taking place in the work environment especially to achieve the desired outcomes in this digital environment (NBS, 2021.) The need for a suitable workplace-based learning can be overcome by having a suitable model of learning in the workplace. This can be achieved through identifying the key learning themes and sub-themes, understanding when these learning aspects can be used in a learning environment and understanding how they are linked to each other. However, identifying the key learning aspects and finding the connections to achieve the final outcome is still challenging.

Previous studies have investigated how project learning takes place in construction projects (Sense, 2003; Illeris, 2002; Billett, 2004), whereas others have explored learning in the workplace (Eruat, 2004; Illeris, 2004; Tynjälä, 2013). Following that, the introduction of digitalisation within construction projects has been explored by several scholars (Geno and Clay, 2016; Berger and Frey, 2016). However, learning in the workplace in the digital era is rarely discussed. Therefore, this research is undertaken to identify the key learning aspects and to see how they are linked from the view of Connectivism (Siemens and Downs, 2009; Chatti; 2007). However, bringing all these ideas together is novel where the learning in the workplace is examined through the lens of Connectivism in the digital era.

The root for 'Learning in workplace model for BIM construction projects' is generated by Tynjälä (2013) and Briggs (1999). There are also other models for learning in workplace introduced by Rylatt (1994), Mathew (1999) and Jørgensen and Warring (2001), which are discussed in detail in chapter 2. Tynjälä's (2013) learning model was chosen as a base for this new learning model for the workplace because it has considered both socio-cultural and technical-organisational environment, which is suitable for the digital environment. Although Tynjälä's (2013) and Wenger's (1998) theories provide some understanding for the formation of this model, it is 'also' centred on the idea of Connectivism (Siemens and Downs, 2009). The model for learning in the workplace created with the findings is divided into three stages: Learning conditions, Learning progress, and Learning outcomes. Each heading embedded in the model has additional sub-themes that influence in practice in BIM-enabled construction projects. On a similar note, '***Participation***' and '***Interpretation***' play a significant role in learning in the workplace.

To strengthen these, the aspects of ***Alignmen***t, ***Insight*** and ***Engagement*** introduced by Wenger has been brought together into **participation** and **interpretation** to produce efficient workplace-based learning. Alignment in this workplace-based learning is about building the relevant learning factors together to a common point to successfully achieve a task. Insight, on the other hand, is about making meaning for the actions that takes place in a project. Finally, engagement referes to building the community, inventiveness and creativity among the resources available in a learning environment. Indeed, **Participation** and **Interpretation** are crucial for identifying what triggers, imposes, encourages or limits the learning that takes place in practice, rather than just influencing the project outcomes. On the other hand, the case study findings show (4.3.1 to 4.3.6) that **Participation** and **Interpretation** are inseparable from learning in the workplace. Interpretation, while participating in the workplace not only helps to solve the identified issues in a situation but also develops knowledge and skills through the work experience gained through practice. Examining learning in the workplace from a connected view is not without contradiction. Flexible learning opportunities and utilisation of the learning aspects in the BIM project environment have encouraged focusing on short-term arrangements for the problems identified in the project environment, rather than looking at the longer-term outlook of the practices. This is essential to successfully complete future projects. However, in these continuous technological changes, short-term arrangements are the initial step to achieve the long-term project goals. The interconnections identified in the workplace will allow professionals to adopt the suitable learning approach and strategies for their projects. Moreover, this connected learning shapes their skills and preserves their jobs, although their job titles or roles may change in the project.

Interestingly, in case study 4.3.4, participation, along with interpretation, can be clearly noticed while the project team was investigating the pipework, which is differently installed to what was discussed in the project specification on site. During this case study, the BIM Coordinator interpreted the issue to the other project team members present in the meeting with the aid of the BIM model. After looking at the model, the site manager explained that they have designed the pipework according to the given mark-ups. However, the Site manager mentioned that even though the pipework is designed as per the mark-ups, it has been installed differently on site. From this, it is understandable that a conclusion about an issue cannot be resolved by an individual in most cases, especially in massive construction projects. Instead, participation of various professionals such as the BIM Coordinator, site manager, and site engineer and their collective interpretation of the information will help to find a solution for an issue.

The case study findings (4.3.1 to 4.3.6) show that Participation and Interpretation are influenced by three learning modes: Insight, Engagement and Alignment. These categories of Participation and Interpretation are derived from data analysis and findings but at the same time these are also acknowledged in Wenger's community of Practice (Wenger, 1998). The Insight sub-theme in learning progress includes orientation, reflection, and exploration which help the professionals involved in the project to understand the problems that occur. Meantime, convergence and coordination included in Alignment play an important role in bringing all the relevant influential features together to prepare the project team members to get involved in the issues identified in the project situation. Along with these two factors, Engagement finally drives them to participate in the situation to sort out the problems identified in the project through features of mutuality, continuity, and competencies. Findings from this study shows all three influences need to be applied at the same time to interpret an activity, while participating in the project environment. In a semi-structured interview, *I2* stated that it is important to understand the basics before starting to learn something

''I was required to understand Bently programming. But it didn't take much time because I know all the basics and with my domain experiences it's all about reviewing the differences''.

Further supporting this, the finding from 4.3.6 shows that understanding the basics of point cloud scanning and setting up a suitable environment to learn point cloud scanning are important to attain its benefits in the BIM-enabled construction projects. These findings demonstrate the impact of Learner's Factors and Learning Context for learning to happen in the workplace .This then leads to learning outcomes that are generated through the combination of these sub-themes. The learning outcome is not restricted to one thing (See Figure 5.1). For example, it could be a personal development, continuous learning or task performance.

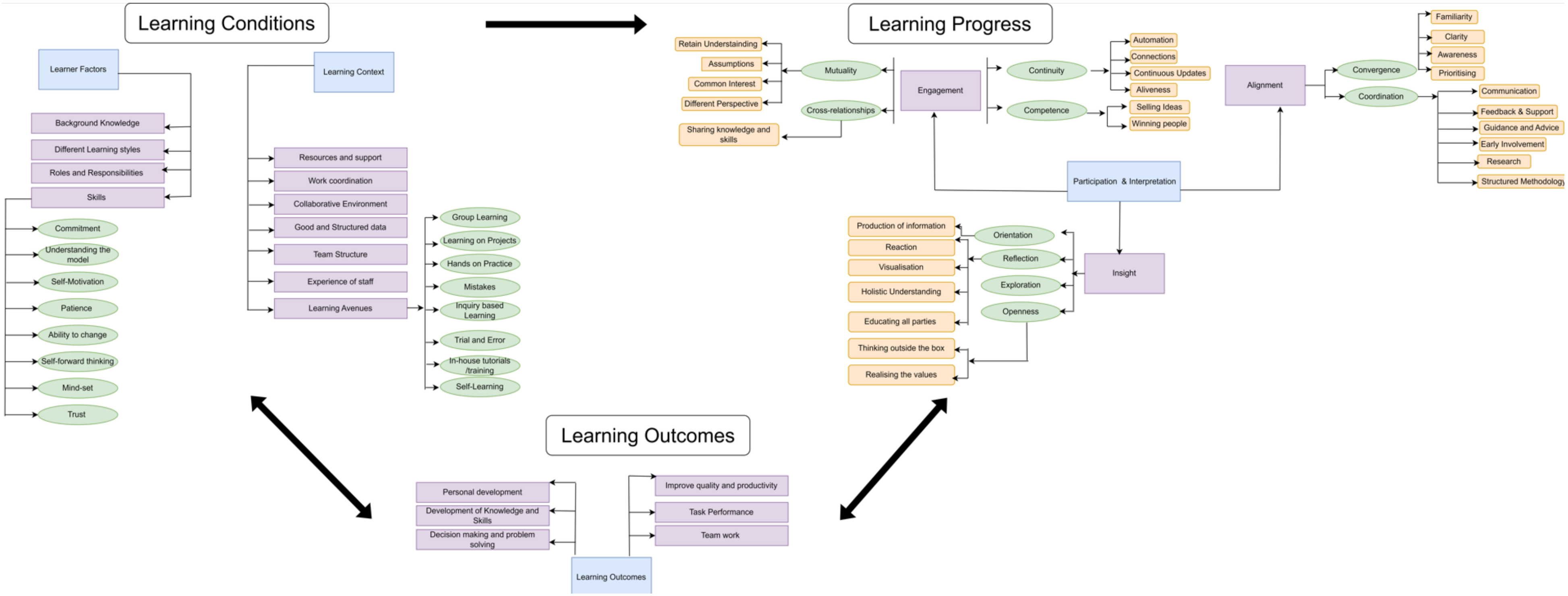

Figure 5.1: Model for Workplace-base Learning

As mentioned previously, the learning focused on the workplace is based on three main stages: *Learning Conditions*, *Learning Progress* and *Learning Outcomes*. From the findings, learning in the workplace in BIM construction projects has not completely ignored the traditional formal learning from educational institutions. This is included in *Learning Context* which is an important stage to learn in the workplace. This is because this is the stage the learner prepares themselves to learn in a workplace environment. At the same time, it does not mean that it is free from the limitations caused by the dynamic nature of the project environment. On the other hand, Leaner's Factors play an important part which is an input from the learner's side. Learning starts from an individual therefore, identifying what is needed from a individual point of few especially before learning takes place is crucial to successfully accomplish the given task. '*Learning Context*' and '*Learner's Factors*' are not contributing to each other. This is because characteristics of each individual are different whereas the sub-themes under learning is common for all the individuals if they are ready to learn in BIM-enabled construction projects. However, the combination of *Learning Context'* and '*Learner's Factors*' influence '*Learning Progress*'. This is again knowing the fundamentals of learning and readiness to learn is key to start involving in the learning progress.

'*Learning Progress*' has a major contribution to learning in the workplace. The contribution of *Participation* and *Interpretation* in digitally enabled construction projects is substantial. The interplay between these novel aspects is affected by three key learning modes: *Engagement*, *Insight* and *Alignment*. This is because understanding the insight of the project and bring all learning related aspects to common point through an effective engagement is vital to learn successfully in a workplace-based environment. Ignoring any of these learning modes will lead to lack of learning in workplace environment. All these finally lead to '*Learning Outcomes*', which are the end products that are achieved through learning in the workplace. Figure 5.1 illustrates the flow of learning that happens in the workplace in BIM-enabled construction projects. Findings show that 'Learning Conditions' has an effect on both 'Learning Progress' and 'Learning Outcomes'. As mentioned above knowing the fundamental to learn and readiness to learn in an environment can decide how they want to learn and what the learner wants to achieve at the end of the learning process.

For example, in 4.3.6, setting up the environment and building up the fundamental knowledge and skills needed for point cloud scanning enable the project participant to understand, focus, and commit on learning point cloud scanning. Focusing more on learning conditions in the first place saves both time and cost. Meantime, '*Learning Outcomes*' has an impact on both '*Learning Conditions*' and '*Learning Progress*'. For an example if the learning outcome is performing a task, then the learner can chose suitable skills and develop an appropriate background knowledge (Learning factor). Moreover, the leaner can select a suitable learning avenue along with relevan resources to perform the task (learning context). This shows how learner is prepared in the Learning Condition stage. Next, knowing what task to perform the learner can participate in relevant actions through interpreting things that focus on specificthe task. During this learner's insight will be performing the task in a successful way hence the learner can align the people and resources accordingly through effective engagement. This shows how Learning progress is achieved in this specifc situation.

Some of the learning themes and sub-themes are also derived from phase 2 semi-structured interviews. For example, *I4*, in a semi-structured interview, mentioned that certain skills and understanding are essential to perform in the given job role and he believed that this can be achieved through basic training.

''So I said there is a base level of training that everyone gets which gives base level of understanding and also the absolute skills set that relate to specific jobs''

On the other hand, according to the *learning outcome*, *learning progress* will change. For example, in 4.3.6 project participants want to start using point cloud scanning therefore they started to communicate with the other professionals who have knowledge on point cloud scanning (*Engagement*). They also started gathering all the essential information about point cloud scanning (*Alignmen*t) and were ready to explore and reflect on it (*Insight*).

However, 'Learning Progress' only contributes to the 'Learning Outcomes'. This can be noticed in all case studies (4.3.1 to 4.3.6). During this, learning progress takes place in order to resolve the issues raised in the project. For example, in 4.3.3, to use the laser scanning images sent via email by the BIM Auditor is analysed by the BIM Coordinator (*Insight*). The results is then compared with the raw data which shows the *Alignment* taking place in the work environment through looking at how resources such as people, information, equipments and facilities utilised during the learning process. Finally, professionals start sharing their views on using laser scanning, indicating the *Engagement* in the workplace.

The workplace-based model that has been developed in this study has not been further validated. This is because all the themes and sub-themes that brough together to develop this model is derived through the data analysis and findings (both semi-structured interviews and case study approach).Hence, there is no need for further validation to show the model is performing as intented and solves the problem it was designed to solve.5.3.2 Key Learning aspects in learning in the workplace in digitally- enabled construction projects

This section highlights the most important learning aspects that influence while learning in workplace is happening in BIM construction projects. Some have been frequently referred in the literature; however, it is important to understand how they have changed or altered in digital-enabled construction projects. The purpose of this section is to explore how these sub-themes are categorised under suitable themes and stages. The fundamental learning aspects for the digitally enabled workplace were initially adopted from the model for learning in the workplace conceptualised by Tynjälä (2013), and Briggs's (1999) 3-P model which is already discussed under Conceptualisation of the learning model (Section 2.4.3). Even though some similar responses were observed in the BIM construction projects, many different aspects influenced learning in the workplace to achieve the goals in BIM-enabled construction projects. Each aspect is discussed in detail in the following sections.

5.3.2.1 Learning Conditions

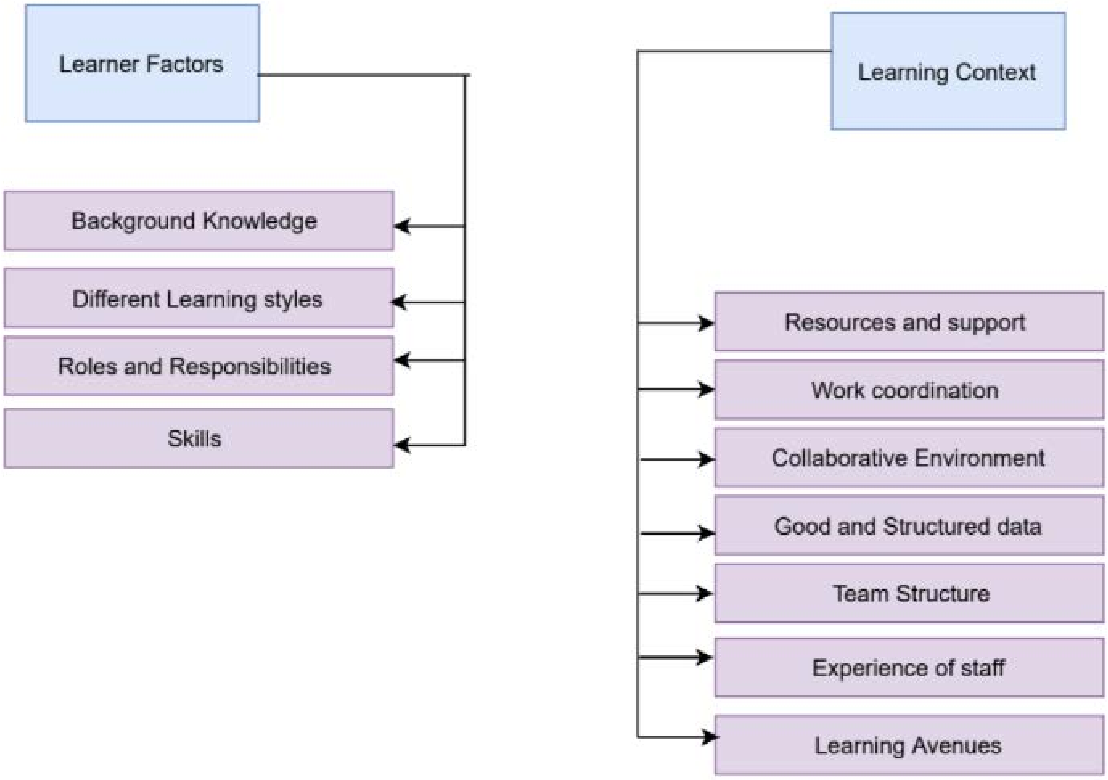

Figure 5.2: Learning Conditions

The *Learning conditions* aspect comprises the basic learning elements to learn in practice. The Learning in the workplace context includes two elements, which is the people-related element (Learner factors) and the element related to Learning context. Sub elements in '*Learner factors*' focus on the knowledge and skills project participants need to have, while stepping into BIM construction projects. On the other hand, '*Learning Context'* is a set of circumstances that enable people to learn in practice-based work environments, which includes both technical-organisational and socio-cultural learning contexts. Findings (4.1.1 to 4.1.3 and 4.3.1 to 4.3.6) derived from the analysis showed that elements within Learning Conditions sets the scene with appropriate environment and abilities to work in BIM-enabled construction projects. In addition, it helped them to mould their key ideas and interests to suit the construction projects. The findings also showed that Learning Conditions and Leaners' factors are not dependent to each other. Learner's factors are different for each individual whereas Learning context can be common to all the individual learners.

Sub-elements identified in 'Learning Context' are essential in BIM-enabled projects because they are accompanied with a wide range of applications such as Revit, Naviswork, and BIM 360 field. Therefore, focusing on suitable contexts (eg collaborative climate, team structure) has helped to build up the fundamental knowledge needed to learn in this collaborative environment. As Eraut (2004b) mentioned, widening the knowledge is essential for implementation of BIM in construction projects and generally BIM construction projects are incorporated with diverse learning options (section 4.1.2).

5.3.2.1.1 Learners' Factors

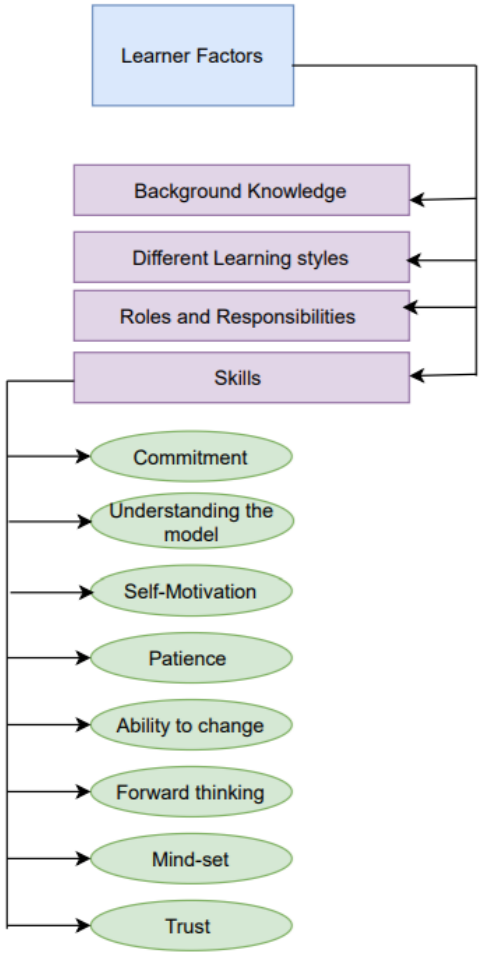

Figure 5.3: Learner's factors for workplace-based learning

The sub-themes under 'Learners' factors' emerged from the collected data (4.1.1 to 4.1.3 and 4.3.1 to 4.3.6) and include background knowledge or basic understanding of the situation, understanding of roles and responsibilities, types of learning and appropriate learning styles suitable for the project (See Figure 5.3). For an example I8 mentioned:

''We understood the basic and advanced training and from there they kind of seed data leads that would have the most knowledge about the BIM processes and BIM applications such as Revit'' (I8)

Moreover, findings from the study (4.1.1 to 4.1.3 and 4.3.1 to 4.3.6) have identified that having certain sub-themes under the main themes help the project participants to prepare well to perform the specific activity or job. For an example the sub-theme "skills" can be further divided into catgories such as commitment, self-esteem, self-motivation, trust, mind-set, patience, self-forward thinking and ability to change, and understanding interconnections between these themes and sub-themes have enabled the team members to participate more successfully in the BIM project. These basic inputs included in this aspect have steered the learning in the collaborative workplace environment, especially when the environment is dominated by the lack of trust. In addition, level of understanding about the data or actions related to the situation can help the learner to prepare more towards the final outcome. For an example know level of details about the data can help the learner to decide how much commitment the learner should put towards the task and what specific skills he needs to develop to successfully complete this task,

