A NEW LEARNING APPROACH FOR DIGITAL CONSTRUCTION

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Abstract: The construction industry is embracing a journey towards digitalisation, and Building Information Modelling (BIM) is playing a key role in this transformation towards digital construction. However, some studies claim that the lack of BIM-related skills among construction professionals is a major barrier to this change. Therefore, adopting a new learning approach is vital to develop the skills which can produce a radical shift in employees' perception of working to achieve the project goals. Semi-structured interviews were conducted and a case study was examined to evaluate current construction practices. These were viewed through the lens of connectivism to understand the complex learning that happens in a rapidly changing digital world. In connectivism, learning is the formation of connections in a network which is no longer an internal, individualistic activity. This study explores how learning takes place in BIM construction projects and recommends that stakeholders within such projects need to approach their learning environment in a connected way to achieve their project goals. Moreover, this allows people to learn continuously and respond appropriately to information on the changing project environment.

Keywords: Building Information Modelling (BIM), Connectivism, Construction Industry, Digitalisation, Learning Environment.

1. INTRODUCTION

Digitalisation has started to change the way work is organised. 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. Industries such as automotive, aerospace and ship building have gone through radical changes and moved forward into digitalisation. However, the construction industry is still lagging behind in terms of efficiency, collaboration and standardisation, which could assist a digital transformation. A study conducted by the National Institute of Standards and Technology (NIST) (2004) states that fragmentation of the industry, interoperability and lack of interconnectivity are causes of poor productivity. Therefore, to reshape the construction industry, new ways of thinking and working need be introduced through the adaptation of digital methods all along the value chain. Conversely, Ramey (2012) argues that technological development can increase social isolation by people spending more time alone, learning these new technologies and using social networks to communicate. Nevertheless, applying these new technologies could help the construction industry to mitigate delays, enhance building quality, utilise resources better and improve safety, working conditions, and environmental capability.

BIM is a part of this digitalisation and is defined as a ''… collaborative way of working underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining the assets'' (HM Government, 2012, p.3). In this definition, collaboration is 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 (Henneman *et al*, 1995). Moreover, these digital technologies within the BIM process

are sufficiently capable of changing the way of working in order to manage processes within the construction industry with the aid of structured 3D models and enriched data using an array of interoperable technologies. Digital technologies are a set of electronic tools, systems, devices and resources that help to generate and store data and their interoperable attribute helps to exchange these collected data in a usable way. Therefore, the idea of introducing BIM into construction projects helps the industry to move towards digitalisation and also to achieve advances in improving productivity and efficiency.

1.1 Building Information Modelling (BIM)

In this digitally transformed construction world, the utilisation of digital technology is vital to satisfy increasing client expectations in terms of quality, efficiencies, engagement, certainty and risk reduction. BIM plays an important role in this transformation of pushing the construction industry towards digitalisation by using models and multi-disciplinary integration in construction projects. Therefore, several countries have started to adopt BIM into their construction projects, with the United Kingdom (UK) being one of them. The UK Government has mandated collaborative 3D BIM for supply chain members throughout the whole project lifecycle (Cabinet Office, 2011). 3D BIM involves maintaining all project and asset information, data and documentation in electronic formats. In the construction industry BIM can be used throughout the project life cycle by clients to define their project needs; by design teams to analyse, design and develop projects; by contractors to manage construction; and by facility managers to operate and maintain buildings (Grilo and Jardim-Goncalves, 2010). In addition, BIM implementation is expected to eliminate waste, increase feedback, delay decisions in order to achieve consensus, deliver fast, built-in integrity, empower teams, and to control the whole construction process (Arayici *et al*, 2011). Even though BIM has the potential to tackle a number of challenges in the construction industry, its implementation has been slower than expected due to various barriers. A lack of skilled people who can work with BIM in the construction industry is one of the major threats to implementing BIM in construction projects (CIOB, 2013; NBS, 2016). Therefore, adopting a new learning approach is vital to develop skills to handle this shift towards digitalisation to access relevant, robust learning and to make connection between existing learning.

