INTERACTIVE LEARNING IN UK CONSTRUCTION PRACTICE: EXAMINING THE ROLE OF BIM PROCESS STANDARDS

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From a construction innovation systems perspective, firms acquire knowledge from suppliers, clients, universities and institutional environment. Building information modelling (BIM) involves these firms using new process standards. To understand the implications on interactive learning using BIM process standards, a case study is conducted with the UK operations of a multinational construction firm. Data is drawn from: a) two workshops involving the firm and a wider industry group, b) observations of practice in the BIM core team and in three ongoing projects, c) 12 semi-structured interviews; and d) secondary publications. The firm uses a set of BIM process standards (IFC, PAS 1192, Uniclass, COBie) in its construction activities. It is also involved in a pilot to implement the COBie standard, supported by technical and management standards for BIM, such as Uniclass and PAS1192. Analyses suggest that such BIM process standards unconsciously shapes the firm's internal and external interactive learning processes. Internally standards allow engineers to learn from each through visualising 3D information and talking around designs with operatives to address problems during construction. Externally, the firm participates in trial and pilot projects involving other construction firms, government agencies, universities and suppliers to learn about the standard and access knowledge to solve its specific design problems. Through its BIM manager, the firm provides feedback to standards developers and information technology suppliers. The research contributes by articulating how BIM process standards unconsciously change interactive learning processes in construction practice. Further research could investigate these findings in the wider UK construction innovation system.

Keywords: Building Information Modelling, innovation systems, interactive learning, management of innovation, standards.

INTRODUCTION

The innovation systems literature underlines the importance of interactive learning to innovation and technological change (Freeman 2002, Lundvall 1998). In construction practice, construction firms interact with and learn from both internal and external sources such as clients, material suppliers, universities and professional bodies (Gann and Salter 2000). Across the United Kingdom (UK), large construction firms are considering to use new process standards aimed at providing structured ways of managing construction information.

Standards are viewed different by scholars. While some view them as institutions, routines, technical infrastructure or common codes for communication, those with interest in social practices argue that they are common, repeatable best practices which streamline social interaction (Hawkins et al. 1995). Studies distinguish between

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product and process standards. While product standards focus on the physical attributes of end products particularly their modularity, compatibility and interoperability (Barlow 1999, Eastman 1996), process standards are associated with the method and organisation of production activities. In preconstruction practice for instance, process standards might refer to the structured ways of interaction between professionals involved in the creation, storage, exchange and exchange of construction information.

Building Information Modelling (BIM) involves the use of set of process standards to provide a common way of creating, storing, accessing, exchange and communicating built asset information (Bsi 2010). By using BIM, there is a view that firms can improve productivity, reduce cost and reduce uncertainty (Nisbet 2012). However, BIM standards are less understood in some sections of the industry especially among civil engineers (Maradza 2014). In an attempt to improve BIM uptake, the UK government recently mandated BIM on all public projects by 2016 (Cabinetoffice 2011). Findings from a few UK government sponsored trial projects indicate that BIM can achieve the desired benefits (Cabinetoffice 2012).

Below are examples of some of the BIM process standards used in the UK.

25. Industry Foundation Classes (IFC) British Standard ISO 16739
26. Library objects: BS 854 (1-4)
27. BS1192: 2007, Publicly Available Specification (PAS) 1192 (1-4) including Construction Building Information Exchange (COBie)

Object library standards - Uniclass2 and BIM execution plan

Lundvall and Johnson (1994) have argued that common codes of communication enhance interactive learning through managing diversity and complexities in interactions. Interactive learning is a process by which a firm attains new competences through networking and drawing competences from within and outside its borders (Lundvall and Johnson 1994). As construction firms increasingly implement BIM (Nbs 2013), how they interact and learn in systemic innovation contexts is of importance to scholars and practitioners interested in managing innovation processes. The research investigates interactions between professionals using BIM process standards in a large multinational UK construction firm. The purpose is to understand the relationship between BIM process standards and interactive learning in construction practice.

THEORETICAL BACKGROUND

Systems of innovation

The innovation systems literature evolves from a socio-economic perspective of technological change (Lundvall 2013). It departs from the neo classical economic model which views as static the innovation process by arguing that the process of innovation is qualitatively different, dynamic, involving complex social interactions between the firm and other organisations (Freeman 1995, Lundvall and Johnson 1994). Lundvall has argued that interactive learning, user producer interactions and innovation are at the heart of economic advancement (Lundvall 1992). Learning is viewed as an interactive process between individuals at the foundational or micro level and is socially embedded. Understanding it is futile without considering the institutional and cultural context (Lundvall 1998). The perspective posits that knowledge is a fundamental resource while learning is the most important process for
innovation (Lundvall 2010). In contrast to other approaches which view innovation as exogenous, the concept argues that innovation is evolutionary and is shaped by many factors over time (Fagerberg et al., 2005).

Whilst innovation systems concept was aimed at understanding variations in national economic activities, scholars soon began to explore its relevance in examining local and regional variations in economic activity. Scholars have proposed concepts of national, regional, sectoral and technological innovation systems, however where boundaries are set depends on circumstances (Carlsson and Stankiewicz 1991). In construction innovation studies the concept has been used by Miozzo and Dewick (2004) to analyse variations in construction industries in five European countries.