5.3.2.1.2 Learning Context

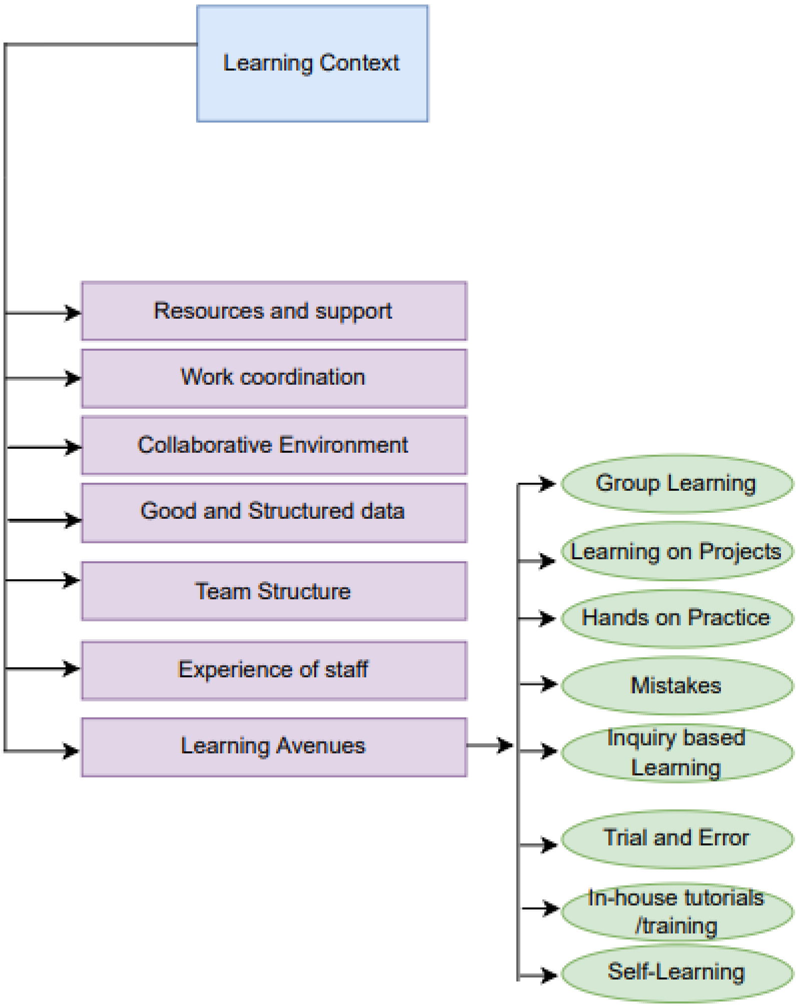

Figure 5.4: Learnin Context for Workplace-based Learning

Sub-themes for learning context is again derived from emerged from the collected data (4.1.1 to 4.1.3 and 4.3.1 to 4.3.6) and include resource and support, work conditions, collaborative environment, good and structured faya, team structure, experienced staff and learning avenues. BIM construction projects are generally associated with a number of information and interconnected activities due to several technologies being embedded in the project. Therefore, the experience of staff in 'Learning Context' has an important role in encouraging learning through engaging with others and tackling the unexpected challenges together (Figure 5.4). According to Nisbett and Ross (1980), unusual incidents are remembered and noticed more and shared among the other participants. Moreover, they have concluded that experiences of participants need to be taken into consideration to create awareness and to cross check through the gathered information, which is helpful to avoid biased or perhaps incomplete information. Lessons learnt in the projects are beneficial during future learning processes in order to avoid mistakes and to repeat success, to provide an edge over other companies and to learn lessons for subsequent phases of ongoing projects (Paranagamage *et al* (2012). Likewise, Williams (2008) emphasised that learning lessons from a project review is a vital and integral part of the learning organisation if competitive advantages are to be achieved. Similarly, several scholars have highlighted that having an expert while learning in the workplace is beneficial to improve the quality of performance (Ericsson et al, 2006), avoid obsolescence (Levinthal and March,1993) improve problem solving (Schmidt, 1993) and making quick decisions using their prior experience and confidence level (Eruat, 2004). This is supported through Interviewee 2 stating:

''we have really qualified and experienced managers who always supported in learnings and they still do'' (I2)

However, challenges such as ill-structured problems, incomplete, ambiguous or changing information, shifting, ill-defined or competing goals, multiple-event feedback loops, time constraints, high risk, contribution of multiple participants and balancing personal choices and organisational norms have been noticed in these BIM construction projects (Klein et al, 1993). At the same time, forgetting the gained experience due to being involved in multiple projects is problematic (Eruat, 2002b). Therefore, in the workplace, experiences need to be transformed and resituated in forms that can be recalled in the chosen situation. Results from semi-structured interviews and case study observation showed that there are several training opportunities provided outside the site as well as on-site through experts.

Case study 4.3.6 illustrates how the benefits of point cloud scan have been explained to the employees to persuade them to attend the training to learn this new technology. Support is also evident through these quotations by *I14* and *I6,* respectively:

''Initial training sort of helped me to use Revit face and Revit modelling techniques and playing around with it is the one actually really helped me be after to embraces sort of really the effectiveness of it'' .

''You need to know how to use the software and therefore you need training and also should know how to use the software efficiently and effectively''.

However, as the Boston BIM forum (2014) highlighted, training period, training budgets, continuous software updates, employees fear of learning new software and process and lack of expertise are some challenges experienced, while providing training to the employees in BIM environments.

In this digitalising world, employees and end users are urged to collaborate for the greater access of information. Ernst andYoung LLP (2011) have stated that, during this transformation, the physical world will be replicated by digital communities which include digital tools and platforms. According to Henneman *et al* (1995), collaboration refers to the involvement of two or more individuals in a joint venture, typically one of an intellectual nature in which participants willingly participate in planning and decision making. Studies have highlighted that BIM involves both geometric and non-geometric data and expects to envision efficient collaboration (Arayici *et al*., 2011; Kymmell, 2008). However, according to NBS (2021), no single standard is followed for the adoption of BIM. According to these studies, collaboration plays a major part in project environment and decision making process. Similar to these studies, Case studies from 4.3.1 to 4.3.6 demonstrate the importance of collaborative activities while making decisions and resolving an issue. According to Azhar *et al*. (2012), close collaboration in BIM-enabled projects is vital to encourage the integration between project stakeholders and provide opportunities to derive maximum benefits (CSQ, 2014). In these studies, collaborations have helped the participants to share and gain knowledge about BIM and different working processes followed by the stakeholders. Furthermore, it has helped to focus more on client's expectations and understand the deliverables related to the project. Case study 4.3.3 shows how collaboration among the project team members works when laser scanning is introduced to complete the tasks. Furthermore, arranging a follow-up meeting to discuss the design changes shows the importance of collaboration. Likewise this is also evident through Interviewee *11* stating:

''we are now sitting round the table and talking with people we have never expected to talk with before'' (I11).

5.3.2.2 Learning Progress

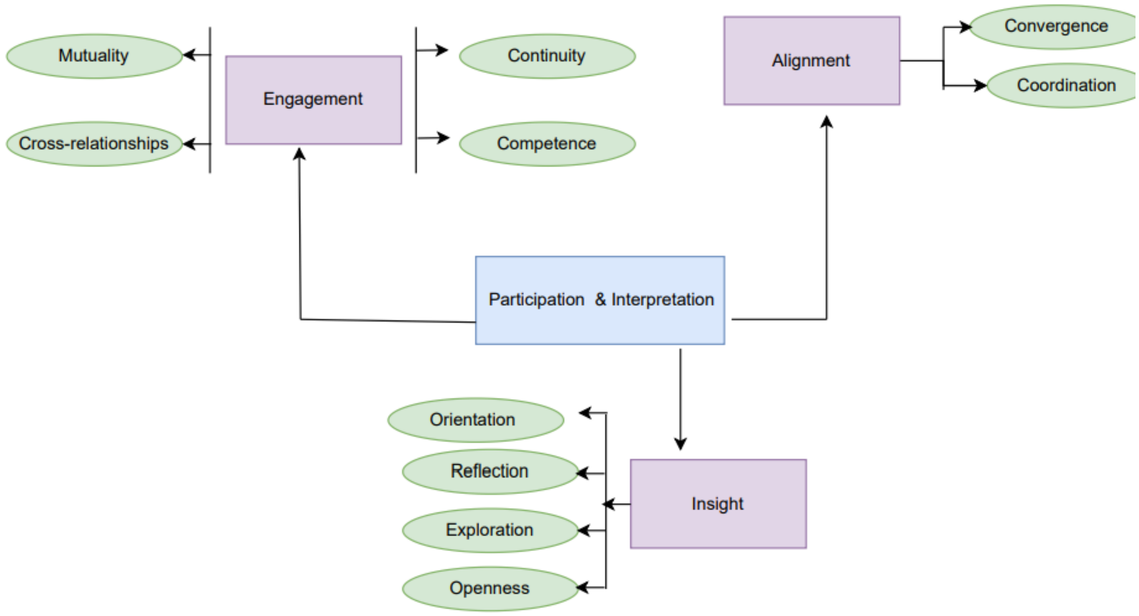

Figure 5.5: Learning Progress

The *Learning Progress* aspect in learning in the workplace is related to the way in which project participants approach learning. This includes the actions/activities that promote learning, and the main purpose of these actions is to make a sensible meaning through the participation of project team members (Figure 5.5). Learning in the workplace in BIM-enabled projects is a continuous process which is centred on the federated BIM model. In the study, it is noticed that participants are continuously involving and interchanging information with others to achieve the tasks and tackle the challenges within the project environment. In this collaborative environment, project participants have different views to solve an issue. However, it is important to bring all the project participants to the same page through agreeing on a view to move forward with the situation or the problem. Therefore, holding different interpretations of the same issue could be challenging to resolve an issue. From the case study findings (4.1.1 to 4.1.3 and 4.3.1 to 4.3.6) the Interpretation of people seems to be the central activity to connect the collected information, activities and artefacts used in the BIM construction projects. According to Eraut (2004), Interpretation is a form of thinking that comprises planning, monitoring one's activities and solving problems and is a key aspect to learn in the workplace environment.

Findings have highlighted that learning in the workplace is continuous and keeps changing due to the implementation of new technologies. The case study findings (4.3.1 to 4.3.6) show that initial plans for making a decision or resolving keep on changing due to unexpected events and human errors. Therefore, there is a need for a dynamic model of workplace-based learning that includes suitable inputs and conditions with constant modification of plans, which are appropriate and realistic for the changing work environment. The case study findings (4.3.1 to 4.3.6) show that *Participation* along with *Interpretation* are essential to achieve a learning outcome such making decisions, career development and resolving an issue. From the findings learning in workplace is successfully achieved when interpretations are taking place during participation. The findings derived from data analysis and findings confirmed this is further strengthened by three key influences: *Insight*, *Alignment* and *Engagement*, which allow the model to be dynamic.

For example, in case study 4.3.2, the exploration and analysis show the *Insight* of the problem. On the other hand, explanation, discussions, and information exchange show the *Alignment*. Involvement of a multidisciplinary team and creating awareness show the *Engagement*. Focusing on these identified sub-themes help to alter the learning according to the changes in workplaces.

5.3.2.2.1 Learning through Participation and Interpretation

The analysis of research data revealed that 'Learning in the workplace' is centred on '*Participation*' and '*Interpretation*', which can act as linkage to connect the learning aspects within the project environment to produce better outcomes during the implementation of digital technologies. Therefore, this section discusses the link between 'Participation' and 'Interpretation' to encourage the connectedness in learning in workplace within the context of digitally enabled construction projects. This does not mean designing a completely new learning approach, instead focusing on these areas will help to shift the existing practice to be seen in a more connected way. This could also be beneficial to resolve the issues that arise in the BIM-enabled construction projects with less time and effort.

Cabrera and Cabrera (2002) stated that individuals and the project team in these BIM construction projects are interested in sharing their knowledge when it is valued and supported; when organisations reward contributing, increases efficacy perceptions, makes employees' sense of group identity and personal responsibility more salient. This is evident in case study 4.3.4 while resolving the clashed pipework. During this, information was gathered from 2D drawings, 3D Model, specifications, and on site information. Moreover, to resolve this issue the BIM Coordinator, Site Manager, and Project Manager used their knowledge on drawings and previous experience. However, Wood and Ferlie (2003) mentioned observations showed that linearity, rational conception of knowledge, and tendency to separate knowledge from activity are some of the challenges faced in networking. For example, in case study 4.3.1, a number of issues were discussed in the meeting, but ductwork installation has been prioritised. This shows how the professionals have extracted the most important information after the logical discussions and act on resolving that issue.

On top of that, the characteristics of team members such as different perspectives, misconception and ignorance are identified as challenges while networking in these BIM-enabled construction projects (4.3.1 to 4.3.6). Therefore, it is important to understand the way of individual's actions (both social and cognitive) and internationalities (Bloomer and Hodkinson, 2000; Somerville, 2002) shape how they participate and learn through work.

The analysis of the findings in this study shows that the key learning activities embedded in the process are achieved through 'Participation' in group activities, working alongside others, tackling challenging tasks on the job, and working with the client and other stakeholders (4.3.1 to 4.3.6). Learning through participation is supported by Wenger (1991) and Rogoff (1995) where they indicated that learning was a direct participation in social practice. Conversely, Billett (2004) argued that, even though the social process view looks at learning as a participation of work, what is learnt from practices are not solely determined by social practices. Instead, involvement of the individual is vital in their choice of how they want to participate and what they want to interpret and learn from their participation (experience). Therefore, in this study, participation is considered as a combination of the individual's direct participation as well as how the individual wants to participate, interpret, and learn from their participation.

The Community of Practice concept (Wenger, 2000) viewed learning through participation. This is embodied in the joint action of a group of practitioners sharing identity, tasks and/or environment. In this approach, the individual does not have much importance separated from the community. In this collective process, the individual's involvement in the learning process is rarely theorised. BIM construction projects are relatively complex, therefore the contribution of each individual is essential to achieve the set target. Therefore, in this study the individual plays a major role in connecting the learning aspects together, thus the individual's different perspectives, dispositions, positions, social or cultural capital, and forms of participation are considered.

Participation is obtained through different ways in a good learning environment. According to Billett (2002a) and Fuller and Unwin (2004), participation has been categorised as expansive and restrictive. The Expansive approach allows time for people to reflect and see learning to progress in their career that allows the participants to cross boundaries. This has been agreed by Nonaka and Konno (1998), who claimed that participation in common spaces allows individuals, groups of people or a community to surpass their own perspectives or boundaries. On the other hand, the restrictive approach is limited to the job involved at that time and only values particular persons or groups.

Findings in chapter 4 showed learning activities in the workplace have been achieved mostly through expansive learning, which has allowed the project participants to reflect on what they have learnt through different ways in the project level such as formal education, listening, observing, reflecting and refining skills, trial and error, and supervision or coaching and mentoring and many others (section 4.1.2 and 4.3.1 to 4.3.6) On the other hand, problems were also solved through interrogation or inquiry-based learning where individuals and groups collected the information through raising questions beyond the cluster of known people within the work practice (Refer section 4.2).

In addition to participation in networks, this study has also acknowledged that different software and tools are often adopted through informal learning in these BIM-enabled construction projects. The understanding of 'Participation' that comes out of the study indicates that it is not just only about the direct learning that is involved in social practice, but also about the individual's view on how they are going to participate and interpret during participation. This shows that learning in the workplace in BIM-enabled projects is not only about formal or incidental learning, but also intentional in some situations (section 4.2). This is similar to the belief of Hodkinson and Bloomer (2002) that learning happens in the workplace is adhoc, structural and informal. However, this study contradicts Tynjälä's (2013) view that learning in the workplace mostly comprises semi-informal and planned activities. Moreover, this study does not comply with Billett's (2004) view that learning in the workplace is intentional; however, it agrees that learning is continuous and the interrelationship between affordance and participation has been noticed in the BIM-enabled construction projects (section 4.2). Moreover, Billett (2004) mentioned that, although learning occurs continuously through formal and informal learning in a structured workplace environment, it is important to conceptualise learning, as participation in the workplace has a huge implication on achieving the project goals. Furthermore, workplace-based learning through participatory process is also beneficial to keep the project participants actively engaged with the whole project lifecycle.

The affordance on both unintended activities such as everyday activities, observing and listening and intended activities such as modelling, coaching, analogies, diagrams, questioning are observed in the study have helped the participants to learn the knowledge required to make decisions to accomplish the task (section 4.2). According to Billett (2001), both direct and indirect guidance support the quality of learning during participation (section 4.2). Similarly, Hodkinson and Bloomer (2002) agrees that learning new knowledge (Accommodation) and refining what is already known (Assimilation) depends on the participant's interest and direct and indirect guidance provided to them. Billett (2004) mentioned that agency plays a significant role in determining how workplace affordance is interpreted and judged to determine an effortful learning through participation. However, he stated that the affordance provided is not evenly distributed across the participants. For example, in some cases relevant information needed for the participants is unavailable, and this is a barrier to complete their task. Grey (1994) in his study argues that it could be tackled through people who have authorisation to control through dividing the labour with their interest and affiliation. This then regulate participation to maintain the continuity of the workplace through regulatory practices. In some cases, participants dis-identify with the social practices with which they engage (Hodges, 1998); resist engaging with the team due to different cultural mores (Darrah, 1996) or training opportunities that compromise their employment options (Billett, 2001a), and avoid new recruits and deny affordances intended to assist their participation (Billett, 2001a). However, in this study it is identified that personal agencies involved in BIM-enabled construction projects have to develop their knowledge through undertaking several training programmes, attending conferences and webinars and through interacting with several BIM related groups (section 4.1). Construction projects moving towards digitalisation still have its own challenges. Moreover, this study's results confirm that agency and affordance have how much impact on participation that takes place in the workplace environment. Apart from the personal affiliation, participants learned in practice through engaging and interacting with co-workers and new tasks where participants' efforts were acknowledged (section 4.2). Moreover, this has also improved the quality of learning outcomes. In addition, Valsiner and van de Veer (2000) have mentioned that knowledge can be generated through social processes (e.g. access to guidance, observation and interactions with other workers) and artefacts/ signs (e.g. workplace and its artefacts). Moreover, Billett (2001) stated that these participatory factors are central to understanding how workplaces afford opportunities to learn.

The combination of literature and what has been observed in the BIM-enabled construction projects in the study set the context for understanding 'Participation' as a dynamic construct. Literature highlights that Participation is a key category for learning in the workplace which helps to identify the information that is not available in documents or any other explicit forms (Lave and Wenger, 1991). In addition, observations in the study showed that it is not only about collecting the information but also about altering the information in relation to problem solving (section 4.2). On the other hand, as Gherardi (2006) mentioned, individuals also learn through participating in day to day activities where participation provides access to knowledge through interacting with others in the organisation or project. Following this, individual participation becomes a part of group. This situation has been frequently noticed in the studies conducted in BIM-enabled construction projects (section 4.2).

This shows that Participation is one of the central concepts for learning in the workplace which has been accepted by several scholars in practice theory (Billett, 2004; Elkjaer, 2004; Handley *et al*., 2006). This not only helps to learn about individual activities (Wenger, 2000) but also to understand the social structures through participation in workplace activities (Rouse, 2007; Nicolini, 2013). Literature has highlighted that collaborative ways of working in technology-driven projects include participation as a key factor to learn in the workplace (Forgues and Koskela, 2009). On the other hand, a study conducted by Gustavasson and Gohary (2012) mentioned that crossing work boundaries while participating in the workplace is beneficial to improve learning that takes place in workplace. This has been also noticed in the study (section 4.2).

Learning has been divided into different paradigms and, according to Harger (2005), learning in the workplace falls into the Emergent paradigm which includes participation and knowledge creation (Hodkinson and Hodkinson, 2004). In addition, scholars believed that participation and knowledge creation are more suitable for 'Learning in the workplace' compared to knowledge acquisition. However, the observations in this research have highlighted that leaning in the workplace is a combination of knowledge acquisition, participation, and knowledge creation.

For example (case study 4.3.6), in point cloud scan training, knowledge acquisition is all about gathering the information on how to use point cloud scanning in the project. Participation is indicated through learning the new technology through the training organised in the work environment. Finally, knowledge creation is the understanding and application of point cloud scanning in the project. These three together form part of the learning that happens in the workplace.

Even though scholars (Billett, 2004; Collin, 2005; Fuller et al., 2005; Fuller and Unwin, 2003) argue participation and knowledge creation are commonly included in learning that take place in the workplace, this study confirms that knowledge creation cannot be separated during learning in the workplace (Refer section 4.2).

The importance of participation has been discussed regarding what individuals afford and how they engage with what is afforded (Rogoff, 1995; Billett, 2002). In addition, participation occurring within construction projects can be shaped through negotiations (Suchman, 1996) and ordering (Engestrom and Middleton, 1996). However, these situational factors alone are not sufficient to learn in practice; therefore, it is vital to understand an individual's actions (both social and cognitive) and internationalities (Bloomer and Hodkinson, 2000; Somerville, 2002) to shape how they participate and learn through work. Supporting this, Billett (2004) mentioned that individuals are important in terms of how they participate and what they want to interpret and learn from participation or experience. Therefore, the individual's input in learning in the workplace has been considered as a fundamental factor in this study, however, it has been confirmed that what is beyond an individual level. In other words, learning is mostly achieved through a collective approach.