1.2 What is connectivism?

Connectivism is new digital age learning, as conceptualised by Siemens and Downes (2009), and concerns social learning that is networked. This defines how learning happens in a rapidly changing digital world. According to connectivism, learning is not only the accumulation of knowledge instead it is about finding what is needed and meaningfully connecting them to the relevant components such as information, idea and people (nodes). The idea behind this is to observe the structure of knowledge as a network, and learning as a process of pattern recognition. This is vital to use and for the application of digital technologies to improve the construction process. The relationship between work experience, learning and knowledge is at the center of connectivism. Application of connectivism in construction projects can help people to learn effectively and accelerate the construction process by connecting the different stakeholders within the project. This does not means that everyone in the project should know everything; instead, project team members should know where to access knowledge and information when they need support. Learning is efficient when the connections are maintained well in a system during the digital transformation. Therefore, people need to be able to make

connections between concepts and information which are current and accurate. This study uses connectivism to identify the learning aspects that influence BIM construction projects and to understand how learning can take place in digitally-enabled projects.

Connectivism is a learning theory that focuses on complex learning in a rapidly changing digital world. It is a combination of principles explored by chaos, network, complexity and self-organising theories. Chaos theory describes how unrelated events may seem, when studied together, to create a pattern that can show relevance beyond the individual events themselves (Salmon, 1999). Subsequently, Siemens (2005) suggests that people can no longer experience everything by themselves alone when they are trying to learn something new. Therefore, it is essential to create a network (people, technology, social culture, and power grids) which creates connections for sharing ideas and knowledge within the learning environment. At the same time, systems, or environments, are complex and comprise different components. Complexity is a position that is situated between order and disorder. Consequently, overall development of the system is unpredictable and uncontrollable due to the non-linearity of interactions. Thus, systems need to be self-organised in order to produce global coordination and interaction. According to Heylighen (2008), this final structure mostly operates as a network with stabilising functions by linking the connections between the agents. Therefore, with the combination of these theories, connectivism is about self-organistaion 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 entities (nodes). The starting point for learning happens when knowledge is triggered through the process of the learner connecting to, and providing information into, the learning community. This happens when individuals apply their personal knowledge to a common system and gained knowledge is then fed back into the same system. This cycle continues and the individual's knowledge keeps on growing through constant interactions with the cycle. The benefit 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 achieve common goals (Siemens, 2004). Siemens (2004) describes 'community' as a cluster of similar areas of interest that allows interacting, sharing, dialoguing and thinking together. A learning community in the connectivism model is described by nodes which are part of a larger network (Downes, 2007). A node could be anything that can be connected to another node, such as organisations, groups, communities, fields, ideas, information/data and emotions.

1.2.1 Characteristics of connectivism

Connectivism considers learning as a process of creating connections between two entities and expanding the network (Siemens, 2006b). Downes (2007) states that knowledge is distributed across a network of connections and, therefore, that learning consist of the ability to construct and traverse those networks. Moreover, he describes this distributed knowledge as connective; thus a change of state in one entity can cause or result in a change of state in a second entity. According to Downes (2007), the application of connectivism has offered the insight of key characteristics, such as diversity, autonomy, openness and interactivity, as part of connective knowledge. He believes that it is essential to develop each of these aspects of connectivism for a connected way of learning.

Autonomy is about self-directed learning, which Mackness *et al* (2010) describe as "the learners' choice of where, when, how, with whom and even what to learn" (p.4). Interactivity,

which is sometimes referred to as connectedness, is grounded in the networking aspects of connectivism and is viewed as the ability to connect with others. This connectedness principle is addressed in communities of practice (Wenger, 2000) and personal learning networks (Richardson & Mancabelli, 2011). According to Downes (2010), the principle of diversity focuses on the availability of multiple perspectives for learning. On the other hand, the principle of openness emphasises the ability and willingness to share information. Saadatmand & Kumpulainen (2014) in 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.

1.2.2 Global view of connectivism

Previous learning paradigms such as behaviourism, cognitivism and constructivism discuss how people learn, as shown in Table 1.

Table 1: Different perspectives of learning

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.