Participation in the workplace is interlinked with learning which is continuous, and the individual's participation deliberately contributes to the enterprise's goals and continuity (Billett, 2001a). Billett (2001a) argues that this leads to maintaining the work practice viability in terms of skills utilisation or quality of service. Moreover, he believes that overall participation in the workplace serves to distribute opportunities in new work activities and access to guidance and support. However, he also mentioned that individuals involved in the workplace might experience different kinds of and degrees of affordances, depending on their affiliation, associations, gender, language skills, employment status and standing in the workplace, because of these regulatory practices. Workplace practice is generally multi-faced, negotiated, regulated, and contested.

Therefore, most of the learning takes place through participation which supports the participants to learn what cannot be learnt alone (Billett, 2001a). Findings presented in chapter 4 showed that participation in the collaborative BIM project environment is one of the key elements in making decisions and during problem-solving process. During this, it is observed that relevant individuals' participation in a situation helps to share relevant information, experience, ideas for achieving their tasks. However, as observed in the studies at some situations, the interests and ideas among the individuals are not democratic or equal (section 4.3.1 to 4.3.6). Therefore, bringing all the participants to a common view is important in making decisions within the projects. This mutual understanding can be reinforcing or disruptive, and therefore resulting in re-confirmation or further negotiations to share common interest is vital while making decisions during problems. Therefore, negotiation plays an important role in bringing all the participants to a common view to achieve their tasks. Furthermore, several coordination processes (eg interaction, mentoring, feedback) noticed in the study have helped to maintain and shape the mutual understanding between the participants to work towards the solutions for the problems identified in the project environment (case studies 4.3.1 to 4.3.6). In addition, this study has suggested that Interpretation of information or actions while participating has as much impact on learning and plays an important role in collaborative BIM construction project environment.

For example, in case study 4.3.4, while designing the vent above the door the alignment of information is achieved through project participants communicating and negotiating with each other. Following that, the level detail of the issue was collected to know the Insight of the problem. Finally, the multidisciplinary team engaged well together to resolve the problem through creating the awareness of the related issues and continuous design changes. During this situation, project participants participated and interpreted their understanding that they gained through past experience. This shows that participation alone is insufficient to learn in the workplace, and instead interpretation should be interwoven with it.

This has been noticed during the accomplishment of tasks and making decisions to tackle the number of project participants and the huge amount of information embedded within the project. According to Eraut (2004), interpretation is a form of thinking that comprises planning, monitoring one's activities and solving problems and can vary for different people. However, the common focus of this is to amalgamate the individualist and collective knowledge from different places and deliver an appropriate way of learning in a situated practice. Knowledge is always a part of learning; however, this digital world makes learning easier and quicker through connecting all the project participants in one place. Some argue that information selected and distorted might differ from existing schema (Klein et al., 1993, p. 18) during the process of accomplishing an activity or making decisions, whereas others claim that each participant has their own interpretation according to what they notice and remember (Schmidt and Boshuizen, 1993). Therefore, project participants setting the right interpretation through connecting the most appropriate learning aspects can provide effective decisions and quick solutions. The combination of participation and interpretation helps to achieve something higher than putting the knowledge together. In addition, it also highlights how project participants should share the knowledge in a sensible way using the influences of Insight, Alignment and Engagement.

Choosing the most suitable learning aspects and understanding their connections at the beginning of solving a situation or making decision provides an opportunity to solve the problem without any further problems or delay in the workplace context. According to the argument put forward in this thesis, learning in the workplace, and learning in the workplace in the digital era, is distinguished through finding the connections between the learning aspects through focusing on interpretation during participation. This is to strengthen the learning in the workplace environment which is related to interconnected activities, sense making processes, and social effects granted by practitioners (Corradi *et al.*, 2010). Findings showed that the level of interpretation during the participation differs in each situation; however, the relationship between learning aspects has an impact on finding the right connections between those aspects to accomplish an activity or make a decision. In such cases, missing out the important connections between relevant learning aspects would further complicate and confuse the purposes of Insight, Alignment and Engagement which can lead to the development of problematic situation.

Although, Participation was considered as a joint action of groups of practitioners sharing identity, tasks and/or environment (Wenger, 2000). In case study 4.1.1, to resolve the mechanical and electrical issues in the BIM-enabled project, project participants attending a meeting started sharing the information related to the issue. For example, the BIM Coordinator pinpointed the clashes of the mechanical and electrical services with the aid of a 3D BIM model and explained his interpretation for the identified clashes. Following this, collecting information from the Service engineer indicated that this issue has mainly developed due to the difficulties of modelling the ducts with a number of services with the limited mark-ups. This shows how the participation in a situation begins with the input of individual knowledge which is then shared among other project participants through connecting the linkage within the network until achieving desired goals. Therefore, the individual's knowledge cannot be completely ignored during learning in the workplace.

The learning in the workplace on which this study focuses is very much related to interconnections which are centred on joint and coherent development of connections between the learning themes and sub-themes through interacting, sharing, dialoguing, and thinking together for accomplishing the tasks or making decisions. Moreover, it also depends on how interpretation happens in that work environment. Therefore, this shows that participation is intertwined with interpretation to learn in digitally enabled construction projects. Furthermore, case study findings (4.3.1 to 4.3.6) indicated that continuous interaction in the workplace during the participation has helped to maintain up-to-date knowledge within the project participants. For example, in case study 4.3.2, the Architect explained the issue to the other project team members through analysing the drawing for the vent, which is located above the door. This was then further investigated in detail through interacting with the related professionals such as the BIM Coordinator and Service engineer. During this interaction, information along with their personal opinions and understandings related to this issue were exchanged. This continuous interaction helped the project participants to know the current situation before coming to a conclusion.

Looking at the findings and literature review on the basis of learning as a networked social process, *Participation* and *Interpretation* play a major role in learning in workplace. This is further examined through the three influences *Insight*, *Alignment* and *Engagement* as introduced by Wenger (1998).

5.3.2.2.1.1 Insight

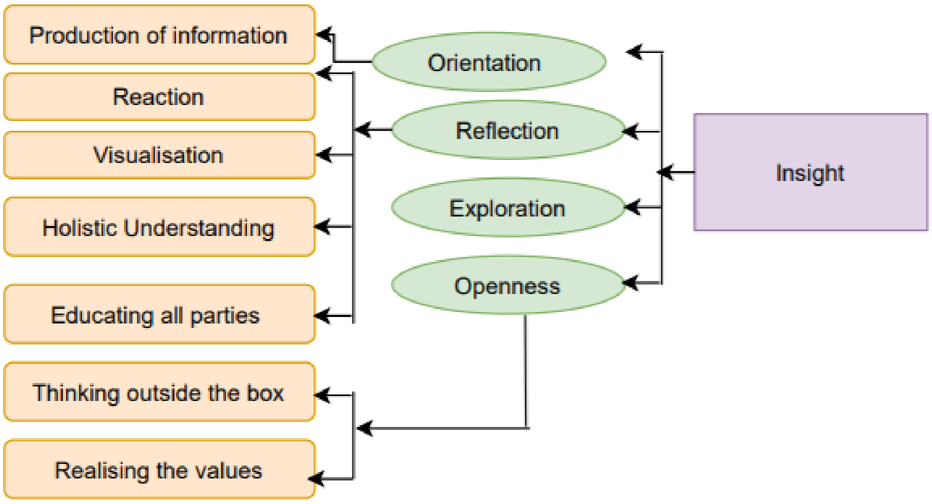

Figure 5.6: Sub-themes of Insight that impacts Workplace-based Learning

As mentioned before, this research has used three key learning modes for learning in workplace environement which are *Alignment*, *Insight* and *Engagement*. When a number of activities take place in a project it is hard to picture the history, possibilities, or the complexities of each activity (Wenger, 1998). Therefore, in BIM construction projects, *Insight* has been used to interconnect the activities to make sense for the project participants involved in that particular activity or job. Base on previous literature (Wenger, 1998) and data analysis and findings *Insight* is divided into four elements: *orientation*, *reflection*, *exploration* and *openness* (Figure 5.6). *Orientation* in this aspect is about adapting to the new changes made in the working environment. In these BIM construction projects, new software was continuously introduced to achieve the targets efficiently and within less time (section 4.2). This shows that contonious learning is encouraged in workplace environment during the introduction of new technologies such as BIM.Supporting this, I6 mentioned:

''I think I have already reflected on some of the things I have learnt. It all depends on the project leader when it comes to change and innovation''.

Therefore, locating new changes in terms of the space, time, and making meaning through utilising the power within the project environmental is needed to tackle problems in the digital world. Production of information, especially the level of detail, was highly focused on BIM construction projects to tackle the information overload. This is to avoid confusion among the project participants and to use the right information to complete an activity or make decisions.

Workplace-based focuses on different workplace activities where learning generally take place through doing, reflecting in one's work, collaborating and interacting with other people, participating in networks and tackling new challenges or participating in formal learning activities (Eraut 2004b; Tynjälä 2008). Therefore, instead of deep and surface learning that happens in a project environment, learning in the workplace also occurs through reflection in these BIM-enabled construction projects. Reflection in this study has been referred to as intellectual and affective activities, where individuals are involved to explore their experiences for generating a new understanding and appreciation (Boud, 1985). According to Degeling, M. and Prilla (2011), reflection depends on five elements: going back to experiences, re-evaluating these experiences in the light of current insights and knowledge, including experiences of others, and deriving knowledge for future activities from this, including the planning and implementation of changes. This can take place through an individual (Kolb, 1984; Schön, 1983) or group of people (collaborative reflection) with positive and negative experiences. Reflection in these BIM construction projects begins with educating all the project participants, reacting to the situation, visualising and understanding the holistic view of the problem. This is evident through *I14* stating in a semi-structured interview:

''*The main thing is you need to be a technological focus person and at the same time the training is also essential. So they need to have the basic understanding through education and then you need to give the training*''.

Wenger (1998) focused on how reflection is achieved in a project environment. In this study, it is noticed that reflection mostly relies on the project participant's experience. For example, in case study 4.3.2 the architect has identified that the design of the vent and position are not correct. However, his prior experience has helped him to focus more on the accuracy of the grille sizes and gather more detail from a project team from on site. This shows that past experience and understanding of project participants have an impact on the focus of the reflection.

Moreover, previous experiences are beneficial to move towards the work context, but also to avoid less fruitful modes of thinking, while achieving the outcomes. This also helped to tackle the sudden deviation that can happen in the BIM project such as design change, and to resolve unexpected problems through agreeing to a common meaning. For example, in 4.3.4, while investigating pipework installed on site, other issues like the positions of cable trays were also discussed. The Project Manager, using his previous experience, suggested that the thick pipe line spotted in the model needs to be moved slightly to the right. In this way, he has brought back project participants' attention to the position of the pipework. Projects that are digitally enabled have incorporated different kinds of tools to support the reflection to enhance learning in the workplace (Fleck and Fitzpatrick, 2009; Scott, 2010).

The next element of *Insight* is '*Exploration*', which refers to trying out new things with suitable tools during opportunities, finding alternatives and pushing boundaries to achieve the goals, connecting to the information and people within the network for a deep or better understanding. Most of the activities in BIM construction projects have the exploration element in terms of completing a job or making decisions. In some situations, 'Exploration' is referred to as 'Analysis', where learning in the workplace takes place through knowing more about the situation and related actions. Findings show that exploration is common in BIM construction projects due to the involvement of a multidisciplinary team structure. Different perspectives, different levels of understanding and knowledge among the project participants have been noted as a process of exploration in these BIM case studies (sections 4.2.1 to 4.2.3).

Downes (2007 and 2010) mentioned that *Openness* in the workplace, which promotes connected learning to share the information among the people involved in the learning network. Supporting that, Saadatmand and Kumpulainen (2014) highlighted that openness has an impact on building knowledge. The characteristic of openness has been found in the BIM projects selected for this study through thinking outside of an individual's comfort zone (section 4.2). This is also supported by Interviewee 6 stating:

''don't be afraid to ask, there is always organisation that spent the whole day in solving problems'' (I6)

Furthermore, interviewees involved in this research mentioned that they are very open to express anything with their team members and outside which directly and indirectly allowed them to learn (section 4.2). This allowed the project participant to learn through giving the confidence to collaborate with the team instead of staying in silos. It also made them to realise that they are in a situation where any silly questions could be asked. All these actions are part of efficient learning in workplace environement. Based on these results, BIM construction projects were realising the values of the additional information and guidance provided directly or indirectly in the workplace. However, the motives behind adopting these factors are largely to complete the tasks and make decisions within the time limitation through promoting the learning that takes place in the workplace.

5.3.2.2.1.2 Alignment

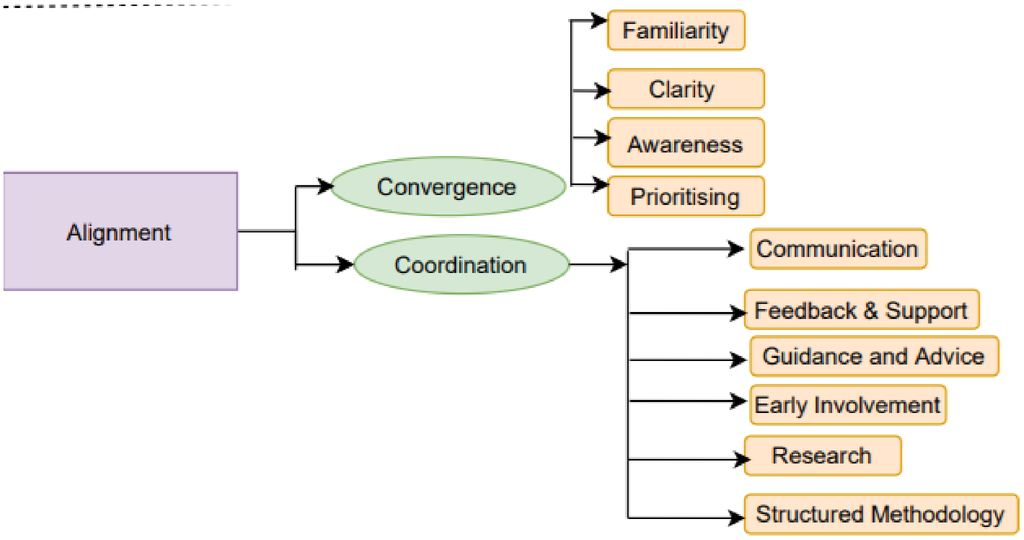

Figure 5.7: Sub-themes of Alignment that impact Workplace-based Learning

Visions in these BIM construction projects have allowed the project participants to open up to think about how different opportunities can help to achieve the project goals through picturing them before those ideas are executed into an action. However, finding the connection between the learning aspects that leads to these actions is challenging. In these situations, 'Alignment' has an impact on achieving the tasks quicker through bringing all the relevant factors to a common point and linking them to understand the issue and make decisions. To build an efficient infrastructure, alignment has included sub-elements such as convergence and coordination (Figure 5.7).

Convergence is about bringing all the relevant data to a common focus or interest through sharing understanding, values, and principles. Findings in this study showed that convergence is achieved by choosing the relevant information, maintaining clarity in both the information and actions, being aware of what is happening, prioritising things and familiarity of doing things (sections 4.1 and 4.2). Presence of an integrated computer system comprising different technologies involved in BIM projects has created more complexity in this picture. As emphasised in chapter 2, it is necessary to implement several technologies in a structured way to work with BIM-enabled construction projects. This has been further confirmed by the observation where different technologies are used to work with BIM models and information. Different people are familiar with different technologies and willing to use them to achieve the tasks. However, that is not viable in a collaborative BIM environment where an entire project team needs to work together using the federated BIM model. This is because using different technologies might cause several interoperability issues, which will take more time to complete the tasks. Therefore, to avoid these issues, project participants are aware of choosing the suitable technologies to achieve their targets. In some situations, some participants have not used that technology before, therefore they are not familiar with it. In this situation suitable training courses and/or one-to-one sessions with experts are provided to get the participants familiar with the technology. For example, in case study 4.3.6 the Service engineer mentioned:

''we haven't used point cloud scan that much and we have purely depended on mark-ups provided to us''.

Whereas, the BIM Coordinator is using point cloud scanning in this project. Therefore, to avoid the interoperability issues the BIM Coordinator explained the benefits of point cloud scanning and encouraged other project participants to start using this new technology with the aid of training.

Furthermore, during the semi-structured interviews, BIM professionals mentioned that 'Hands-on Practice' is vital even though people learn in different ways (section 4.1). For example, Interviewee 6 in a semi-structured interview in phase two stated:

''I think unless you use the tools you never be able to soon after the training and use tend to forget it. That's the danger in it if you are learning it'' (I6).

In these BIM projects, persuasion and leadership played an important role in bringing the ideas and information and ensuring that it was acceptable by the project participants.

Co-ordination in these chosen BIM studies has been provided in number of ways to align and prepare them to engage with the situation. Communication, feedback, and support are adopted in these studies to mould the project participants to perform well in the learning activities. A number of studies in construction have indicated communication is one of the key soft skills needed to successfully achieve the project goals (UKCES, 2012; Smith and Tardif 2009; Kymmell, 2008). Continuous learning in these BIM projects is mostly obtained through communication with other project participants within the workplace. Moreover, as Styhre *et al* (2006) stated, communication in these projects is achieved through both written communication (eg: documents and protocols) and verbal communication; however, findings show that verbal communication is more common between the project participants in learning in the workplace. Moreover, as Kyndt *et al* (2009) mentioned, these BIM projects have embedded communication tools such as phone, internet and common space to learn (the federated BIM model) within the project environment. This effective communication has enabled project team members to adopt flexible working patterns, tackle unexpected issues arising in the workplace, satisfy client's expectations, and maintain the relationships within the team.

For example, in case study 4.3.4 the communication between the BIM Coordinator and Site Manager has confirmed that pipeworks have been designed according to the instruction but installed differently on site by sitting on the pedestals.

Supporting this, *I16* in the semi-structured interview stated:

''One of the very important comes to picture is everyone should have a clear communication between the project participants''.

Moreover, communication in these BIM studies has been adopted for information transmission, negotiating ideas and to spread novelty. On the other hand, feedback in the collaborative environment is important where some participants proactively improve their knowledge with the wider network, whereas others have less interest in developing their learning. This is supported through *I3* stating:

''Chatting with that person about what software they use and getting support from them in telephone or Skype to get over the challenges'' and in addition he also mentioned that ''we try to use things like social medias in terms of getting the communication to help'' (I3)

Learning in the workplace, as discussed in chapter 2, is not static and improves continuously. Therefore, short-term and long-term feedback is important. However, according to Eraut (2004b), most organisations are occupied with short-term feedback to provide confidence to the participants and resolve situations quickly. Like Eraut (2004b), most of the feedback provided in these BIM projects was short-term, just to sort those issues arising in the project environment, rather than providing long-term feedback to support the future. However, as Klein et al (1993) mentioned, multiple feedback loops in some situations have weakened the motivation and lessened the commitment of workers, which is a barrier for decision making. Findings in this study, indicate that there are also other sub-elements as listed in Figure 5.7 to allow the project participants to find an effective solution within a short period of time (4.1 and 4.2).

5.3.2.2.3 Engagement

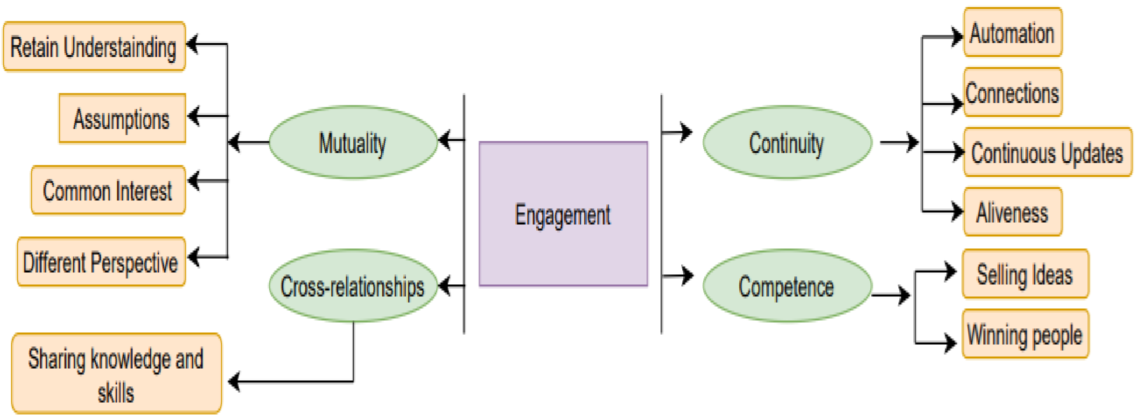

Figure 5.8: Sub-themes of Engagement that impact Workplace-based Learning

Engagement is just not a matter of activity but of community building, inventiveness, social energy and emergent knowledge ability (Wenger, 1998). Engagement in this study is the amalgamation of Mutuality, Cross-relationships, Continuity and Competences (Figure 5.8).This is supported through Interviewee 2 saying:

‘‘Process implemented after detail design phase to deliver information to modelling teams were done through ACAD drawings, pdf’s and excel sheets or 3D geometry and to convert it into a 3D Informative model to check and resolve the coordination errors’’ (I2).

Moreover, engagement is about transforming the personal viewpoints to a group of people involved in the project. To support this, a combination of facilities such as mutuality, competence and continuity is needed.

Engagement in this study is the amalgamation of Mutuality, Cross-relationships, Continuity and Competences (Figure 5.8). Mutuality in this study refers to agreeing to something common to two or more participants. Sharing the retained understanding is one way of maintaining the mutuality in these BIM projects. This includes project participants’ level of knowledge, managing the expectation, managing the information, level of understanding and knowledge of principles, which encourages the project participants to work in joint activities. On the other hand, project participants sharing the assumptions and discussing their different perspectives with the other members helps to reach mutuality through negotiating with the team. For example, in the case study 4.3.2, a number of views on the position of the exit sign board were discussed by project participants. However, at the end, after negotiating with each other they finalised its position on the wall.

Continuity in this study has referred to a constant progression of learning throughout the project. Even though continuity is related to human memory (Wenger, 1998), this study has focused on continuity in relation to activities that take place in order to learn in the workplace. Qualities of continuity in BIM studies were evident through connections between learning aspects with workplace; automated activities taking place in the project, continuous learning opportunities available in projects and through continuous updates of technologies. In addition, aliveliness, which is achieved through close observation of the project sequence, has confirmed the continuity in BIM construction projects. This is commonly agreed by the interviewees. For example, Interviewee 1 mentioned:

‘I am still learning and I am planning to improve my BIM development after my masters’’ (I1)

Competence in the workplace differs according to the situations in which project participants are engaged. According to Eraut (2004b), competencies from the individual perspective are related to personal attributes such as enthusiasm, dediction, patience, determination and discipline whereas the social view definition refers to social expectations. As Eraut (2004) noticed, competences keep on developing, especially due to the introduction of new software adopted in these BIM construction projects. Findings show that project participants involved in the project develop their competences through engaging in more practice with the combination of peripheral participation.

I3, in a semi-structured interview, highlights the importance of practice:

‘‘*But the practice bit is the key thing for me that kind of compare BIM for the first time you entered in the keyboard. So it is very difficult to understand BIM, if you don’t practice it every day. It is very easy to default*’’.

Wenger (2006) motivates the community to have shared competences and, in this study, this is achieved through group training and in-house training (section 4.1). This is supported through Interviewee *14* saying:

‘‘initial training sort of helped me to use Revit face and Revit modelling techniques and playing around with it is the one really helped me be after to embraces sort of really the effectiveness of it. So also using

the other software such as Naviswork 360 glues in the projects and playing around with the tools'' (I14).

Expanding the competences needed to work with BIM projects has allowed the project participants to sell their ideas and to compete with other competitors. Apart from these key elements the articulation of this aspect has included awareness of what is happening in the project and prioritising which is more important to achieve the goal.

5.3.2.3 Learning Outcome

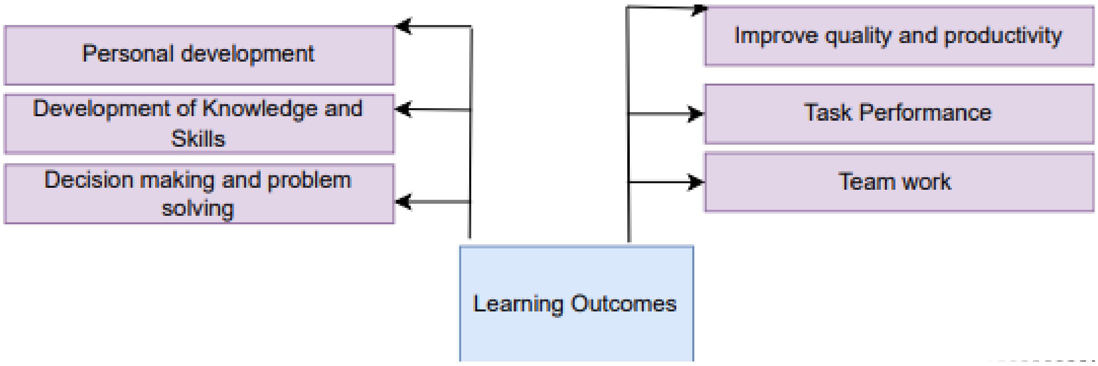

Figure 5.9: Learning Outcomes of Workplace-based Learning

Finally, different *Learning outcomes* are achieved through the combination of both *learning conditions* and *learning progress*.This concept of learning outcome includes the themes such as personal development of the project participants, developing skills and knowledge in the work environment, making decisions and resolving complex issues, improving the quality and productivity and performing the task, which all emerged from the data analysis. The application and integration of existing knowledge and learning something new are the key intentions of learning outcomes. Although this is generally the last phase of learning, thinking about this at the beginning helps to provide an effective learning outcome which digital transformation in the built environment is trying to achieve.

Findings 4.3.1 to 4.3.6 showed that the connection between the key concepts are not linear and vary according to the context. However, results from these BIM studies showed that considering 'Learners Factors' and 'Learning Context' at an early phase in the beginning would be more beneficial in terms of preparing the project participants to get involved in BIM construction projects. Moreover, a detailed investigation on three influences: Insight, Alignment and Engagement of learning in the workplace, shows that Learning Progress is centred on Participation and Interpretation, which keeps the BIM-enabled projects able to evolve as the environment changes. Nevertheless, connections between aspects in Learning Conditions need to be understood in the first place to direct the project participants in the right way to learn in these digitally-enabled construction projects. These aspects in this study have been examined through the lens of Connectivism, which has helped to find the connections and relationships between them. The learning in the workplace model that has been developed to help to link the key learning aspects identified in the workplace environment.

This section has presented a number of factors that influence learning to demonstrate how they affect learning in the workplace to focus the learning activities that take place in a digitally-driven environment. In other words, they have focused on making sense of different connections through the explanation of how ‘Participation’ and ‘Interpretation’ that influence the accomplishment of tasks and making people aware of what to do or what must be done. This idea of making meaning through linking the learning aspects in the workplace has been examined through the lens of Connectivism, as has been discussed. This philosophical view of Connectivism in this study looks at learning in the workplace in a different way; however, it is not considered as a different way of doing things. Therefore, the argument is that the accomplishment of tasks in the digitally-driven project environment needs to focus on the connections between the learning related to the aspects situated within the workplace. Therefore, to make effective decisions as well as to solve the unexpected problems in the digitally-driven project environment, participants need to see both explicit and implicit knowledge that is driven by individuals and groups of people (teams) through looking at possible connections of learning themes and sub-themes. Findings from both the semi-structured interviews and case studies have indicated that learning in the workplace in this digital era is more related to social learning that is networked opposed to traditional learning that take place in educational instutitions. Moreover, as Siemens and Downes (2009) believed in Connectivism, Paavola et al (2004) considered learning beyond knowledge accumulation and extends to participation and knowledge creation (Paavola et al, 2004). However, the learning environment in construction projects keeps on changing due to the introduction of new technologies and working methods. Therefore, the research findings also identify that a flexible learning environment is also important in order to learn effectively in workplaces, especially in digitally-driven environments. Hence, continuous updates in learning themes and sub-themes in the workplace and connections between them are essential to achieve the project targets in this digital environment.

5.4 Summary

This chapter demonstrates that connections and interrelationships between three key learning aspects: Learning Conditions, Learning Progress, and Learning Outcomes, in BIM construction projects are not linear. However, as shown in Figure 5.1, the concepts are contributing to each other forwards and backwards excluding *Learning Conditions* which only contributes forwardly to *Learning Progress*. The implication of this helps the learner to link the whole learning process that take place in the workplace to successfully perceive the desired and efficient learning. *Learning progress* only affects *Learning outcomes* because the fundamentals of it are drawn from *Learning Conditions*. Therefore, there is no chance of going backwards. The lens of Connectivism in this study has allowed to identify the significant learning aspects that impact on workplace-based learning and the way it is connected to each other. From the findings from both the semi-structured interviews and case study observations, the research has concluded that a combination of participation in, and interpretation of, a work situation plays a major role in learning in the workplace. Moreover, Participation in this study is considered as combination of the individual’s direct participation as well as how the individual wants to participate and learn from their participation. In addition, findings also revealed that both the combination of Interpretation and Participation are combined with three key influences: *Insight*, *Alignment* and *Engagement*. These novel ideas merged together has created a Model for Learning in the Workplace for BIM-enabled construction projects. This created workplace-based learning model helps to form an effective learning strategy in BIM-enabled construction projects. This will also promote learning that take place in workplace and creates a common understanding of learning expectations in BIM-enabled projects.

CHAPTER 6: CONCLUSION

6.0 Introduction

The aim of this thesis was to understand how learning is taking place in BIM-enabled construction projects. This investigation has taken the challenge of understanding workplace-based learning in the digital age through identifying and understanding the key learning aspects that are associated with the learning that happens in the work environment. This final chapter of the thesis begins with section 6.1 which relates to the achievements of the study to the original objectives. Following that, sections 6.2 and 6.3, respectively identify and discuss the limitations and contributions of the research. Section 6.4 then identifies potential areas for future research. Finally, the chapter concludes with section 6.5, sharing the personal experience of the research journey.

Two well-known BIM construction projects within the West Midlands, UK, were selected to explore the learning that takes place in BIM-enabled construction projects. These BIM-enabled construction projects provided the context, from which 6 case studies of 20 were selected to investigate the workplace-based learning in greater depth. The purpose of this study is to develop a model for workplace-based learning for BIM-enabled construction projects with the aim of connecting the aspects related to learning. The purpose of the model is to form an effective learning strategy for BIM-enabled construction projects through understanding the connections between learning themes and sub-themes. Moreover, this model will promote the learning that takes place in workplace and creates a c common understanding of learning expected in BIM-enabled construction projects. This model that is created using the concept of Connectivism will create a new way of looking at learning from a connected approach. Overall, this model helps the project participants involved in BIM-enabled construction projects to shift from traditional way pf learning approach. The main themes and sub-themes related to workplace-based learning that have been established in this research show that learning that happens in the digital work environment goes beyond knowledge creation and knowledge acquisition. In other words, it is more centred on both ***Participation*** and ***Interpretation***. The connections between the identified learning aspects that supports ***Participation*** and ***Interpretation*** are illustrated through a workplace-based learning model.

As was discussed in chapter 5, both semi-structured interviews and case study findings demonstrated the awareness of the need for a different way of the workplace-based learning environment.According to chapter 2, traditional ways of learning such as formal, informal and non-formal learning in workplace provides the fundamentals to learn in the work environment. Consequently, this is also evident in the case study findings (section 4.2) where participants learnt through these traditional ways while learning in their work environment. However, due to the adoption of advanced technologies, the work environment has started to digitalise. Hence, professionals are not always be able to learn effectively with these traditional ways alone. Therefore, this study emphasis that different learning approaches are now needed to learn new things and to enhance the existing knowledge in the work environment to cope with these new technologies.

Building Information Modelling that has been adopted in construction projects worldwide to manage project data in an online model, which is then implemented in the virtual environment for different purposes. An array of technologies is used in construction projects; however, BIM is increasingly mandatory in construction projects in many countries. For example, usage of BIM is mandatory in the UK's public sector construction projects.In otherwords, mandatory is about achieving the requirements set in BIM level 2 (now it is superseded by UK BIM Framework). Therefore, this study has used BIM as a context to investigate the learning that takes place in work environment.

In this study, workplace-based learning is examined from a connected view using the concept of ‘Connectivism’ to explore and understand the learning aspects that are associated to workplace-based learning. Construction projects centred on a federated BIM model involves both human interaction and non-human artefacts. Thus, linking the appropriate learning aspects through the lens of Connectivism has promoted a different way of learning through identifying and connecting the relevant learning aspects within the workplace Understanding the learning aspects and categorising them in different phases of learning in the work environment has helped to effectively link the stakeholders within the project, helped professionals to stay up-to-date, plan and organise the tasks effectively and to collect detail information about a product or activity. In addition, understanding the characteristics of these identified learning aspects has encouraged more collaboration and to think outside the box in the workplace. Furthermore, the connections identified in BIM construction projects through Connectivism have allowed project participants to continuously alter their skills and competencies according to the project needs. This has helped to tackle the rapidly-changing digital world where a person’s working habits and their functions change with the introduction of new technologies and tools. Making a connection with the relevant learning aspects within the working environment developed the ability to identify the most important and relevant information among project participants and to move along with the changes that took place in the construction projects. Overall, from the findings, the Connectivism approach is no longer an internal, individualistic activity: instead, the knowledge is distributed across the networks of people. In other words, learning starts from an individual however the gained knowledge will then distribute into a system where two or more people are involved. At the same time knowledge gained in the learning network will also be fed back to the individual. Hence, this connected approach followed in this network will keep the learning up-to-date.

This study has involved three key phases: ***Learning conditions***, ***Learning progress*** and ***Learning outcomes***, where each these categories is involved with a number of sub-themes (See Figure 6.1). The findings collected from BIM professionals and BIM-enabled construction projects clearly indicate the importance of ‘***Participation*** and ***Interpretation***’ through the combination of ‘***Alignment***’, ‘***Insight***’ and ‘***Engagement***’ (see section 5.3.2) to perform learning in a better way in BIM-enabled construction projects. The findings obtained from this study have not only captured learning themes and sub-themes that are appropriate for each phase, but also highlighted the need to create a suitable learning approach for digitally-enabled construction projects. This needed to tackle the ever changing digital world and to more effectively learn in workplaces.

The Workplace-based learning that took place in the BIM construction projects were analysed through day-to-day activities in practice. Analysis showed that ***Interpretation*** *while* ***Participating*** has a significant role in sense making through thinking about appropriate opportunities to achieve the goals (**Insight**), bringing the right things together ***(Alignment)*** and building the community and transforming the personal views into groups ***(Engagement)***. A single federated BIM model acts as a heart for information flow in BIM-enabled construction projects. The information gathered in this model can be used by different professionals involved in the project and the interpretation differs according to their understanding and needs. So, the findings highlight that having the interpretation while learning is important. Moreover, they show that ***Interpretation*** is more effective when it is done while ***Participating*** in the specific learning situation. Therefore, the combination of ***Interpretation*** and ***Participation*** emerging from the analyses, suggesting that adopting BIM in construction projects is not a straightforward process. Instead, this study depicted that ***Interpretation*** and ***Participation*** are intertwined with ***Insight***, ***Alignment*** and ***Engagement*** to use their full potentials. This novel way of learning, identified through this investigation, has helped the project participants to be aware of what and how they need to learn to survive with the changes that take place within the project in which they are involved. Overall, the findings show how workplace-based learning could be done differently and more effectively in digitally-enabled construction projects.

6.1. Objectives and Research Achievements

This section reviews the objectives and achievements of the research in detail to explain the significance of the research findings.

Objective 1 and 2: To review existing literature on the digital skills deficiencies during the implementation of digital technologies construction projects

This objective has covered three key topics: digitalisation, skills deficiencies, BIM and workplace-based learning. At the time when the review was carried out, the literature review on digitalisation revealed that the construction industry is in need to focus on new technologies. This is mainly because professionals working in construction projects have begun to see and do things differently with the use of new technologies. Moreover, this shows that focusing more on digital technologies benefits both the project success of the project and the overall performance of project participants. Conversely, the literature also demonstrates that changing customer expectations, cultural transformation, outdated regulations, and identifying and accessing the right skills are challenges faced during digital implementation (Economic Forum, 2016). However, lack of digital skills among the construction professionals is one of the key cause for slows down the digital trabsformation in construction industry (NBS, 2021, CITB,2018). Therefore, there is a need to upskill these skills in the construction industry through structured learning approach. This then leads to the next key topic: Building Information Modelling. From the literature, most of the construction companies have begun to think of coping with digitalisation have started to adopt BIM in their construction projects. However, research shows that BIM adoption in construction projects is slow. One of the reasons for this is not having a suitable learning approach in the workplace (RICS, 2020; NBS, 2021). Finally, exploring concepts of learning, different types of workplace-based learning, learning in projects, and some key learning themes in the workplace has given a holistic picture of how learning has been perceived in the workplace.

Objective 3: To investigate the skills deficiencies and the need for workplace –based learning in BIM-enabled construction projects

This objective was achieved through conducting 20 semi-structured interviews with BIM professionals who had more than 2 years of experience in BIM-enabled construction projects. The key purpose of this is to understand how learning is perceived in BIM-enabled construction projects, opportunities provided to learn in BIM-enabled construction projects and to identify the key drivers that influence learning in these projects. The semi-structured interview results showed that appropriate learning to engage with BIM-enabled projects is challenging. This objective has helped the researcher to understand the significance of workplace-based learning. Following that, some of the learning aspects that has implications on workplace-based learning have started to emerge during the investigation. However, an in-depth exploration is achieved through the next objective.

Objective 4: To determine how workplace-bases learning takes place in BIM-enabled construction projects

In this objective, the phenomenon of learning in the workplace was explored in more detail through a case study approach. The major achievements of this research has been derived in this phase through observing project meetings, conducting semi-structured interviews, and analysing project documentation. It showed that workplace-based learning during the shift towards digitalisation and adaption of new technologies has considered learning beyond knowledge creation and knowledge acquisition. Instead, social interaction, which is considered through '***Participation***' and '***Interpretation***', is frequently considered in the process of learning in the workplace. ***Participation*** at work refers to the individual's involvement, including how people want to participate and what they want to interpret and learn from their participation. ***Interpretation*** refers to a form of thinking that comprises planning, monitoring one's activities and problem-solving.

This investigation identified that workplace-based learning is occurring continuously within BIM construction projects in many different ways. However, the findings showed that the rational conception of knowledge, and a tendency to separate knowledge from activity are some of the challenges faced in learning. In addition, characteristics of project participants such as different perspectives, misconception and ignorance also acted as a barrier for workplace-based learning. '***Participation***' plays a key role in learning in BIM construction projects and is commonly observed in group activities, working alongside others, tackling challenging tasks on-job and working with the client. Findings also revealed that ***Participation*** in these BIM construction projects is more about reflecting on what individuals have learnt through different ways (eg formal education, listening, observing, reflecting and refining skills, trial and error, and supervision or coaching and mentoring, interrogation/inquiring) and through applying them at the right moment in the project. Furthermore, findings indicated that ***Participation*** in digitally enabled construction projects is beyond direct participation that involves social practice, and is about the individual's view on how they are going to participate and interpret during their involvement. This multi-faced and collaborative learning environment in BIM construction projects highlighted that ***participation*** is intertwined with interpretation. Participants' ***Interpretation*** in these case studies happened through expressing their own thinking and the knowledge which they have gained from past experiences. This has helped for effective planning, monitoring both intended and unintended activities, solving problems and shaping decisions and solutions while participating. In addition, findings showed that interpreting things while participating has a positive on a project participants' knowledge and skills. Therefore, it is evident that both ***Participation*** and ***Interpretation*** are inseparable in a digitally enabled work environment.

<u>Objective 5: To develop a model for workplace-based learning in BIM-enabled construction projects.</u>

This final objective is the amalgamation of all the gathered learning themes and sub-themes collected from both semi-structured interviews and case study approach for the purpose of developing the workplace-based learning model. This developed model can be adopted by any construction professionals to apply in a technological project environment. The concept of workplace-based learning is same in all the industries therefore, this model can be used in other industries through slightly changing the themes and sub-themes. This is because learning cannot be ignored in any environment when there is a specific target to achieve. Therefore, learning to take place learner's factor with learning context should be considered in the beginning to prepare an individual/team to learn. Following that, learning participation along with interpretation should happen to achieve the learning progress. Successfully completing these stages will achieve the final learning outcome targeted by the learner. This entire learning process is same for any environment but themes and sub-themes that are related can differ according to the learning requirements and learning environment.

The identified learning themes and sub-themes, according to its characteristics were categorised into three different phases: ***Learning conditions***, ***Learning progress*** and ***Learning outcomes***. The associated themes and sub-themes and how they impact on workplace-based learning are discussed in chapter 5. The model uses these identified learning aspects to allow the project participants to think and learn in a different way to tackle the changes that take place in BIM-enabled construction projects. For example, design changes, which are generally identified through a clash detection process, are very common in BIM construction projects. Thus, to tackle these situations, the right combination of learning context and learner's factors along with the right interpretation (explaining the situation in more detail) are needed to complete related tasks or resolve the problem. The other achievement of this investigation is identifying the interconnections and understanding the patterns of learning aspects to improve their learning and to make effective decisions. Firstly '***Learning conditions'*** sub-themes includes '*Learners*

Factors' and '*Learning Context'* to begin the learning in an environment. Learning in digitally-enabled projects needs these aspect included in '***Learning conditions***' to continuously learn: however, from the investigation it is clear that workplace-based learning is not a linear approach. Instead, learning that occurs in the workplace differs according to the context and availabilities. Following that, the '***Learning progress'*** theme, which is centred on '***Participation***' and '***Interpretation***', has a significant part in workplace-based learning in BIM-enabled projects. This is because BIM construction projects are involved with large number of information and stakeholders, thus each individual has their own interpretation in term of their experience or beliefs. To avoid this and to continuously learn, BIM construction projects have focused on interpretation, while participating through combining three learning modes which are ***Insight***, ***Alignment*** and ***Engagement*** to look at what triggers, imposes, encourages or limits the learning that takes place in the workplace. Finally, the '***Learning outcomes'*** aspect explains the end product achieved through learning. The final product in BIM-enabled projects differs according to the learning situations in the project environment.