Behaviourism and cognitivism view knowledge as external to the learner, and the learning process as the act of internalising knowledge, whereas constructivist principles state 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 considered 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 driven by the formation of connections in networks. Siemens (2004), from 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, in connectivism theory, is actionable knowledge which can also exist outside people and which focuses on connecting specialised information sets. These connections enable people to learn more from the current state of knowledge (Siemens, 2004). In other words, the connectivism model of learning is no longer an internal, individualistic activity because the knowledge is distributed across networks. Moreover, connectivism works through understanding decisions which are based on rapidly changing information. This is important in the digitalising world, because a person's working habits and functions change with the introduction of new technologies and tools. The notion of connectivism considers that overall knowledge continues to grow and evolve; however, 'important' or 'valid' knowledge is now different from prior knowledge. Therefore, people need to differentiate between important and unimportant information to make the right decisions. Furthermore, learners should have the ability to search for current information, to filter secondary and extraneous information. Moreover they should also have the right skills to apply the relevant information to achieve

their targets. According to Siemens (2008), seeing the connections between the entities in the learning environment is a core skill in the new digital age. Therefore, connectivism could be used to consider how learning happens in the digital world; however, at the same time, it also has a negative side.

Verhagen (2006) argues that connectivism is nothing more than a pedagogical view because it involves no new principles and has not explored the processes of how people learn. According to Chatti (2007), connectivism omits some concepts such as reflection, learning from failure, error detection and correction, and inquiry, which are essential for learning. Even though Kop and Hill (2008) agree that connectivism is not a separate learning theory, they argue that it shifts the control of learning from tutor to autonomous learner during the development and emergence of pedagogies. Supporting this, Ally (2007) mentions that the world has become networked and learning theories developed earlier are less relevant; however, this theory is not a standalone one for the digital age. Instead, it is a model that integrates different theories to guide the design of online learning materials. On the other Foster (2007) claims that connectivism needs to be considered as a learning theory because the limitations and full range of connections within which learning can take place are considered within the theory. 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.

Taken together, this literature reveals there is a need for a new learning approach in construction projects during the digital transformation which is more than the acquisition of knowledge. Learning in connectivism is not only the accumulation of knowledge but also the meaningful connection between the nodes in the learning environment. Therefore, this paper seeks to identify the key aspects that emerge from the basic connectivism characteristics that are highly influential in creating a connected learning approach in BIM construction projects. This is to encourage more people to implement BIM in construction projects through mitigating the lack of skilled people and widening their existing knowledge.

2. RESEARCH METHODS

The aim of this study is to explore how connectivism helps people to learn and improve their skills in order to acquire knowledge related to digital construction during the implementation of BIM. This is achieved by actively looking for new emerging aspects from the key characteristics (autonomy, openness, connectedness and diversity) of connected learning methods. Data for the study were collected by conducting semi-structured interviews and from a case study observation. The purpose of the semi-structured interviews was to understand the significance of skills deficiencies and to obtain the in-depth experience of professionals engaged in BIM construction projects. Pre-set open ended questions were employed in the interviews to obtain a wider view of the situation, which also helped the researcher to understand the importance of learning during BIM adoption. Twenty people working in the UK construction industry in a variety of roles were interviewed, such as BIM co-ordinator, BIM manager, BIM consultant and BIM technician. All the interviewees chosen had more than 2 years' experience in BIM construction projects. The professionals interviewed were from both public and private sectors and were chosen by considering their experience and involvement with BIM-related activities in their construction projects. The interview duration was approximately 40-50 minutes. Two pilot studies were carried out before conducting these interviews, which helped to refine some of the questions and restructure the sentences. The interview questions for the study 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 were related to the interviewees' role and experience in handling and using BIM in their construction projects. The literature has explored several benefits of BIM and this section 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 primary skills during the implementation of BIM in construction projects. The questions in part two were developed to address the significance of the skills deficiencies in BIM construction projects highlighted in several construction reports (CIOB, 2013; NBS, 2016). 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 learning to acquire knowledge and the need of new learning approach to make connections during the transition to digital construction.

A case study is "A strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence" (Robson, 1993, p.146). A case study approach was adopted for this study to identify the aspects of connected learning needed for the implementation of BIM projects and to understand how people learn during technological innovations. The interviews and case study approach are part of an ongoing PhD research. The chosen case study is a £31 million fully integrated BIM construction project in the UK, a 100,000 square foot extension of an educational building. The building is being constructed to provide space for 3,000 students and staff members and features 650 rooms, a student hub and lecture theatres. It also includes a new library, and teaching and IT spaces. This high-tech university project has used Level 2 BIM for its delivery and detailed planning, with completion anticipated in September 2017. The key purpose of engaging with this project was to explore what is happening in practice. Moreover, this case study exploration encouraged an in-depth investigation of skills issues and learning opportunities while working with BIM. Case study research uses multiple sources (Yin, 2003). In this research, data were gathered from interviews and by observing the project meetings held every fortnight. Notes were taken during the observation process. The purpose of choosing project meetings was to obtain a collective understanding of how the organisations interact and communicate with each other in a BIM environment. Data collected from both the semi-structured interviews and the case study were transcribed and Nvivo was used for analysis. Nvivo in this study has been employed to evaluate, interpret and to explain the social phenomena regarding ''Learning in Practice'' in BIM construction projects.