Findings demonstrated that themes and sub-themes attached to '***Learning conditions'*** can influence both ***Learning progress*** and ***Learning outcomes***. This is because ***learning conditions*** that include ***learner's factors*** and ***learning context***, sets the scene to learn in the workplace. So, the design of ***learning conditions*** will decide the learning progress and what learning outcome can be achieved. On the other hand, ***Learning Progress*** can only influence the ***Learning outcomes***. Learning process in the work environment can happen both intentionally and unintentionally. The case study findings (Refer to 4.2) show that most of the learning that takes place in day-to-day life happens unintentionally. Therefore, it is hard to decide the ***learning conditions*** according to the ***learning progress*** that occurs instantly. On the contrary, the way in which ***Learning progress*** takes place in a project will influence the ***Learning outcomes***. Lastly, ***learning outcomes,*** which is the end results of learning that takes place in the work environment, can influence both ***Learning conditions*** and ***Learning progress***. In other words, if the learner is aware of what they want, then suitable learning conditions, as well as, learning progress can be considered.

These connections identified between learning aspects allowed the project participants to focus on networking through constructing, organising and interacting with the content including developing their behaviours, skills, and competencies needed for the project environment. On the other hand, the connected digital environment supported project participants in discussing and sharing insights within their specialised communities of practice. Nevertheless, creating a dynamic and independent learning for the workplace through focusing on ***participation*** and ***interpretation*** helped to balance resources and methods and to maintain the connection between people who are socially independent and participate in the learning environment. Hence, this study has promoted this connected approach for learning through generating a model for workplace-based learning for the digital age. This learning model for workplace helps the project participants to effectively learn through identifying the appropriate learning aspects and to understanding the connections between them.

Overall, the study has achieved its research challenge of understanding how learning is taking place in BIM-enabled construction projects in the digital age and has provided a practically relevant learning model for the digital workplace. Furthermore, this research has identified the key themes and sub-themes that affect learning in the workplace in digitally enabled construction projects and their interconnections. The study has also emphasised the impact of '***Participation***' and '***Interpretation***' on learning. Furthermore, it has highlighted the combination of 'Participation' and 'Interpretation' with the three learning modes: Alignment, Insight and Engagement. Therefore literature, concepts, methodology, findings and explanations of the study together showed that learning in the workplace has shifted from the traditional way of formal learning. Instead, learning in the workplace is considered in this study to be more focused on a project participant's ability to identify the connections between the key learning themes and sub-themes that contribute to the learning that takes place in learning environment.

Finally, the study has generated a model for learning in the workplace through combining the key concepts and explanations discussed here. The model, includes the key ideas of concepts and explanations, facilitates valuable insights regarding the operation of the model in various contexts and phases of construction projects. This can be also applied in different industries contextualized learning sub-themes under the key themes.

6.2 Limitations of the Research

Learning in the workplace is associated with all professionals working on the project. However, this study, which has adopted BIM as a context, has been restricted to the views from BIM professionals only. Therefore, the learning themes and sub-themes are potentially limited. It would be important to widen the learning themes and sub-themes through considering other professionals' inputs. However, this was not possible to achieve due to the limited resources of a PhD study.

The other significant limitation is that this thesis has restricted its view of learning only to the 'workplace' context: but arguments and the final learning model for workplace can be applied in various other contexts through slightly changing their learning themes or sub-themes suitable to their context.

The methodological approach chosen for this study has limitations that need to be acknowledged. Firstly, semi-structured interviews were conducted with twenty BIM professionals, and stopped when knowledge acquisition reached its saturated point. Moreover, all the BIM professionals interviewed were from the United Kingdom. Therefore, empirical generalisation on how learning in the workplace occurs in different countries is problematic. Although the concepts and arguments derived from the two UK-based case studies depict the nature of learning in the workplace in BIM-enabled construction projects, these concepts and arguments are generic and can be applied in any industries or any BIM construction projects in any country. Moreover, the empirical data collected from these six case studies relied mainly on field notes taken during the observation process, as recording meetings and observations was not allowed due to the informed consent access agreement. Although the researcher has sought to clarify the unclear recorded data through semi-structured interviews and reviewing project documentation, the limited number of professionals involved in semi-structured interviews, and data collection without any recording backups, number of observation for each case study (i.e. 1 per case study context) and inaccessibility to all project documentation, were significant limitations of this study. However, referring to recordings to understand practice may sometimes be confusing in some situations. In this study, conceptualisation of workplace-based learning is considered as progressive therefore, data collected through different methods adds value to the results.

The researcher in this study has used a selection of case studies to show how learning is taking place in the BIM-enabled construction projects. However, it is acknowledged that different people can use their own way of explaining the situation using different way of writing terminologies and titles. In this study, the researcher's purpose was to picture how learning is currently happening in BIM construction projects. This was to be achieved through choosing practical examples and selecting the right terminologies to represent, as well as, to build up the arguments to achieve the research challenge. The style of language used in the study has maintained a clear, concise, and logical order. The researcher has avoided over-using jargon or sounding overly formal or more academic to simply explain the practical learning issues faced in the construction industry. However, this needs to be acknowledged as a limitation because different writers are comfortable using their own way of using the language according to their interest, taste and personal views of the research problem. Finally, this research has only focused on the noticeable activities that took place in BIM construction projects, and unnoticeable activities in workplaces where problems did not arise could not be considered. Even though learning happens throughout the project, it is the researcher's belief that the learning process can be clearly normalised through collecting the data in different situations where problems arose in the project environment.

6.3 Contributions of the Research

The contribution to knowledge of this research is achieved in two contexts: theoretical (academic) and practical. With the theoretical context, initially the study presented a unique set of literature through exploring the studies on digitalisation, BIM and learning in the workplace. This led to the investigation of workplace-based learning in BIM-enabled construction projects. Furthermore, the study has critically examined theoretical concepts from different streams and it has allowed the researcher to identify her own theoretical position based on ongoing arguments reported in construction studies. Moreover, this study has identified more practicable learning aspects that influence the workplace-based learning in digitally enabled construction projects. This has formed a novel practice-based explanation for '***Participation***' and '***Interpretation***' through combining three learning modes: ***Insight***, ***Alignment*** and ***Engagement***.

As a part of the theoretical discussion, this study has delivered a learning model for workplace-based learning for project participants working in BIM-enabled construction projects. The main purpose of this learning model is to illustrate the key learning themes and sub-themes and to explain the connection between them to promote workplace-based learning. Moreover, it is to maintain the connections between the learning aspects to continuously learn and to tackle the rapidly changing digital technologies within the construction projects. Literature, as well as, the practical examples, have demonstrated that '***Participation***' and '***Interpretation***' play an important part in learning in digitally-enabled construction projects. This extended idea of learning in the workplace highlighted that, due to massive information flows in construction projects, interpretation along with participation is necessary. This enables the project participants to mutually agree on a common thing in the collaborative environment, while completing an activity or making decisions. Finally, the three modes of learning, Insight, Alignment and Engagement, not only show how things are achieved in BIM-enabled construction projects but also how they impact on learning in the workplace. Therefore, through understanding these perceptions it is beneficial for project participants to look at what triggers, imposes, encourages or limits the learning that takes place in practice. Therefore, a holistic understanding of this model can be a starting point for learning in the workplace through the process of the learner connecting to, and providing information into, the learning community.

Meanwhile, within the practical context, this best practice-based workplace-based learning model developed from established findings provides a practical guide for construction firms in pursuing a suitable learning approach. However, themes and sub-themes need to be modified according to the contexts, interests, and different views of learning. Better understanding of the identified themes and sub-themes for workplace-based learning can promote an effective learning approach and strategy suitable for the project. The model also provides a roadmap for BIM-enabled projects and encourages different ways of learning to tackle the fast-moving digital world. On the other hand, this will also direct the professionals towards appropriate training essential for the chosen learning approach. This study has focused on practice-level activities to understand the trend of learning that takes place in BIM-enabled construction practices. The novel way of looking at workplace-based learning through P***articipation*** and ***iInterpretation*** with the combination of ***Insight***, ***Alignment*** and ***Engagement*** can provide answers for what skills or resources are needed to engage with the BIM construction projects. Sub-aspects identified under each aspect discussed in chapter 5 in this study have helped to manage the changes that takes place in the BIM construction projects. However, methodology and concept of workplace-based learning adopted in this study opens up a space for critical argument on learning in the workplace environment in terms of different 'contexts', 'behaviours', 'emotions', 'learning patterns' and any other categories related to learning. However, sections 4.1 and 4.2 have provided examples and discussions on how these ideas are practically relevant to tackle the current issues faced in practice through recognising the interconnections and understanding the patterns of connections in decision making to improve their learning to work in the digital age. Understanding the new way of learning in digitally-enabled environments from a Connectivist viewpoint is another achievement of this study. This new learning approach adopted in this study is expected to help the project participants to cope with rapidly-changing technologies.

This learning model for workplace-based learning is expected to be used by construction project team members working in BIM-enabled construction projects to achieve their set targets. Although this study is a combination of philosophical, theoretical and empirical levels, connecting the learning themes and sub-themes is the key to understand how learning is taking place in BIM-enabled construction projects.

Finally, this practical contribution in this study has provided a new way of looking at learning in BIM-enabled constriction projects. Making connections with the suitable learning aspects are the first and foremost conditions underpinning workplace-based learning environments. Although ‘Participation’ and ‘Interpretation’ are identified as key learning themes, it has been argued that connection with insight, alignment and engagement is essential to make any valuable meaning. To achieve an effective learning in the workplace, the concepts in this model can be implemented along with the good practice followed in the organisation. The model created in this research has only been validated based on the use of triangulation method. In other words, the collected data is cross checked with different case studies adopted for this research. Scope exists for further validation in terms of testing the model empirically within companies. This will be pursued in future work.

6.4 Directions for Future Research

The study has focused on workplace activities to understand how learning is taking place in digitally-enabled project environments. As explained in the findings and discussion, the connections were made between the learning themes and sub-themes between the practice-level activities at a project level. However, looking at this issue from a project level (micro level) to an organisational level (macro level) could help to connect the learning aspects in a wider perspective, and also allow more suitable learning approaches to be adopted in the workplace. Therefore, to tackle this problem, construction projects need to be extended to the organisational context to smoothly achieve the set goals within the organisational level. Therefore these outputs, solutions and connections between the learning themes and sub-themes identified at the project level need to be examined in organisational level. This wider application of this model for learning in the workplace can help to quickly promote the connected approach introduced in this study. Although the model is flexible for use in any context, it is important to make modifications through changing learning aspects or sub-aspects that are not suitable for the given context. At the same time, to achieve positive results it is important to categorise the learning aspects in the most suitable learning category. Failing to do this can cause confusion and decrease the value of the learning model within that particular context. Therefore, future research needs to pay attention to these considerations while applying these concepts and ideas to a broader levels such as organisational level.

Case studies were focused on the construction phase therefore it can be considered at design stage as well. Moreover, additional case studies could be conducted from different sectors to show the characteristic of Connectivism in BIM construction projects. Moreover, in this study the new way of workplace-based learning environment in the digital age is achieved through focusing on complex situations where problems arose in BIM-enabled construction projects. This practice-based research can be considered in random learning situations which include both normal and complex situations, to open up critical spaces, allow alternative perspectives and to understand how things come together to learn in the workplace environment. However, the concepts and ideas embedded in this study have formed a starting-point to undertake learning in a different way to tackle the digital influences in construction projects. Finally, this model generated in this study can be applied in different learning contexts through tailoring it with suitable learning aspects to tackle a wide range of complex problems. As a conclusion, this practise-based approach adopted to understand the workplace-based learning is recommended in organisational contexts in the construction industry.The suitable themes and sub-themes under the key learning stages: Learning Condition, Learning Progress and Learning outcome needs to identify. Also, it is important to see whether any other learning themes and sub-themes can fit into the organisational context. Most importantly, it will interesting to see how the combination of Participation and Interpretation works in organisational context.

6.5 A reflection on the research journey

As a Quantity Surveyor, I was not familiar with social science research before commencing my PhD research. This study, at my personal level, has helped me to build up number of skills and capabilities needed to conduct a social science research. Although I came across different research methods, research techniques and philosophies in my Master's degree, I did not have an in-depth understanding to apply them in a PhD study. In addition, investigating the literature on digitalisation, skills, Building Information Modelling, and workplace-based learning has helped me to explore new concepts and theories.

Critical thinking, especially while exploring the literature, was developed with the support of my supervisors. However, identifying the relevant information in the initial phases was challenging for me. I have also developed my critical writing through addressing supervisors' feedback and attending workshops and conferences.

During this PhD journey, I also understood that there is no quick or 'right' solution for any research problem: instead, a step-by-step process is needed. I finally realised that there is no absolute or solid answer for any problem where it can differ according to people's views and subjective perceptions. On the other hand, my supervisors encouraged me to have a holistic understanding about a problem before drawing a conclusion. This actually allowed me to think outside the box rather than sticking with one single idea and I was encouraged to look around all the possible arguments that are suitable for the problem.

Following this, the supervisory team has also advised me to ensure my evidence was trustworthy before presenting conclusions. This experience with the supervisory team has enabled me to develop an open mind-set, while reading the publications and talking with people in terms of my research. Furthermore, knowledge and capabilities expanded during this phase has benefited me to choose the most appropriate research method for the study.

In my first year of PhD, I had only a very limited amount of knowledge in certain areas such as digitalisation in the construction industry, BIM, skills deficiencies in BIM construction projects, and workplace-based learning in construction projects. However, at the end of the research I had gained a huge amount of knowledge about each topic. Therefore, this has not only developed my academic knowledge, but also impacted on my personal and professional development.

During this journey, several months spent on literature review has provided me a clear understanding of philosophical and methodological issues including research design and process. With this knowledge I was able to obtain reliable and valid data from the investigations. However, during the data collection process I came across some challenges. For example, while I was conducing semi-structured interviews with BIM professionals, the interviewees started to provide answers outside the scope of the research.

Initially, I did not know how to bring them back into track: however, talking with supervisors and research colleagues gave me an idea of giving prompts to limit their answers with the subject area.

I have carried out 6 case studies through observing their meetings, conducting semi-structured interviews and analysing their project documentation. This experience has provided me opportunities to associate myself with several industry professionals and experts in the area of my research. Discussion with these industrial professionals allowed me to see the application of theoretical knowledge into practice. From my second year onwards, I started writing and presenting conference papers. This has increased my confidence and the feedback from committee members involved in the conference has helped me to improve my academic writing. Starting to use Nvivo for the first time for this research study has exposed me to this software. Overall, this PhD journey for me was eventful through experiencing ups and downs. However, it has taught me a number of lessons in terms of personal and professional levels. In terms of personal development I have learnt to think outside the box, improved my academic writing skills and critical thinking, developed to maintain persistence and enhanced my communication skills. On ther hand, in relation to professional skills I learnt to work under pressure, improved my organisational skills and time management and improved my adaptability. Overall, this PhD journey has helped me to build-up my confidence in research.

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Appendix A

Interview Questions

PART-1

Individual Learning

1. What do you think Building Information Modelling (BIM) is?

Check list: BIM as a process/technology/ new way of working/product/ digital model/intelligence

•If they do not fit into these categories then should define BIM (My approach): BIM is an intelligent model-based process that provides insight to help you plan, design, construct, and manage buildings and infrastructure.

2. What is your experience in using BIM in construction projects?

- Did you follow any formal or informal training to understand BIM?
- Which sector did that BIM project/s belong to?
- What was your role in the BIM project/s?
- How long have you been using BIM?
- Will the implementation of BIM be useful in future construction projects?

3. How did you learn to understand/use BIM?

• Prompts: Through training, communication/collaboration, conferences, regular group meetings, education etc.

• How do you think BIM can be learnt within project teams in construction projects?

4. What are the barriers and constraints did you experience while learning BIM? (Individual)

• What would be the key barriers if BIM technology is learnt in groups?

5. How did your learning help you to use BIM technology effectively?

6. Do you think training can provide appropriate people and environment to effectively use BIM? Or do you need education to get that environment?

PART-2

What needs to be learnt in BIM?

1. What do you think the skills deficiencies are when using BIM?

2. What are the primary skills necessary to work with BIM? Rank them in order?

3. How do you think the above mentioned skills can be acquired?

4. At times we learn by making mistakes; what are the mistakes did you experience while working with BIM?

5. If you get another chance how would you avoid these mistakes?

Prompts: Practice, Degree Program, Training Program

PART-3

What do you advise/suggest to other construction professionals about learning BIM?

1. How did the transition in learning occur within your work context?

(e.g.: from AutoCAD to BIM, started learning new software such as Revit, CostX, Synchro)

2. Did you go through formal or informal learning? How did that learning happen?

3. What training programs did you follow to learn BIM?

4. Were there any other opportunities to learn BIM?

5. Did your company encourage you in any way to learn BIM? (Prompt: Promotions, Increment in salary)

6. Were there any performance support provided during using BIM in your project?

7. What sort of tasks you complete with the aid of BIM? (Rank them in the priority order)

8. Mention one or two main tasks and list the other professionals involved during those tasks?

9. What sort of knowledge did you have when you started this job?

10. What are the skills you are still lacking (or need to improve) to complete these tasks that are allocated to you?

11. What sort of advice would you give for the people who are interested in learning and using BIM?

Is there anything you would like to add to this topic?

I would like to thank you for your valuable input to this research and appreciate your time.

Sample Interview Transcripts

Sample -1

Interview Questions

PART-1

Individual Learning

1. What do you think Building Information Modelling (BIM) is?

Check list: BIM as a process/technology/ new way of working/product/ digital model/intelligence

- If they do not fit into these categories then should define BIM (My approach): BIM is an intelligent model-based process that provides insight to help you plan, design, construct, and manage buildings and infrastructure.

BIM is about what is the software available and my job is implementing BIM on site. So I am training people , I am doing the models and reviewing them and doing the clash detection , upload them convert them accordingly to the software, update the drawings on the system and also providing everyone help who needs it because it is fairly a new system that's why everyone needs help and I am available for everyone to help.

BIM is definitely all the above and it is new piece of kit which is not fully developed yet but the opportunities are much wider compare to what we are using at the moment. For example on site we have ipad and every single member of the team can go offline and review the model, do the check list and do the snags and when he come back to the office can upload to the system for everyone to review to update and respond to him and comment on any problems. At the moment it is a way to simplify the way people are working and to improve the work how it's been considered and how it's been preceded. So this is the way how to book a now and meet the future reality and resolve the problem immediately instead of waiting and calling so on. Obviously it is still under development and I can see the space for the improvement of BIM. So definitely when you study the BIM you can see the options are undeliverable but at the moment software is restricting it. So we are only waiting for the better software technically.

2. What is your experience in using BIM in construction projects?

Prompts: Did you follow any formal or informal training to understand BIM?

I have got the mentor who is my boss and he has practiced BIM longer than me and he was doing before in smaller projects and using the Revit, CAD and so on. Later on he moved into the construction industry and started to increase his knowledge on BIM and he was able to working by cooperating with BCU to generate the models and to teach me how to use the software. Because the software are many more, we have got 4D presentations when you got to show the construction simulation you can attach the cost to it. Then you got the 5D stimulation. You got models you can use different software for construction, facility management, software for presentations and software for construction stimulation therefore these are separate bits and he was able to show me where to look for information provide me some details and I was able to ended by myself because I did it all by myself. Without anyone I was able to understand and able to do what am I doing. Before joining this job I have learnt through university course and I was doing small voluntary jobs for the facility management here in BCU. So I was doing the presentation very simple taking the photographs, taking note about the rooms on the campuses using ipad. So it wasn't BIM but it was like collation gathering information about the buildings for the facility management. Later on I was doing more jobs on in Revit, so it was like enough to start work on BIM on a construction site.

Learn Revit by self-learning. Because when I was starting in BCU I was using in every single project which I was ask to do. Therefore it was straightforward and understandable for me to learn more in Revit.

- ➢ Which sector did that BIM project/s belong to?

Educational sector (New library and new facility)

- ➢ What was your role in the BIM project/s?

I was in the entry level so I was appointed as information manager and offered a position for BIM technical manager.

- ➢ How long have you been using BIM?

1 year before I was just gathering information so it was not actually BIM.

- ➢ Will the implementation of BIM be useful in future construction projects?

I believe so. But the problem is they take all people in one place and at the moment sub-contractors are not fully involved in the process. So they are staying behind. So I believe the only way to fully implement BIM is to invite everyone and teach them how to use it and what they can get from it. So at the moment we are using all techniques with the new technology. We double or quartile the work at the moment because I receive all the recommendation but it is not coded correctly or structured in a way which may be useful for the future facility management. So I have to do all by myself so I believe it will be changed in next couple of years where they will be a structure way when we are working from the beginning to the end because at the moment we just receive bunch of details and bunch of the comments and they are not structured in a way anyway. So this is an extra work for us.

3. How did you learn to understand/use BIM?

    - Prompts: Through training, communication/collaboration, conferences, regular group meetings, education etc.

yeah I had few meetings and I went for a conference. But it was like small minor ones. Now my boss told me that I will be invited to the training for the Synchro. So I will be doing presentations about 4D presentation and we will be doing some training on BIM level 2 which is now mandated by the UK government. So I believe NPS training course and also education helped as well.

    - How do you think that BIM can be learnt in project teams in construction projects?

The only way is give them the tool and explain how to use it and they need to understand that this tool is useful and simplify the work and improve the work. I think they need to be fully aware what are the opportunities what are the possibilities of this technology bit.

4. What are the barriers and constraints did you experience while learning BIM?

I believe some people are more reluctant to use more than technologies because not every single person using in the construction industry is young and not willing to take new tasks. So they don't prefer not doing anything than the things that they are doing for last few years. This is problem where new bits are introduced they want to do it the old way (resistance to change). They think it's more job for them and they don't want to adopt the new methods and stick with the old one and also they are not getting paid more for this.

When I stared using BIM using the software was the major barrier. Because the software was very clunky and it took us 3 months to set it correctly.

What will be barriers if the BIM technology needs to be learnt in a group ?

The biggest problem is to know the tools and the software (lack of understanding).

5. How did your learning help you to use BIM technology effectively?

I learnt BIM during the construction process of the project and levering the knowledge at the same time. So learnt through hands on practice.

6. Do you think training can provide appropriate people and environment to effectively use BIM? Or do you need education to get that environment?

Both are important because they should have some basic knowledge to put this using it in a correct way.

PART-2

What needs to be learnt in BIM?

1. What do you think the skills gaps are when using BIM?

People don't know the basics so should start with the basics and later move on to what they need to do with the software and tools or tablets or mobiles.

2. What are the primary skills necessary to work with BIM? Rank them in order?

They already know how to understand the paperwork to work with BIM and now it is important to replicate what they use on. Get use on site to form how they are structured. And then we are moving all those forms into the tablet so what they have is they just remove the paper work and all the paper work is on tablet. So they have already got the primary skills because they already use paper works so the only thing they need to know is how to use the tablet instead of paper work. So they need better technological skills.

3. How do you think you can acquire them?

Training and presenting the possibilities of the tools and we let the tablets with them for week or two. So when we come back we receive quite a few questions about their doubts. Then we explain how to use it and fix something for them because in the projects we change lot of things all the time so we have to fit the team on site. So they need to practice and tell us what exactly they need. So they know what they are doing and we will get to know what they want.

4. At times we learn by making mistakes; what are the mistakes did you experience while working with BIM?

The problem with the software is its changing rapidly so every 6 or 8 months the software is changing. So when we start project there will be a different tool and at the moment it will be out of date. We are building the building for 2 or 3 years and the software change 3 or 4 times within that period.

5. If you get another chance how would you avoid these mistakes?

Prompts: Practice, Degree Program, Training Program

It's useful to read newsletters and updates on BIM. Also we need to know what government are planning what are the competitors are doing in the same time. Also what are the different companies are doing, we need to interact and understand ourselves and what we need and what everyone else need.

PART-3

What do you advise/suggest to other construction professionals about learning BIM

1. How did the transition in learning occur within your work context? (e.g.: from AutoCAD to BIM, started learning new software such as Revit, CostX, Synchro)

I found out that Revit is much more useful and user friendly so instead of doing dozen of unnecessary models we are doing one single model and create the sections and you already got what you want. And if you need more detail you just draw in a model itself in a section so it is much more useful.

2. What training programs did you follow to learn BIM?

Tutorial on Youtube and read some information about how to use it.

3. Were there any other opportunities to learn BIM?

It's a fairly new bit of knowledge and it was really hard to find anything even in the internet. so you need to be very careful and look for it very precisely to find out anything about BIM. And the abbreviations that are looking are really specific and hard to find. Technically I had some meetings which are training sessions for the crew and the meetings with architects and sub-contractors was not like a training session for me but it was a training session for them.

4. Did your company encourage you in any way to learn BIM?

Prompt: Promotions, Increment in salary

Yes, it was like a process. I have just offered a BIM positions so now my condition is change and obviously have to do more because that why they created a new job role and descriptions and they a have changed few details. So it is basically change of description and increase of the wages.

4. What sort of advice would you give for the people who are interested in learning and using BIM?

They can start to download free software. And then get the many options they can use the IFC models they can use Autodesk as a student. They can download free Revit as a student. So i am sure they have got all tools they are available free for them so they can even download sketch up or Revit creates basic shapes in this software and push them into the BIM and check how those elements are changing when the details are changing what the possibilities are within the software. So this is the only way to understand it.

Is there anything you would like to add to this topic?

What we are doing is very specific projects where clients have clearly set the requirements. So we are doing exactly what BCU wants. So I have noticed that in construction industry BIM is in much lower level than what we are doing. So we have only got the basic model and information about it nothing else. In 2022 government is planning to introduce BIM level 3 therefore more details about the single element will be introduced. Also will get some parameters which are going with the models which will be more complicated and advance than this.

I would like to thank you for your valuable input to this research and appreciate your time.

More information: people don't understand what they are want don't have understanding what BIM managers are asking them.

To develop skills people in the construction industry should understand that the things they have done before is not efficient anymore. First they need to understand what goal they need to achieve and the way they need to provide the details or data to achieve this goal. First before considering the skills they should change the knowledge about using BIM. Another problem is that in each stage different people are involved so some of the data gets out of date.

Sample-2

Interview Questions

PART-1

Individual Learning

7. What do you think Building Information Modelling (BIM) is?

Check list: BIM as a process/technology/ new way of working/product/ digital model/intelligence

- If they do not fit into these categories then should define BIM (My approach): BIM is an intelligent model-based process that provides insight to help you plan, design, construct, and manage buildings and infrastructure.

First of all when you think of finding a team ours is an in- house team in associated architects and we got a strategy for what we do for the new software and then what is potentially more interesting is to create a project team and particularly learning from like doing Park side and then Curzon building. Most of that is the same team and same architects and same main contractor same client and same mechanical and electrical contractor. What we learnt from BIM is, this was our first major BIM project which was Park side and the lessons we learnt is how we did all sort of things such as how we need to get extracted data , what we put and what form of documentation we hand in at the end. Also one side of BIM is Revit and BIM authoring tools. Then there is an analysis tools and then there is BIM as a process, and different mind sets and how you do things. For me learning Revit was relatively easy where we had a 3 days course, through approved Revit and course provider as a fundamental course for new starters. So as new starters we started ideally early on a project using fairly simple objects and just placing standard doors and wall and didn't create any content and used the existing ones. So when the complexity of the model increases the mandated requirements also increases so started to know more about how to create the objects and people started to move with the project. Then we have gone into in-house tutorials and focused particular topics like how to create new objects like doors and etc. then several of us have done proved exams for professionals which we do with external providers. Then within the office across projects we have quite a lot of internal secret events, some of the other teams have the pulses and negatives of things we have done in the projects such as don't model it like this. We use do this through arranging the sessions and when the new software comes in on boards we will arrange learning for the people who needs to learn in depth and then provide knowledge to the rest. But as a wider multidisciplinary team what was interesting is when were first learning the Revit we held the series of 3 day workshop for the architects, structural engineers and MEP engineers where we all sat in a room we took turns to learn and we began to understand what everybody else is modelling and what issues they came across. So we got some ideas what the issues are for an example if there is a radiator and wall clashing then that is going to be problem. So that 2-3 days training was really useful.

BIM is very much the process and it has different mind-sets of creating objects with the data creating at once. So we know all drawings, schedules or analysis is looking at single central information. And require the mind-sets for everything we do so trying to avoid that 2D annotations specific to one drawings that embedded data into the object and looking at how we might restructure in compare to how we could traditionally setup in the AutoCAD. And really thinking about how thinking beyond our deliverables in architects. That is how the data we got can be used by other people and what we need to do to enable other people such as cost consultancies. If we got the right data in the model they can consult the model by anorag or something and do quicker take off and tell us sooner about the cost.

8. What is your experience in using BIM in construction projects?

Prompts: Did you follow any formal or informal training to understand BIM?

In terms of learning Revit we had the team training sessions officially and we sub connected by detail training in our office from training granted. In terms of understanding the overall process that's been more from informal reading to the various standards and trying to understand what works and what doesn't and feedback with the rest of the team.

- Which sector did that BIM project/s belong to?

Educational building

- What was your role in the BIM project/s?

Architect and BIM manager, setting up the protocols and standards for the rest of the team.

- How long have you been using BIM?

Revit since 2010 and before that Autodesk architecture (4 years)

- Will the implementation of BIM be useful in future construction projects?

Very much so. One of the building deliverables will be BIM models for FM. It is very much useful for the client for ongoing maintenance. We are using it on site how it snagging and 360 field. Compare top the models, walkthroughs, taking photographs and fag up and any snags. The photographs and the issues that are put on to the model through cloud database can be accessed by the BIM managers will get that instantly. That is the exploitive from Revits where the same models are taken for all purposes. I think that the most useful thing in the Revit. There is also some efficiency in speed, creating schedules and drawings and to enhance coordination.

9. How did you learn to understand/use BIM?

   - Prompts: Through training, communication/collaboration, conferences, regular group meetings, education etc.

Partly through training, through use in several of internet websites and forums to know about the features. But then with group, group training with some of other engineers and contractor, particularly for clash detection side.

How do you think that BIM can be learnt in project teams in construction projects?

Within our office we learnt through fundamental 3 days training and they have 50 people in our office. Then divide them into 4 teams and in each team where two of them will be super users. Then sent on courses for the allocated time to train and learn the features that they can help. And they then responsible for training the rest of their team and then we have cross inter office secretive events to share knowledge. Made a presentation for the previous to identify what went wrong and then the deeper understanding is provided through recommendation (for team) to do it better for the future projects. eg: not putting too much details in the model and 2D model is embedded with less details which is lighter in the model.

10. What are the barriers and constraints did you experience while learning BIM?

The first one was computer hardware. Upgrading into the new hardware was a difficult task. But it a less of an issue now. Because typical computer you run it can generally run it. 5 years ago when we buying Revit computers it was a big issue. Then it is about software and licences which is expensive.5000-6000 pounds for Revit licence. And another 2000 pounds to run it on. So at the moment we have got ¾ of our computers are capable of running it with enough of licence for half of it concurrently. So one of the frustrations is if you decide that if you want to do your project in Revit you might not always get the licence to do the drawings because somebody else is using it. And the investment side catching up with the ambition to use on the projects. then there is also temptation when things don't work out easily something are much much quicker in Revit and some things are not. When things go wrong it's too easy to put back everything in AutoCAD in less there is a client demand or contractor demand to do it in BIM for the other reasons for beyond on creating our own drawings.

What would be the barriers if the technology is learnt in a group?

I think there is always going to be good bits when you learn in groups learning overall concepts and explaining and understanding other people's view. But I think you still need the time to go back and try out. So when we are teaching Revit we learn in group of 6. We are presenter and each person has their own Revit computer while they are doing it . They have got half an hour of BIM overview an then another half an hour to try out and learn it. I think unless you actually use the tools you never be able to soon after the training and use tend to forget it. That's the danger in it if you are learning it.

11. How did your learning help you to use BIM technology effectively?

I think the best bit the cost discipline groups you have and understand the changes that I make will impact on somebody else and also the changes they make may impact on others. And so that has given understanding that why those certain things are done in a particular way. Because for lot of process you can do things in certain different ways and some of them might be helpful to others and some of them might not be helpful.

12. Do you think training can provide appropriate people and environment to effectively use BIM? Or do you need education to get that environment?

Both of them. We as medium size architects we apart from or director level, everyone below director level part one graduates , part two graduates, architectures and associates will always been as one of the tools we use and as you pick very often the case is part one and part twos have got slightly different higher revit skills because they have taught here. And some of the architects are learning it as they go along, because architecture has the bigger understanding of the building what they are drawing and why they are drawing it. And some other architecture will have better way of drawing it and how to it professionally. So I think you do need both. Ideally both from the same person. And that is one of the frustrations we have with some of the larger engineering companies with hieratical structure. There is a big difference between the designer and the Revit modeller. They might have couple of people in the way; Revit Modeller might be good at making the Revit model but might not understand what it that he is actually putting into the model. That has brought a lot of wrong clash detection and we very often get the Revit modellers rate the of clash detection and they personally want the designer to say yes, the design will allow to move that duct but it can be moved in the Revit model but don't know whether it can be actually moved in the real life situation. You need to know how to use the software and therefore you need training and also should know how to use the software efficiently and effectively. So they almost become transparent and you can concentrate on design rather than concentrating on how revit let me model certain objectives. You need enough ability in the programme to just be able to model it rather than concentrating on how the design looks like.

PART-2

What needs to be learnt in BIM?

6. What do you think the skills gaps are when using BIM?

I think it is mainly starts with medium complexity, when you starting to add lots of customs data or parameters into an object. It is very very easy to just place objects in the line it exist. And it is also an understanding how to put the data into the object and to extracting it most efficiently and tagging out the drawings or scheduling and also knowing how to structure on a model so that it helps other people to handle it better whether it is MEP engineers running a part of analysis on a model and QS taken information from the model.

The objects in the model aren't built by the actual suppliers or sub-contractors and that where the skills are greater.

7. What are the primary skills necessary to work with BIM? Rank them in order?

Communication and coordination tool. So you need to be able to think in that mind-set in collaboration mind-set.

8. How do you think you can acquire them?

I think it is more of an understanding of an overall construction process and also experience in working in multidisciplinary team. Because you are producing an isolated drawings for part of an overall model and lots of people feed into.

9. At times we learn by making mistakes; what are the mistakes did you experience while working with BIM?

Not to put too much of details. Should know what is the appropriate level of details for the rich object.

By doing manual annotations, when the model changes the annotations doesn't change automatically.

10. If you get another chance how would you avoid these mistakes?

Prompts: Practice, Degree Program, Training Program

Setting out the outsets and agreeing standards and key goals for the project. And agreement across the teams. So make sure we got the information and provide level of information and then training and education within our practice to make sure that the right information is put into right place in the right way rather than just drawing a coloured line on a plan. Sticking the information on the wall and photograph on the plan raise the information about the wall so you don't have to change any changes. So it's all about the process rather than the end product.

PART-3

What do you advise/suggest to other construction professionals about learning BIM

1. How did the transition in learning occur within your work context?

Because the client wanted and had the vision of managing the entire estate using BIM. They only wanted to use Revit in order keep everything up-to-dated rather than using other software such as AutoCAD and others. Therefore team of 6 had to do that which had the initial training. Then passed the knowledge to the others in the office and we have built through that.

(e.g.: from AutoCAD to BIM, started learning new software such as Revit, CostX, Synchro)

2. What training programs did you follow to learn BIM?

Revit and Naviswork training for the consultants. Client helped to set up the project and made sure that everybody has sat on the same place.

In house training in scheduling, curtain walling and other different topics for small groups. Then we teach this to the other people in the office when their project gets to that level.

Also the cloud rending and cutting edge visualisation side was taught by the new students joins the company.

2. Were there any other opportunities to learn BIM?

Awful lots of conferences such as BIM for manufacturing, BIM for SMES and BIM for FM working groups.

Currently most of conference rather than discussing about the topic they spend more time in networking which is not very helpful. Lot of lectures about internet forum which is not helpful either.

4. Did your company encourage you in any way to learn BIM?

Prompt: Promotions, Increment in salary

This project came through when the recession was going through so BIM was essential to continue the employment. There were no promotions or increased salaries. Just he ability to expand your knowledge beyond using AutoCAD basically which was used for years. And also the BIM benefits are for the people were on the BIM projects who got very fast computers to use Revit.

11. What sort of advice would you give for the people who are interested in learning and using BIM?

Really thinking about the structure of the model and the data and not putting into too much details. Also don't be afraid to ask, there is always organisation that spent the whole day in solving problems. One of the things we do is Audits of the CAD and Revit projects which are part of our QA procedures. This can help the things that are consistently done wrong to be done better. Then we target trainings to those items and also have internet certificates do they know how to do auto schedule by looking at things.

Is there anything you would like to add to this topic?

I think it is about how you would actually caped particularly with suppliers and sub-contractors. You think that they don't know how to do BIM and showing them what you have decided to do or finding ways that they can teach of these process to explore the Excel sheets and they may come back into the model. And rather than spending additional time modelling things somebody else is low. I think the contractors, clients and consultants are getting educated very well and understand why the tools are very useful for the process. But people like good carpenters struggle to understand BIM.

I would like to thank you for your valuable input to this research and appreciate your time.

Extra information:

It is not very much an age thing and what level you are through because we get very very conceptual and very very technical contextual associates. So I think it is more to do with putting a specialist in it because it is been perceived in a technical manner.

Appendix B

Case studies

Mezz underneath the stairs

One of the design meetings has spotted an issue regarding the Mezz underneath the stair core which is going out to the canal side. Therefore, the building has got a duct in between the plant and canal side. BIM coordinator has explained this complex problem using the 3D models during the design meeting. From the graphical representation BIM coordinator showed the cable trays that are going straight to avoid the clash with the duct position. Moreover, he highlighted the stairs that was positioned on the front side of the Mezz where the problem was identified. However, BIM coordinator mentioned while communicating with the other team members mentioned that it is hard to spot the problem in the model and referred to the iCloud scan to show the dislocated cable trays. From his intelligence and understanding with the model he assumed that cable trays need to be shifted into the right row. From his prior experience he indicated that it is vital to consider and change because to avoid the clashed due to lots of services running into the plant. The other issue discovered was that some of the cable trays looks simple in the model which goes straight does not goes straight in the site. Instead it goes further down therefore instead of going straight it was going straight and coming back. Hence there was an additional route. BIM coordinator discussing with the team mentioned that cable trays needs to be rerouted in the model by pushing them further down and bringing back to the normal route as designed in the model. BIM coordinator during the discussion clearly spotted the cable trays in the model showed the cable trays where one needs to be shifted right by 431mm and other two needs to be shifted 408 mm right to be routed in the right direction. Site engineer attended the meeting after understanding the problem clearly mentioned he will organise arrangements to make this cable tray shifted to the right positions as discussed in this meeting.

The situation about the mess underneath the stair core was discovered by the BIM coordinator during the design checks in the model. During this situation the BIM coordinator mentioned that he used to conduct a design check every fortnight and then discuss the issues with the team members in design meetings conducted every fortnight to clarify things (eg: information and dimensions) and to indicate the clashes and errors in the design. Due to the mess underneath stair core there is a duct running between the plant and the canal side. BIM coordinator explained this problem to the other team members attended in the meeting through the graphical representation using 3D models. This clear visualisation has helped the team members to understand the situation. Cables that are going straight to avoid the ducts and stair case that is positioned in front of the Mezz which was problematic in this situation were shown in the model. Although 3D models were used to visualise this problem team members did not clearly understand the issue regarding the stair core indicated in the model. While communicating with other team members BIM coordinator also agreed that it is quite hard to explain the problem through using the 3D model because it was hard to identify the dislocated cable trays in the model. Therefore, BIM coordinator referred to the iCloud scanning where dislocated cable trays were shown in red colour (Ability to change). BIM coordinator with his background understanding and intelligence with the model assumed that cable trays need to be shifted into the right row. Moreover, from his previous experience in this field advised that it is important to consider and change the position of the cable trays to avoid the clashes that can be caused due to number of services running into the plant.

The other issued rose within this situation was about the cable trays running through the ducts. BIM coordinator discovered that cable trays that looks simple in the model which goes straight does go straight on the site (Competent). Through analysing the model further in depth identified that it goes further down which means instead of going straight it does go straight and come back, hence there was an addition route on site. Therefore, team members have raised up questions (Interrogate) about the trust regarding the information visualised in the 3D model.

Supporting this BIM coordinator (Dan) mentioned that:

‘‘If you have questions, just ask without holding it back. Normally people work in silos and keep struggling’’.

The discussion and negotiation between the team members concluded that there is a need to reroute the cable trays in the model by pushing them further down and bringing back to the normal route as designed in the model. Moreover, through the investigation and visualisation of 3D BIM model BIM coordinator explained that one of the cable trays in the model needs to be shifted right by 431mm and other two needs to be shifted 408mm right to rerouted in the right direction. Site engineer attended the meeting understood the problem clearly and mentioned that he will organise the arrangements to make this cable tray shifted to the right positions as discussed in this meeting. This shows site engineer's willingness to learn on project and engage with new problems. In addition, mutual understanding between BIM coordinator and site engineer regarding this problem and resolution methods are explicit in this situation. Moreover, BIM coordinator's collaboration with site engineer has provided guidance to sort this issue on site. Even though problem was identified and solution were analysed in the design meeting, the case study shows that implication in real life situation is vital to consider knowing the practical possibilities of the solutions identified in the meeting.