3. FINDINGS

The construction industry is characterised by fragmentation and structural issues. In addition, the environment in the industry is always in a state of change due to technological innovations. Currently, BIM is playing a major part in the digital transformation process. According to the literature, identifying a new way of learning is important to understand how people work and run a project smoothly during technological innovations (NIST, 2004; Siemens, 2004). As part of the wider research work, this paper seek to identify the key aspects that emerge from the basic connectivism characteristics that are highly influential in creating a connected learning approach in BIM construction projects. Based on semi-structured interviews and the case study, this study has identified the following five aspects: openness to learn, continuous learning, community of practice, interactive tasks, and discovery learning as part of creating the connected learning environment in BIM construction projects. The features identified in these five aspects confirmed that this new learning approach helps to make efficient decisions,

improve skills and to widen the existing knowledge. However, the most appropriate aspects for the learning environment depend on the situation where project activity takes place.

3.1 Openness to learn

The learning environment in construction projects often involves broken learning and feedback loops, where the architecture of the production system is always fluctuating with the changing shape of the project (Gann and Salter, 1998). Hence, there is a need for an environment which better adapts to people's needs, open to integration with any innovative technology which facilitates the integration of the tools used for project completion. Openness to learn is a valuable feature needed in construction projects because of their rapidly changing nature. From both the interviewees and the case study this feature is observed in several situations. Interviewee 11 mentioned that ''*I went to a two day Revit course and watched several YouTube videos and made 100s of mistakes*''. This statement shows that people within BIM construction projects are encouraged to learn from their mistakes. The lessons learnt from these mistakes were also observed in the case study in a situation where a design clash between a radiator pipe and staircase was identified. This was caused by a BIM coordinator's mistake of not considering the half landing in the staircase. Therefore, the coordinator and architect, after trying several options in the model, decided to move the radiator pipe to the right hand side of the staircase, which provided a better route and did not clash with the staircase. In this situation, the BIM coordinator took on the ownership of his mistake and learnt to carefully analyse the specifications before modelling. Moreover, learning from this mistake has taught him what is needed and what works for the project.

In some situations, learning also took place by listening to people and accepting constructive criticism from other team members. At the end of a meeting, the architect spotted that wrong NRM codes had been provided by the other team members and guided them to look at the NRM code standards before replacing them with the correct ones. During this situation, team members in the meeting listened to the architect and accepted the constructive criticism provided on the NRM codes. Moreover, the structural engineer's and mechanical and electrical (M&E) engineer's interaction with the architect shows the openness to learn about these codes. In BIM construction projects software keeps on changing, however project team members are ready to change and learn the new programmes to use them in the project. In the case study, Naviswork was used to conduct clash detection; however, project team members had now moved to BIM 360 Glue, which is a cloud-based coordination and collaboration solution which connects the whole project team, streamlines project views and coordinates the workflows. This illustrates that project team members are open to learn new things according to project changes. In another situation in the case study during the lighting installation, it was diagnosed that the curtain wall linked to the lighting needed to be moved. During this situation, the M&E consultant, BIM coordinator, architect and structural engineer came together to discuss alternative ways to solve the issue by closely examining product details and project documents. In this way, project team members were motivated to learn from each other by asking several questions to understand the alternative ways suggested by each other. This teamwork shows that team members are open to learn and motivated to understand alternative methods to resolve problems. Project team member's openness to learn in the above situations in BIM construction projects were observed through learning from mistakes, accepting constructive criticism, being ready to change, and learning from others. Moreover, interactions with others have increased the motivation of the project team members and helped them to expand their current state of knowledge.