Data assignment

One of the issues picked up in a design meeting was related to the data assignment to the federated BIM model. Project manager in this meeting mentioned that they have already setup a federated model where they have assigned all the data assigned to it. However, he stated that one of the main problem they are facing is about the quite a lot of data assigned to the model. Moreover, he said changes in the systems and materials are back and forward process. Therefore, due to this uncertainty he complained that in some situation they must do the exercise pretty much from the scratch rather than keep doing the same *thing. Following this project manager mentioned that most of the things have been constructed but they are still getting emails recently and regularly about the updates which make the process difficult. During this discussion the BIM coordinator asked about the when are they going to be in the stage 2? For the question raised by BIM coordinator, project manager said that most of the allocated work complies with BIM level stage and as far as his concern no updates are coming around therefore in theory they are going to be in stage 2 but the problem is anytime they could be bomb barded with the new information. And BIM auditor mentioned information are always passed to the relevant team when they in the position to do it.*

One of the key issues discussed in this meeting was about the data assignment to the federated BIM model used throughout the project. In this meeting project manager has indicated their difficulties due to number of information assigned into the model. This shows the improper management of handing data before feeding them into the model. This result also indicated that people did not know to choose the right thing to be fed into the model instead they have fed all the information collected for the project. Project manager also said that systems are materials in the project keeps on changing which has sometimes led them to the exercise pretty much from the beginning instead of doing the same thing. This indicates the need for continuous updates in the project to stay current. On the other hand, project manager mentioned about emails that he still receives even after the tasks are completed which is a distraction. This shows that the person who oversee distributing the emails are not aware of what is completed and what is not.

During this discussion BIM coordinator asked

When is this project going to achieve BIM level 2?

This shows that people within projects are learning through inquiry-based learning. Following this to answer this question project manager said most of the allocated work comply with BIM level stage and as far as his concern no updates are coming around therefore in theory they are going to be in stage 2 but the problem is anytime they could be bomb barded with the new information. The answer provided by the project manager indicates his holistic understanding about the project as well his awareness about the future problems that can be raised in the project environment.

On the other hand, BIM coordinator during the interview mentioned the way they are maintaining the information.

''We can easily fill in forms, spreadsheets and we can push our information back into the models is the physical changes happen to the models''

Moreover, during this situation, he has clearly shared the information regarding BIM level 2 about the standards, software used, and discussion on how they have completed the tasks. At the end of this discussion about this issue BIM auditor mentioned information are always passed to the relevant team when they in the position to do it. This shows that people's roles and responsibilities in the project to complete their allocated project tasks. In this case study communication and interaction between project manager and BIM coordinator indicates the team work that happens within the project. Moreover, this also shows the collaborative environment in this BIM project.

Clashes between cable trays and beams

In one of the design meeting BIM coordinator spotted some clashes between cable trays and beams. BIM coordinator started analysing the issue through looking at the visualisation of BIM 3D model. Service engineer through looking at the model and using his prior experience assumed that these clashes could be due to the missing cable trays which sometimes accidently get deleted. During this analysis BIM coordinator also identified the cable trays sitting behind the columns. From the 3D model presented in the meeting team member also identified that cable tray that were clashing beams got bigger than it is originally designed in the model. Moreover, BIM coordinator from his intelligence with the model mentioned that cable trays have moved automatically in the model not with the beam but also penetrates the retaining walls. Therefore, Service engineer after identifying and analysing the positions of cable trays agreed to pull the cables behind the columns and retaining walls to the right positions and advised double check the missing cable trays including altering the cable trays to the right sizes as it is specified.

This situation is about the cable trays that clashes with the beams. This was highlighted among the other clashes because this clash was found in several places of building and caused other adjacent aspect to clash as well. This problem was analysed mainly through using visualisation of 3D BIM model (resources). This also shows BIM coordinator's prior knowledge and experience. While looking at the model Service engineer with his prior experience assumed that this clash could be due to missing cable trays which sometimes accidentally gets deleted (experience, assumptions). Service engineer's assumptions on missing cable trays state his holistic understanding of the project.

Furthermore, in this situation BIM coordinator also discovered the cable trays behind the column. This shows his openness to view the issues around the ongoing situation. This also shows that the BIM coordinator has the mind-set to look around and see the other related issues during that situation. From the 3D model presented in the meeting team member also identified that cable tray that were clashing beams got bigger than it is originally designed in the model (continuity-automated). Moreover, BIM coordinator carefully looking at the model and using his prior knowledge and experience mentioned that cable trays have moved automatically in the model not with the beam but also penetrates the retaining walls. This shows the level of understanding of the team members who have thought that cable trays are clashing with the beams instead of penetrating through the retaining wall.

In addition, BIM manager of this project in his semi-structured interview mentioned:

‘‘First, they need to understand what goal they need to achieve and the way they need to provide the details or data to achieve this goal’’.

Therefore, BIM coordinator after identifying and analysing the positions of cable trays he guided the Service engineer to pull the cables behind the columns and retaining walls to the right positions. Moreover, he also advised the Service engineer to double check the missing cable trays including altering the cable trays to the right sizes as it is specified. The involvement of BIM coordinator and the team members shows the collaborative environment and team working conducted to resolve this issue.

Toilet Connection

One of the issued discussed in the meeting was about toilet connections taken up to all levels. BIM coordinator and Service engineer after analysing the model stated that the position of toilet connection needs to be changed because it was designed with mark ups from the old version of the model. During this analysis about the toilet connections BIM coordinator raised a question ‘Can some of these toilet connections can be removed?’’. Service engineer replying to that mentioned that it cannot because they cannot go back of the toilet. Moreover, he mentioned this all depends on how close the centre is on toilets and cannot get fittings that allow you to get back of the toilet because there are two toilets either side of it on the same level. Therefore, pipes to the toilets needs to go one after the other. However, in this situation BIM coordinator noticed that these toilets connect are installed in a different way than expected from how it was discussed in the meeting and mentioned in model. In this different way team members on site have connected fitting to get install two parallel pipelines however the distance between the pipelines is not achievable in their method. However, site engineer reported that this is achieved in site through chopping or cutting the fittings or could do through cross connections. Moreover, from his experience he mentioned that it all depends on the fittings because it needs to provide the force to let the water down through the connections and he stated that all the fittings they have checked didn’t allow them to do it. During this situation, connection issues between gutters and down pipes were also mentioned and Service engineer from his experience stated that this can be sorted through slightly moving and rearranging the cable trays running next to it. However, toilet connections are quite complicated to deal with therefore this issue was handed over to the building service team. In this way it is easy to sort the problem because building service team has a holistic understanding about all the connections related to sanitary works and connects which will help to make efficient decisions.

This case study was about the toilet connects that has been taken up to all the levels. BIM coordinator and Service engineer after looking at the model (resources) (Intelligence with the model) from their prior knowledge and experience identified that the connections need to be changed. Moreover, both of these professionals were involved in this project since the project started (holistic understanding) that therefore they mentioned these changes are necessary because they are designed using mark up from the old version of the model (Continuity). During this analysis about the toilet connections BIM coordinator raised a question regarding ‘‘Can some of these toilet connections can be removed?’’. (Inquiry based learning, communication). This shows members have the opportunity clarify their doubts with the other team members in the project. Service engineer for the raised question mentioned that it is impossible to remove because there is no access to go back of the toilet. Moreover, he explained that this all depends on how close the centre is on toilets and cannot get fittings that allow you to get back to the toilet because there are two toilets either side of it on the same level. Therefore, he advised that pipes to the toilets needs to go one after the other (Level of understanding). However, during the discussion BIM coordinator observed that these toilet connections are installed in a different way than expected from how it was discussed in the meeting and mentioned in model (reflection: reaction). This indicated that there is miscommunication while installing the toilet connection on site. In this different way team members on site have connected fitting to get install two parallel pipelines however the distance between the pipelines is not achievable in their method (Poor planning). However, site engineer reported that this is achieved in site through chopping or cutting the fittings or could do through cross connections (Mind-set, ability to change, skills, thinking outside the box). From this he also shared the information about how this has been done in the site. This also shows that team members have different perspectives to achieve the same task within the project.

Supporting this BIM coordinator mentioned that:

‘‘You need to be very quick learner. Because it is always a new piece of software, tools and technology. So, you should be able to pick it up quickly and automatically from the experts’’.

Moreover, site engineer said from his previous experience it all depends on the fittings because it needs to provide the force to let the water down through the connections. However, he stated that that all the fittings they have checked didn’t allow them to do it. After the communication between BIM coordinator and Service engineer including other team members attended the meeting came to conclusion that these toilet connections are quite complicated to deal with therefore it is better to hand over this issue to the building service team (decision making). In this way it is easy to sort the problem because building service team has a holistic understanding about all the connections related to sanitary works and connects which will help to make efficient decisions.

On the other hand, during this situation connection issues between gutters and down pipes were also discovered and further analysed with the team members (team work). This indicates that team members are aware of what is happening around while they are focusing on an issue. During this situation Service engineer from his experience in this field stated that this can be sorted through slightly moving and rearranging the cable trays running next to it.

Pipe work location

In one of the design meeting issue regarding pipework location which was identified in the model was raised. In the beginning if the meeting BIM coordinator raised a question to the team members presented in the meeting ‘Does anyone know about the pipe work locations?’ This was raised because at the time scanning was conducted the pipe works were not completely installed. Architect tried to explain the location using 2D drawings and 3D BIM models. However, BIM coordinator mentioned it has been changed a lot after several design changes in the model. Moreover, he added that he was not sure about the duct work which is clashing with the frames closer to the canal side of the building. Therefore, during this situation architect also double checked the coordinates of other adjacent building element such as glass fab to see whether they are clashing with these pipes. Architect from his understanding stated that one of the reasons for this clash causing due to the duct work is due to deleting the block wall in the model which was on the model and didn’t allow the architect to sync the model. So, architect mentioned that the model won’t be showing is the elements that aren’t framed around that stair and should be done soon. Therefore, he mentioned others need to coordinate with the outline mass of the stairs. During this situation Service engineer raised a question ‘‘whether there is any route through actual steel frame?’’. For this architect answered that is one a higher up and none in this level within the floor. On this situation BIM coordinator also observed that in the model pipe work looks like it is bending however in site they didn’t know what to do and they have finished in a random place where pipe ends. This is clear shown in the iCloud scanning. In addition, BIM coordinator mentioned that this will be problematic when someone come and wanted to put a radiator there because there *won't be any pipelines to connect the radiator. Therefore, this discussion ended concluded saying that pipelines need to be routed around it rather by moving a little bit up rather than stopping it there.*

The case study focused on the pipe work locations in the building. This was initially identified through the 3D model and then raised to the team members. BIM coordinator in the beginning of the meeting raised a question 'Does anyone know about the pipe work locations?'(Inquiry based learning) because pipe works were not completely installed while iCloud scanning (resources) was conducted.

Supporting this architect in the semi-structured interview mentioned people involved in the project should not

''be afraid to ask, there is always organisation that spent the whole day in solving problems''.

During these lots of discussion and negotiation regarding pipe work locations were analysed in the BIM federated model. In addition, during this discussion tried explaining the location using 2D drawings and 3D BIM models (resources). However, BIM coordinator mentioned that design has been changed several times due to availability of materials and client's requirements since the 2D drawings and 3D model were produced (continuity). Therefore, because pipe works location has not been confirmed yet. Moreover, BIM coordinator added that due to these design changes he was not sure about the duct (confident) work which is clashing with the frames closer to the canal side of the building. Therefore, during this situation architect also double checked the coordinates of other adjacent building elements such as glass fab to see whether they are clashing with these pipes (self-forward thinking). This is to make sure that they are complying with the new design changes without clashing each other. Architect from his understanding with the model and data involved stated that one of the reasons for duct work clash is due to deleting the block wall in the model which was on the model and didn't allow the architect to sync the model (communication). So architect mentioned that the model won't be showing is the elements that aren't framed around that stair and should be done soon (sharing information). Therefore, he advised other team members to take outline mass of the stairs into consideration while they are modelling any elements or making any changes in the model (awareness). During this situation Service engineer raised a question ''whether there is any route through actual steel frame?'' (Interrogate). This was raised to clarify whether there is any pipe works going through the steel works out of their concern (awareness). For this architect answered that there is one a higher up and none in this level within the floor (sharing information).

On this situation BIM coordinator also from the 3D BIM model observed that pipe works looks like it is bending (assumption, reflection). This was only spotted from the understanding of BIM coordinator and team members presented agreed with the observation (level of understanding). Therefore, after contacting the site engineer it was confirmed that in site they didn't know what to do and they have finished in a random place where pipe ends which is clearly shown in the iCloud scanning (miscommunication). Moreover, this also shows that improper planning before executing the design on site. This situation clearly shows the lack of link between what is happening on site (real life situation) and in model. From previous experience BIM coordinator mentioned that that this will be problematic when someone come and wanted to put a radiator there because there won't be any pipelines to connect the radiator (making aware) Therefore this discussion ended concluded saying that pipelines need to be routed around it rather by moving a little bit up rather than stopping it there (decision making). Discussion between BIM coordinator, architect and Service engineer explicitly shows the team work in the collaborative environment.

f) Lighting settings out

In one of the design meeting attended lighting setting out was considered a serious issue. Therefore, the team members have brought this issue forward. Architect looking at the model stated that lighting setting out in the building was 2m down last time. However now due to Mechanical and Engineering (M&E) consultant has shifted these lightings a bit higher, lighting have changed from previous positions. However, M&E consultant mentioned that Revit files did not allow the lightings to move further up. Therefore, during this meeting lighting specifications were checked again to see the minimum level of allowance for height of the lightings used in the buildings. Architect viewing the 3D model and from his prior knowledge and experience mentioned that lightings must touch the ceiling. However, the design manager from building service team attended the meeting said that he was not sure how to move the lightings further up. BIM coordinator in this situation mentioned that the instructions regarding the lightings are not given properly to the other team members in terms of expectations. Therefore, team members without correct instructions are not prepared to do or take responsibility to make changes. In this situation BIM coordinator suggested to use laser scanning which is Autodesk recap files that can straight away link to the Revit models (eg: exposed levels-ground, mess and half of level 1) to position these lightings. In this situation lighting locations were also double checked with the manufacturer's details and discovered that some of the lighting positions were tweaked a little bit with the aid of manufacturer's details. Therefore, at the end of the meeting further discussion was arranged with the architect to explain more on how to fix the length of the lightings and to know his expectations regarding the lightings in the building.

This case study is about the lighting setting out in the building. This issue was raised in the meeting through Architect stating that lighting setting out in the building was 2m down last time (sharing information). This observation of architect shows his involvement with the 3D model and understanding the data embedded in it (intelligence with model, level of understanding). Following that he stated that this is due to Mechanical and Engineering (M&E) consultant shifting these lightings a bit higher which lighting have changed from previous positions (awareness, continuity). This show that architect is aware of what is happening in the project due to the continuous design changes. However, in this situation M&E consultant explained the difficulties of moving the lightings further up and concluded that at the end Revit file did not allow the lightings to move further up. Through this M&E consultant reflected on experience about how he faced problems while trying to move the lightings further up. At the same time mentioning about Revit files which did not allow them to move the lightings upwards shows familiarity of using the software.

In addition, BIM manager in his interview stated that:

''They already know how to understand the paperwork to work with BIM and now it is important to replicate what they use on''.

This discussion has led the team members to explore on lighting specification. Therefore, during this meeting lighting specifications were checked again to see the minimum level of allowance for height of the lightings used in the buildings. This is to clarify more about the information on lighting that are provided to the project team members. Furthermore, architect through the 3D model and from his previous experience and knowledge mentioned that lighting needs to touch the ceilings. While this discussion design manager from building service team attended the meeting said that he is not sure about moving the lightings further up and requested further guidance and advice to complete that task. However in this situation BIM coordinator mentioned that the instruction regarding lightings are not properly and clearly provided to the team members in terms of the expectations (lack of clarity). Also in semi-structured interview he mentioned that even though he teaches

''People in one to one basis showing them how to do it but then again when I check the system there aren't following what I taught them''.

Furthermore, this shows that lack of organisation of work where team members does not even have fundamental information to sort this problem. Therefore, members without sufficient information and correct instructions are not prepared to do or take responsibility to make changes. In other words team members are not confident enough to make changes or take responsibility regarding making changes due to insufficient information. During this situation BIM coordinator to ease this situation advised to use laser scanning which is Autodesk recap files that can straight away link to the Revit models (eg: exposed levels-ground, mess and half of level 1) to position these lightings. This shows that diverse opportunity to learn about the positions of lightings (learning avenues). Following that lighting locations were also research more through double checking with the manufacturer's details and discovered that some of the lighting positions were tweaked a little bit with the aid of manufacturer's details (consulting-checking). Finally, at the end of the meeting further discussion was arranged with the architect to explain more on how to fix the length of the lightings and to know his expectations regarding the lightings in the building.

Lift near the lobby

Architect in the meeting raised a question regarding the egg platform lift near the lobby. He mentioned that the survey conducted two weeks back shows that the lobby is about 45-50mm low than its original position designed in the 3D model. Architect thinks about the walls on the either side of the lift is in the tolerance area however the platform is considerably slightly bigger than expected. He also advised the team members that due to this changes stair need to be 50mm bigger than it was. Therefore, he said they need to make it 100mm shorter through moving the front riser in front of it (move 25mm). At the same time, he made aware that both the duct underneath are only 300mm deep therefore the riser needs to be moved according to that. Architect mentioned that from looking at it this change would work but and mentioned that there is no access to that riser (it is the one which goes top of the lift). During the discussion Service engineer in this situation mentioned that there is no need of access and the only access needed is for the fire damper. Architect to make sure asked BIM coordinator to show the location of the fire dampers and finally found out that fire damper for the duct sits underneath the stairs.

This issue started with raising a question regarding the egg platform lift near the lobby. This indicates the interrogation among the team members. Following that architect mentioned that survey conducted two weeks back shows that the lobby is about 45-50mm low than its original position designed in the 3D model. In this situation 3D model and the survey results were used as the resources to analyse this issue a bit further. In addition, architects' prior knowledge and experience including the intelligence with the model have helped to identify the changes that happened in the lobby. This also shows the continuity of the project where design keeps on changing. Architect from his experience thinks that the walls next to the lift are within the tolerance area however the platform is considerably slightly bigger than expected. This not only depicts the communication between the team members but also experience of the architect but also how he has used to assume things in relevant situations.

BIM coordinator in the interview explained the way they maintain the level of knowledge within the project participants.

''we can make sure that they have got the basic knowledge and if they don't have we provide them training from the beginning''.

With that knowledge (level of knowledge) architect advised the team members to change the stairs height needs to be 50mm bigger than it was to balance the other building elements in the design. Therefore, he guided the BIM coordinator using the 3D model how to make the alteration in the stairs. He also said that they must make the width of the stairs 100mm shorter through moving the front riser in front of it (move 25mm). This depicts that to make a change the other adjacent elements need altered as well while redesigning process (automation). During this design alteration process architect also made aware of both the duct underneath are only 300mm deep therefore the riser needs to be moved according to that. During this discussion architect also mentioned that from looking at it this change this would work but and mentioned that there is no access to that riser (it is the one which goes top of the lift). The confident level of architect to say that this would work has come from his experience in this field for a longer time than the other members presented in the meeting. The opening a statement about the access to the riser shows that architect wants to clear something or wants to get more information on riser access from the team members (communication). Understanding that clearly Service engineer said that there is no need of access to the riser and the only access needed is for the fire damper. This again shows Service engineer's experience in his field and shows the different perspective compare to others. This also shows how team members share information among them with the project. Architect to make sure asked BIM coordinator to show the location of the fire dampers and finally found out that fire damper for the duct sits underneath the stairs. This shows that architect does not believe what site engineer has said until he sees the 3D model to make sure what has been mentioned by the site engineer is true. This shows the matter of trust among the team members involved in the project. Architect's keenness to find out the location of the fire damper with the aid of BIM coordinator depicts the team work in the collaborative environment to understand more about something related to the project.

Conflict on window position

In one of the design meetings BIM coordinator using the 3D model has identified a window which was situated between two columns and discovered there was also no steel work to connect it. This issue in the meeting was shown to the other team members in the meeting through the visuals pulled out from the model. After this was reported site engineer on site was conducted through the phone while meeting was taking place. During the conversation with the site engineer BIM coordinator collected more information on the setting out dimensions particularly for window and steel connected to it. BIM coordinator through talking with the site engineer also double checked that the information they have got is correct. After analysing on the elements on site through site engineer the specification provided was checked against the collected information and the model designed for the window. This exploration with the team members have led the BIM coordinator to identify that the cill needs to be raised a little bit up to rectify the identified error. Moreover, during this discussion architect after discussing with the team suggested that glazing for the window needs to be split into several sizes (six or four, no longer than 3000mm and 1800mm wider including the constraints).