3.2 Continuous learning

According to Tannenbaum (1997, p.438), continuous learning is ''the process by which individual or organisational learning is fostered on an ongoing basis.'' Moreover, he declares that organisations can only learn when the individuals/teams employed within them are continuously learning, which also encourages the acquisition and application of new skills and ideas. BIM is a new way of working; therefore, tasks within BIM construction projects are executed differently to the traditional approaches, using advanced technologies. The interviewees highlighted that they are continuously learning to work effectively and to make right decisions in BIM construction projects. For an example Interviewee 19 stated ''*I initially started learning BIM through tutorials on YouTube and read some information about how to use it and I am still learning during the construction process of the project.*'' Moreover, he added that he has applied these techniques and gained knowledge to select the correct elements and procedures to create the BIM model. This illustrates that learning is not only continuous, but also helped to make connections in the project.

In the case study, the project team members were learning in multiple ways, such as observing and interacting with more experienced people at work; trying new and alternative approaches; asking for help or advice from other team members; and finding ways to improve their knowledge and skills through various learning avenues (i.e. training, seminars and self-learning). In the case study, it was found that when professionals wanted to install handrails in a building there was an issue regarding riser sizes and intrusions of steel connections. In this situation, the project team members handling this problem did not have enough skills to resolve the issue and sought more advice from other project members involved in the project. Therefore, a team member from another organisation came forward to resolve the problem using his experience. The solution to resolving this problem was explained in detail with the aid of 3D models, 2D drawings and specifications. Discussions included options for handrail installation, consideration of other building elements during installation, and different materials that can be used for handrails. Learning in this incident was gained through interacting with an expert. Furthermore, interviewees mentioned that having the right mindset is also important for continuous learning. Interviewee 5 stated that ''*I think having a beginner's mindset is beneficial.*'' Also in the case study, in a meeting the architect mentioned that even though ''*…there is BIM as a process, and different ways of doing things, it is important to have a beginner's mindset.*'' These characteristics of making connections, learning in multiple ways, learning from an expert and having a beginner's mindset enable the project team members to explore the ideas further and adapt to the constantly changing environment.

3.3 Community of practice

According to Siemen (2004), learning is no longer an internal, individualistic activity because knowledge is distributed across networks. Communities of practice are groups of people who share a common vision of something they do, and learn how to do it better as they interact regularly (Wenger, 1998). A BIM learning community is formed by a group of interdisciplinary people who share common goals. However, objects within BIM projects are created and developed over time and can be viewed differently by other project team members. Therefore, a common focus is important during the working towards a common goal. In the case study, windows in upper floors were modelled with blinding. However, in a meeting the BIM coordinator suggested that windows without blinding do not make any difference. Supporting this, the quantity surveyor mentioned that it would also be cost effective for the client. After

analysing the lighting impact with and without blinding, blinding from the windows was removed in the BIM model. This shows that project team members do consider suggestions given by other team members and their acceptance indicates that they all work towards a common focus.

In another situation, a riser went higher than was designed, therefore the frame sizes and sizes of services needed to be changed and the top of the riser needed to be waterproofed. In this situation, a collaborative team including designer, contractor, sub-contractors (M&E) and suppliers (waterproofing, frames) became involved in resolving the issue. During this process, several inquiries regarding risers and their position were raised. To tackle these collective inquiries raised by the project team members, a BIM champion from the contractor's side was approached to find a solution. This person explained the procedures to fix the upstand in the front phase and top. He also indicated the places where extra steel was needed. Moreover, options to alter the frame sizes and sizes of services were also discussed with the team by referring to 2D drawings, 3D models and specifications. Teamwork in this situation provided opportunities to share and connect different ideas and knowledge to complete the task. In other words, professionals learnt different things from each other in this community. These observations show that working together with interdisciplinary teams, collective inquiries, a common focus, and collaborating within the team are needed to make effective decisions.

3.4 Interactive tasks

Interactive tasks are effective and intentionally planned instructions that make learning a shared social experience (Look, 2011). Most of the tasks in BIM construction projects are interactive, allowing project team members to learn from each other as they work collaboratively and cooperatively. In the case study, communication between the project team members took place through observation, discussion, questioning, sharing and transferring knowledge. For example, the total numbers of floor boxes including their positions were discussed. The team had initially decided to install 45 floor boxes; however, feedback from the manufacturer suggested that these could be reduced. This was because the client had not requested any power supply in some of the seated and common learning spaces. Therefore, in response, alternative ways of positioning the floor boxes were suggested by the team members. In addition, the architect also raised the question of furniture that needed some extra floor boxes, and the BIM coordinator shared additional information about data cables and highlighted the clashes with floor boxes in the meeting. These comments from peers were taken into consideration to finalise the number of floor boxes and their positions. This situation illustrates that the process of feedback and response, including peer discussion, helped in making decisions without additional cost.