This situation is about a window which has been discovered in between two columns. BIM coordinator had identified this issue through the clash detection process in the 3D model. This shows that the problem has been identified through using 3D model as a key source. Following that BIM coordinator using the model and his intelligence with the model has also discovered that there is also no steel work to connect these windows and columns. For the team member to understand more about the identified issue BIM coordinator has pulled out the visuals of the clash identified (visualisation). This has helped the team members not only understand where the clash has happened but also to understand why it has happened (level of understanding). After the team has understood the problem BIM coordinator wanted to know about what has happened in the site regarding this issue (real life situation). Therefore, he has decided to make a phone call to site engineer during the meeting in front of all the team members to know about the real situation (communication). During the conversation with the site engineer he shared all the information on the setting out dimensions particularly for window and steel connected to it. BIM coordinator after collecting the information from the site engineer double checked whether his information he has got is correct (consulting-checking). Following that after analysing the elements on site through site engineer the specification provided was checked against the collected information and the model designed for the window. This shows the site engineer's reflection after the conversation with site engineer. This analysis with the team members has led BIM coordinator to discover that the cill needs to be raised a little bit up to rectify the identified error (decision making). This shows that problems are sometimes connected to each other. Moreover during this situation architect using his prior knowledge and experience has suggested that that glazing for the window needs to be split into several sizes (six or four, no longer than 3000mm and 1800mm wider including the constraints). BIM coordinator's determination to link the design and the real-life situation shows his effort to get the information and design correct to rectify the error identified. Also, the team work to solve this problem shows the collaborative environment in the project.

Conversely BIM coordinator during semi-structured interview highlighted the that little bit of background knowledge is sufficient for private company like them however he stated

''…having an in depth understanding about what it is all about and what is actually going to take out of the ground'' is important in BIM projects.

Structural movements and screeds

During one of the design meetings drawings on screed that clearly describe about the joints in the screeds and tiles were pulled out for the discussion by the architect. In this situation architect mentioned that positions of the building elements seem be incorrect and he assumes that there is an error in the model however he is not quite sure where the error is coming from. During this process architect was concerned about the design rather than looking at the details. Structural engineer after looking at the drawing asked the BIM coordinator to show this section on the federated model. After analysing the model bit further with the aid of BIM coordinator where he viewed the section from different angles, at the end concluded that the allowance for structural movements of screeds and tiles were not considered while creating finishes with the screeds. In addition to this he spotted that there is corridor space looked empty without anything on top that space. Moreover, from his understanding he said that he is expecting that these structural movements have the capability to break the screeds and corridors in 6m distance. In this situation there were lot of discussions on the importance of leaving this allowance for structural movements in the buildings. Moreover, during this sub-contractor has risen for the detailed information from the tiles/screed manufacturer to define the tile sizes. Therefore, to resolve these drawings were suggested to be altered with the consideration of structural movement that can take place automatically after the installation. At the same time this change were also recommended to be done in the 3D model.

This case study was about the focus on structural movements and screeds in the building. Architect during his design check has identified that the positions of the positions of the building elements seems be incorrect and he assumes that there is an error in the model however he is not quite sure where the error is coming from (level of understanding). This issue was spotted through looking at the architectural drawing for this project (resources). This shows that architect does not have much trust in the data included in the model to the confusions. Architect's prior experience has led him to identify the problem but he is kind of distracted by the design rather than concentrating on the details about the position of the building therefore he was kind of lost in this situation. Sharing this information among the team members also shows that architect wants to make to aware that there is a problem in this section as well as to get a clear picture of what has caused this (awareness, level of understanding). Following this structural engineer after looking at the drawing asked the BIM coordinator to show this section on the federated model. Visualisation in this problem helped all the team members including both structural engineer and architect to understand the problem more clearly (level of understanding). Also, structural engineer has requested the BIM coordinator to show this section on the federated model and during this BIM coordinator using his skills shows the section from all the angles and pulled out all the information requested by the structural engineer. This research shows BIM coordinator's intelligence with the model and their team work to understand the problem. After analysing the model with the aid of BIM coordinator, structural engineer explained the architect the problem for incorrect position of building elements is due to avoiding the allowance for structural movements of screeds and tiles were not considered while creating finishes with the screeds. In addition to this he spotted that there is corridor space looked empty without anything on top that space. This shows team member's mind-set to look at the problems that happens around the problem they are focusing on. Moreover, from his understanding and experience he said that he is expecting that these structural movements have the capability to break the screeds and corridors in 6m distance. Importance of leaving the allowance for structural movements in the buildings was discussed in the meeting. This is make aware how serious is the situation and therefore members have to consider this while designing and making decisions. Moreover, during this sub-contractor has risen for the detailed information from the tiles/screed manufacturer to define the tile sizes (sharing information). This shows that sub-contractors are expecting more details regarding tiles and screeds to complete their task (level of details). Therefore, to resolve these drawings were suggested to be altered with the consideration of structural movement that can take place automatically after the installation. At the same time this changes were also recommended to be done in the 3D model. This shows the continuous updates (continuity) which are necessary to solve these kinds of unexpected issues.

<u>Cable tray clashes</u>

An issue regarding the lighting coordination and cable trays were raised in the meeting by the BIM coordinator. BIM coordinator raised a question whether the cable trays need to be in this floor (1st floor) or any other floor because it is clashing with the steel frame. This clash detection has been identified while going through the design checks in BIM 3D model. Service engineer looking at the model indicated that they have put the cable trays in the wrong level. Following that there were couple incidents regarding bus bar and some cable trays again clashing with the columns. BIM coordinator identified that cable trays clashing with the beam because of the new structure brought for the doors. Some of the cable trays were clashing with the extended column pad and some cable trays inside the retaining wall. These were highlighted to both Service engineer and architect during the meeting and requested them to consider these issues while modelling other elements. In this discussion BIM coordinator also asked the team members to use the panoramas (panoramic view pictures) while dealing with these clashes. BIM coordinator said he has checked some of the clashes in this panoramic view and he said it clearly shows where the cable trays are coming from and helped him to get a clear picture of how it looks like. Service engineer mentioned that he tried to attempt this panoramic view but not familiar with it and runs out of the licence. For this BIM coordinator was more than happy to teach him and share the licence with their company.

This case study was about the clashes between lightings and cable tray clashes in the project. BIM coordinator started the meeting with the question ‘‘whether the cable trays need to be in this floor (1st floor) or any other floor’’. This was raised because from the 3D mode he has identified that some of the cable trays were clashing with the steel frame on the first floor. Question rose during the discussion shows that interrogation among the team members and the 3D model has used as a resource to identify the problem. BIM coordinator with his prior knowledge and experience and with his intelligence with the model has identified several other cable tray clashes. Service engineer looking at the visuals in the model (visualisation) and with his holistic understanding about the building design indicated that the cable trays that are clashing with the steel work is on the wrong level. Following that there were couple incidents regarding bus bar and some cable trays again clashing with the columns. During this BIM coordinator from his knowledge suggested that these cable trays can be moved little bit to the right where there is plenty of space that can be seen from the model (visualisation, level of understanding). On the other hand, BIM coordinator also identified that cable trays clashing with the beam. Architect mentioned that this was due to new structure brought for the doors (continuity). In this situation architect shared all the information regarding the new structure of the door to the team members presented in the meeting. The visuals in the 3D model along with the information provided by the architect have provided a clear understanding about the position of the new structure of the door. Further analysis about the cable trays have spotted some other cable trays which were clashing with the extended column pad and some cable trays inside the retaining wall. These were highlighted to both Service engineer and architect during the meeting and requested them to consider these issues while modelling other elements. This is to make awareness of what they have focus in terms to avoid the clashes identified. During this discussion BIM coordinator recommended the team members to use the panoramas (panoramic view pictures) while dealing with these clashes. This is to motivate the team members to adopt new technologies that are introduced in this field. In addition, BIM coordinator in the semi-structured interview explained the way he started to use these panoramic views. He stated that he was

‘‘…taking the photographs, taking note about the rooms on the campuses using iPad’.

Following that BIM coordinator explained how he has checked some of the clashes in these panoramic views and he said it clearly shows where the cable trays are coming from and helped him to get a clear picture of how it looks like. Through sharing his experience (learning avenues) BIM coordinator was trying the team members to realise the value using panoramic view. However, the Service engineer attended the meeting mentioned that he tried to attempt this panoramic view but not familiar (familiarity) with it and runs out of the licence. Therefore, BIM coordinator said he is more than happy to teach him how to use the panoramic view and arranged a training session for him (learning through in house training). Moreover, he also agreed to share the licence to the company (Sharing facility).

Ducts in the lobby clashing with the pedestal

In one of the meeting BIM coordinator with the use of 3D model has identified an issue regarding ducts which was clashing with the pedestal and the problem here is there is no support provided in this situation. While exploring this problem they have also identified that this duct which is underneath the floor is also problematic. Moreover, during the discussion, the ducts in some places have been found are shorter than it is designed in the model therefore architect suggested that in this case support could be taken out. While this discussion structural engineer said ''just to let you know that we probably going to do some adjustments in site rather than waiting for the software solution company because we want to finish the job within the time''. Therefore, they suggested that are going to put the pipes where they have got heating and pipelines and amend them in site either to left or right to avoid the clashes. However, member from the software solution company mentioned they are struggling to keep up with the changes. Moreover, he said this is due to them not getting the information from level 1, 2 3, 4 and 5 quick as possible. He also said this is because they haven't issued any drawings for these levels. Instead he said ''we have only issued information on ground floor with certain amount of assumptions''. The floor layout from the architect has made confusions due to the assumptions made regarding bridging section which is possibly required for level 1. So structural engineer requested that information should come fairly quickly.

This situation is about the ducts clashing in the buildings. BIM coordinator in the beginning has used the 3D model to identify the clashes regarding ducts (resources). BIM coordinator using his prior knowledge and experience along with the intelligence with the model has identified these clashes. Firstly, he mentioned about the duct which was clashing with the pedestal and the problem here is there is no support provided in this situation. This problem was shown to the team members through the visuals pulled out from the model (visualisation). This has helped the team members to understand where the clash is taking place and why it is happening (level of understanding). During this exploration process BIM coordinator has also identified that this duct underneath the floor is problematic. This was easy to identify through the visuals that was presented in front the team members (Visualisation). In this meeting architect looking deeply into his architectural model further confirmed that that some of the ducts clashes are shorter that it is designed in the model (Sharing information). Moreover, using his prior experience architect mentioned that in this situation the extra support provided to the ducts can be removed.

While this discussion was going on structural engineer mentioned ''just to let you know that we probably going to do some adjustments in site rather than waiting for the software solution company because we want to finish the job within the time''. This shows that structural engineer wants to inform the team members about what is happening in site (awareness). Also from this statement there is no good communication between structural engineer's team and software solution Company. Therefore, structural engineer's team said that are going to put the pipes where they have got heating and pipelines and amend them in site either to left or right to avoid the clashes (continuity). This is to help the team members to plan their other activities to according to these changes and to be aware of the change that is happening around them.

Supporting this BIM manager indicated

‘‘we need to interact and understand ourselves and what we need and what everyone else need’’.

On the other hand, members from the software solution company mentioned they are struggling to keep up with the changes. Moreover, they mentioned that this is because of not getting the information from level 1, 2 3, 4 and 5 quick as possible. This shows the poor information management among both structural engineering team and software solution team. Also, the member from software Solution Company mentioned that they haven’t issued any drawings for these levels. Instead he said ‘‘we have only issued information on ground floor with certain amount of assumptions’’. In this situation having insufficient information (lack of sharing information) has lead the software solution team members to assume things to complete their tasks. At the same time, they mentioned that the floor layout from the architect has made confusions due to the assumptions made regarding bridging section which is possibly required for level 1. This shows that there is no enough details about the bridging section provided to this team (level of details). So finally, to avoid these clashes identified in this meeting structural engineer requested all the team members to share all the information related to in the federated BIM model so that all the team members can access to those information and plan according it (sharing information, common space).

<u>Projectors clashing</u>

BIM coordinator during the design meeting has discussed about the projectors in egg theatre which was clashing with everything on the way and following that ceiling was also clashing with the frames from the both sides. This was identified through the clash detection process in the 3D model which was conducted by the BIM coordinator. Team members asked to show the visuals of these clash detection on the model to get a clear picture of it. During the analysis project engineer presented in the meeting also spotted that this is also clashing with the ductwork and clashing with the ceiling design and finishes. Team members looking at this issue understood that this clash is complicated compare to the others because it causes number of other clashes in the model. Therefore, architect mentioned that it’s better to approach a specialist within the organisations involved in this project to sort out this issue. The other thing architect mentioned was however they can slightly move the ceilings to the right to avoid the clash between the frames. In this meeting architect highly recommended the team members to approach the specialist because he said that his team has not got the competent to suggest solution for this issue because their team have not got access up to that level where projector was placed. Therefore, specialist or specialist team is essential to deal with the issue related to that level but it could be solved if they can drop the level of projectors a little bit down. Moreover, he mentioned that when they designed the structural grid for that level the client went through different people and process however the architecture team was not involved in it. So finally, the team has contacted to hire a specialist to sort out this issue identified in this meeting.

This situation was about the projectors clashing in the building. BIM coordinator in the design meeting has pulled out the clash about the projectors in egg theatre that he has identified through the clash detection process (Visualisation). BIM coordinator from his prior knowledge and experience including with the intelligence of the model identified these clashes and mentioned that they are clashing with number of other elements in the building. In the beginning of the meeting BIM coordinator mentioned that projectors in egg theatre which was clashing with everything on the way and following that ceiling was also clashing with the frames from the both sides. During this discussion team members asked to show the visuals of these clash detection on the model to get a clear picture of it (level of understanding, interrogation). This in another way makes the team members aware of what is happening around the project. While looking at the visuals pulled out from model project engineer spotted that this is also clashing with the ductwork and clashing with the ceiling design and finishes. This shows that project team members presented in the meeting are very open to the problem because they rather than focusing on problem discussed in the meeting looks around the other problem related to it (openness). In other words, this also shows that their mind set to tackle many problems at the same time. Multidisciplinary team (team structure) involving in this collaborative environment looked at the issue and decided that it is too complicated to be tackled by themselves because it causes number of other clashes in the model. Therefore, in this situation architect advised the other team members to approach a specialist within the organisations involved in this project to sort out this issue. He also explained that design team has not got enough capable people to tackle this issue due to the complexity in this issue (competent). Moreover, he mentioned that their team has not got access to those levels where projectors were places and but it could be solved if they can drop the level of projectors a little bit down. However, in this situation architect using his prior experience suggested that they can slightly move the ceilings to the right to avoid the clash between the frames. At the same time, he suggested that hiring a specialised team or specialist is the best option essential to deal with the issue related to that level but it could be solved if they can drop the level of projectors a little bit down (experience).

On the other hand, architect during the semi-structured interview mentioned:

‘‘I think it is more to do with putting a specialist in it because it is being perceived in a technical manner’’.

During the discussion architect mentioned that one of the reason that they are unable to sort this issue is because while designing the structural grid for that level the client went through different people and process however the architecture team was not involved in it. This shows that organisational structure about who to involve and when to involve during making decisions in the project. So finally, the team has contacted to hire a specialist to sort out this issue identified in this meeting (decision making).

Clash between door heater and pipeline

An issue regarding door heaters and pipelines were discussed in one of the design meeting. BIM coordinator during the clash detection process in the 3D model identified that heater located next to the door was clashing with the pipelines. Architect in the situation mentioned that the reason for that is due to the pipe line shifted to the place and Service engineer added that this issue needs to be sorted soon to avoid further clashes that can be cause because of this. During this meeting BIM coordinator raised question about duct work creation. Building Service engineer mentioned that according to duct work family creation it cannot be moved in Revit model but it is worth having a play around it to understand the model. Following that BIM coordinator mentioned that there is lot of connections related to the duct work and identified more in this kind of family. Therefore, he requested the Building Service engineer to explain more about the families and specifications related to them. Service engineer mentioned that to avoid this issue he has kind of deleted all kind of access in the model and in some cases activated visibility option to turn them down. After looking at the Service engineer’s alteration in the model BIM coordinator mentioned that connections are coming in and out therefore to make the duct connection transparent in the model.

This case study was about door heater clashing with the pipeline. This issue was identified in the 3D model (resources) and was discussed in the design meeting by the BIM coordinator. BIM coordinator using his prior knowledge and experience has spotted that this clash in the model. After looking at the model architect with his prior experience mentioned that the reason for these issues is due to the pipe line shifted to the place. This shows his holistic understanding of what has happened before related to this issue.

During the semi-structured interview architect mentioned that this knowledge has been mostly developed through sharing information with the other team members. He mentioned that he normally makes

‘‘presentation for previously identified issues that went wrong and then the deeper understanding is provided through recommendation (for team) to do it better for the future projects’’.

Following that Service engineer from his understanding assumed that this issue needs to be sorted soon to avoid further clashes that can cause further clashes due to this. During this BIM coordinator raised question about duct work creation. This shows the interrogation between the team members in this project. For this Building Service engineer mentioned that according to duct work family creation it cannot be moved in Revit model but it is worth having a play around it to understand the model. This indicated the level of understanding that building Service engineer have regarding family creation. Following that BIM coordinator mentioned that there is lot of connections related to the duct work and identified more in this kind of family (research). Therefore, he requested the Building Service engineer to explain more about the families and specifications related to them. This indicates that BIM coordinator is trying to learn more about the family creation that he is not sure about through inquiry based learning. This also shows the team work in this collaborative environment in this project. During this situation Service engineer mentioned that he has tried to delete all kind of access in the model and in some cases activated visibility option to turn them down (visualisation). This depicts his effort to resolve this issue using his knowledge. However, after looking at the Service engineer's alteration in the model BIM coordinator provided the feedback saying that connections are coming in and out therefore to make the duct connection needs to be transparent in the model.

Details about the sockets and distribution board

In one meeting architect discussed about the details about the sockets and distribution board. During this architect has used 2D drawings, 3D models and specification to analyse the positions and details about the sockets and distributions boards. Architect after the research asked the Service engineer whether these can be achieved as designed in the model with the specification provided. BIM coordinator at this point mentioned that this is important to clarify because they are already late from the scheduled time to install the mechanical and electrical (M&E) services. Moreover, they also looked at the all the information assigned to sockets and distribution boards are correct. Supporting this other member in BIM meeting mentioned that drivers of M&E need to consider before the installation because this will be beneficial to achieve the client's needs. However, Service engineer mentioned it is enough to concentrate on what they are doing and the other issues will be snagged in the model if it causes any difficulties. Also, the standards in the Revit model was discussed in the meeting because Revit is American and team members identified that it does not have UK standards. Therefore, electrical board against the room were hard to locate and placing the sockets in the right places were problematic. Therefore, at the end team agreed with the standards that they are going to adopt in this project in terms of Revit model to avoid the confusions in position of sockets and distribution board.

The case study started with the discussion about the sockets and distribution boards in the building. Architect with the use of 2D drawings, 3D models and specification (resources) mentioned that analysed the positions and details about the sockets and distribution boards in the model. This shows that architect's mind-set to get the information correct before the execution. To clarify more after his research with the team members asked the Service engineer whether these can be achieved as designed in the model with the specification provided. This interrogation between these team members shows that architects planning to get the good structured data for the sockets and distribution boards. This clear through architect looking at the all the information assigned to sockets and distribution boards are correct. Service engineer for the question answered that it can be achieved if the standards are correct as specified in the design. In this situation BIM coordinator at this point mentioned that it is also important to clarify this information soon as possible because they are already late from the scheduled time to install the mechanical and electrical (M&E) services (time). This is in other words to show the other team members that they are behind the scheduled timeline and indirectly stating that all the team members needs to stick with the deadline (awareness). Supporting this other member in BIM meeting mentioned that drivers of M&E need to consider before the installation because this will be beneficial to achieve the client's needs. This shows that team members have realised the value of getting the information correct in the first place. However, Service engineer mentioned it is enough to concentrate on what they are doing and the other issues will be snagged in the model if it causes any difficulties. At the same time statement from Service engineer shows that he has a different perspective than others and believes more in automation. This also shows that Service engineer is suggesting a new way of working which is snagging methods to the other team members presented in the meeting. Following this analysis about the standards in the Revit model was discussed in the meeting because Revit is American and team members identified that it does not have UK standards. Therefore, electrical board against the room were hard to locate and placing the sockets in the right places were problematic. Therefore, at the end team agreed with the standards that they are going to adopt in this project in terms of Revit model to avoid the confusions in position of sockets and distribution board.

Supporting this architect in the semi-structured interview mentioned that

‘‘Setting out the outsets and agreeing standards are the key goals for the project’’.

Coming towards a common conclusion shows the mutuality between these multidisciplinary team members in this collaborative environment.