In another situation, an issue regarding the doors that went into the vent riser was raised. This was due to uncertainty over the number of doors marked in the setting out. The project team analysed the number of doors in the model and started commenting on their position. During this process, the quantity surveyor also explained the door details to the M&E engineer with 2D drawings and highlighted the door that went into the riser. After understanding the problem, the M&E engineer became involved in the discussion by commenting on the door position (i.e. he mentioned that a duct ran near the door and needed to be considered when altering the door position). After communicating with each other, the team members came to the conclusion to revise the door schedule and its position. In this situation, the peer support provided by the quantity surveyor helped the M&E engineer to understand the issue rose in the meeting. During

these situations, interactive tasks in the BIM construction project allowed the project team members to stay connected with the task and motivated their involvement in the BIM project. From the above discussion, it is evident that team members' knowledge was widened through the features of feedback and response, peer support and communication within the team.

3.5 Discovery learning

According to Bruner (1961), discovery learning is an inquiry-based, constructivist learning approach that takes place in problem solving situations where the learner draws on his or her own past experience and existing knowledge to discover facts and relationships and to learn new truths. During the clash detection process in the case study, a concrete upstand clashing with the surface was highlighted by the BIM coordinator. Inquiries regarding the landscape were raised by the architect; however, from his experience, he suggested that additional paving was needed in this situation. Therefore, the team explored the issue by reviewing the perimeter all the way through the landscape area and suggested that the thickness of the concrete upstand needed to be reduced to avoid clashes with the surface and agreed to add the additional paving suggested by the architect. This experience, shared by the architect with the project team members, helped to avoid further clashes and to make decisions.

In another situation, a new ceiling which had been added was clashing with the lighting. The architect and the building service engineer explored different ways of moving the ceiling and lighting. While this exploration was taking place, the architect also realised that the pipes into the risers also needed to be taken into consideration when moving the ceiling and lighting. After analysing alternative ways, the problem was resolved by deciding to slightly lift the ceiling upwards (at the top of the staircase), after the building service engineer had moved the lighting. In this situation, a constructivist view was observed, whereby the problem was resolved by both the architect and building service engineer understanding each other's ideas and experiences. Moreover, this also helped the architect to focus on other related elements such as pipes when making alterations to the ceiling and lighting. Features such as inquiry-based learning, sharing experiences, exploration and problem solving in the above situations promoted active engagement and helped the project team members to build on their prior knowledge and understanding.

This study has explored the aspects that are essential for a learning approach to a BIM construction project. Currently, technology is rapidly evolving, while the construction industry is trying to enter a digitalisation mode. To create a connected learning environment, a new learning approach including the discussed aspects is needed in the new digital age. Moreover, in this ever-changing world, continuously evolving learning is required to address the changes and to connect with other nodes in the learning environment to identify patterns, to learn and to make decisions. Thus, stakeholders in BIM construction projects need to view their environment from learning ecological concepts to cope with the rapidly changing digital environment.

4. CONCLUSIONS

Digitalisation of the construction industry has been expedited by the introduction of BIM. However, BIM adoption is slower than expected due to the lack of skilled people to work with it. Hence, to overcome this, project team members need to recognise the interconnections and

understand the patterns of connections within the learning environment to improve their learning in practice in the new digital age. The connectivist viewpoint can be used to understand this new way of learning in a digitally enabled environment. This new learning approach views learning as actionable knowledge and considers the learning that exists outside people, which focuses on connecting specialised information sets. However, the aspects which were identified in the study as part of this new learning approach, namely openness to learn, continuous learning, communities of practice, interactive tasks and discovery learning, also need to be recognised in order to understand the connections and relationships that exist in the learning environment. Thus, to move towards digitalisation through implementing BIM, and to learn in this environment, stakeholders need to see the world in a connected way (i.e. the connectivism concept) and should attempt to create an ecological system for learning that allows people to continuously learn to cope with the rapidly changing digital environment. This study is part of a PhD research which will continue to explore how project team members can create a Learning Ecology within the work environment in practice to address BIM challenges.

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