Despite its wide use, the innovation systems approach has been has been criticised for what Edquist called "conceptual diffuseness" (Edquist in Fagerberg et al., 2005: p.186). He singles out inconsistent definitions of the term "institution" and lack of clarity on the boundaries of the system. Another critique concerns the function of an innovation system. Lundvall (2010) explains that the function of an innovation system is to produce, diffuse and exploit economically useful knowledge. However, Edquist (1997) questions whether there can be an agreed function of an innovation system. Other scholars have criticised the concept for addressing the national context, yet globalisation has dissipated the nation state (Carlsson 2006). Lundvall concurred, adding that the "all countries have become small" (Lundvall 2010: p.02). Moreover systems are dynamic, complex and rapidly changing to the extent that developing a consistent methodology for studying them is difficult if not impossible (Carlsson et al. 2002). In addition, little emphasis is placed in understanding the concept at the micro level. Lundvall (2010) refers to this as the micro foundations of the innovation system.

In spite of the criticism, the concept provides a useful analytical framework for examining the dynamics inherent in the innovation process. By integrating the role of social interactions, the institutional environment and the cultural context, the concept provides a useful way of building an in-depth understanding of the innovation process.

**Interactive learning**

Learning is the process of acquiring knowledge (Nonaka and Takeuchi 1995). Arrow (1962) has argued that learning is not only spurred by R&D but also through social interactions between people. He adds that learning takes place through problem solving and involves drawing from previous experiences. Innovation systems scholars have argued that it is through interactive learning that firms can explore and exploit knowledge. Studies mention three types of learning which are: learning by doing (Arrow 1962); learning by using (Rosenberg 1982) and learning interacting (Lundvall 1985). Whilst learning by doing and learning by using refer to experiential competence building, interactive learning is viewed as involving the exploitation of communication networks to source and accumulate tacit and codified knowledge (Lundvall and Johnson 1994).

Learning processes are collective, cumulative, dynamic, context dependant and shaped by the institutional environment. Gregersen and Johnson argues that, "different kinds of knowledge diversity are the basis of interactive learning, and they depend on communication between people and groups of people with different knowledge endowments" (Gregersen and Johnson 1997: p.486). As a result Johnson in Lundvall (2010) suggested that learning categorisation should resemble the intensity of human interactions. He proposes four kinds of interactive learning and they are: imprinting, rote learning, learning by feedback and searching.
Interactive learning occurs internally and externally to the firm. Scholars suggest that internal learning occurs through interactions between employees in problem solving activities, training, job rotation and communication between individuals and departments. Externally learning occurs through feedback users and producers, and between organisations (Lundvall 1985). Although the innovation systems concept is useful in examining the process of innovation, it largely informed by studies in industrial firms (Freeman 1982). According to Davies and Brady (2000), learning processes in construction firms are different from those witnessed in industrial firms. They argue that firms utilise temporary project teams which disband upon completion and interactions are short term. This affects learning from projects; between projects and firms, and between firms and other organisations (Winch 2010).

**Construction innovation systems and interactive learning**

The concept of innovation systems is yet to gain traction among construction innovation scholars. The concept has so far been limited a few studies which sought to examine the performance of a European construction industries (Miozzo and Dewick 2004). This research views the primary goal of a construction innovation system as facilitating interactive learning processes in order to produce knowledge required to advance the development of new or improved services for the built environment. The boundary of the innovation system is set around the actors identified in the analytical framework proposed in Figure 1 below. The ability to simultaneously create and source knowledge between projects and from the firm’s institutional environment is seen as the vital cog that drives innovation in construction (Winch 2010).

In construction firms, interactive learning is characterised by face to face discussions between individual professionals, recruitment of new employees and transfer of staff to other projects (Dodgson et al., 2008). Salter and Gann (2003) have explained that learning occurs through face to face meetings, training, job shadowing and IT technologies, however they also note the influential role of the context and the firm’s environment (Salter and Gann 2003). Scholars acknowledge the dynamics and complexities surrounding learning from external sources. They suggest that learning tends to occur through participation in joint ventures, industry conferences and engagement in R&D activities (Gann and Salter 2000, Miozzo and Dewick 2004). Blayse and Manley (2004) have identified clients, technical standards and the firm employees as potential sources of learning. Gann and Salter (2000) have proposed an analytical model to illustrate knowledge flows (See Figure 1 below).

**Standards**

Views on standards vary with some scholars suggesting that they are useful for diffusing technologies, managing market entry for new products and compatibility between different technologies (Freeman 1995). Nelson and Nelson (2002) have suggested that standards provide a social infrastructure for technology transfer. Others have suggested that standards support production economies but they can limit innovation (David 1985). Studies distinguish between product and non-product standards (process standards) (Hawkins et al. 1995). Product standards are concerned with the physical attributes of products, particularly their quality, modularity, compatibility and interoperability (Barlow 1999, Eastman 1996). Barlow and Ozaki (2005) explains that necessitated product and process innovation in Japanese construction. Process standards are associated with the method and organisation of production activities.
In construction the debate on process standards has focused on "the introduction of processes that facilitate the production of a variety of models using the same machinery and material inputs" (Barlow and Ozaki 2005: p.15). Whyte and Lobo (2010) have discussed the role of standards as digital infrastructures for delivering construction projects. They suggest that standards facilitate collaboration between teams involved in construction practice. Other scholars have examined the role of standard processes on large infrastructure projects and have noted that they influence interactions between professionals (Brady and Davies 2010). Thus there is a simmering debate on the relationship between process standards and innovation.

**Figure 1: Framework for understanding knowledge flows in construction adapted from Gann and Salter (2000)**

**RESEARCH METHODS**

This interpretive study uses a case study design to provide an in-depth account of the complexities surrounding the use of BIM process standards in a single large international construction firm headquartered in France. The firm's UK division has a turnover of £1.2 billion in 2012. The UK division has been involved in the design and construction of award winning landmark projects. The firm is selected because of its size (above £1 billion turnover), experience in supporting standards development, participation in government BIM trial projects and it was ready to provide access to the researchers. In the UK, the firm has 5 divisions and the civil engineering division is the largest by turnover. Although BIM is being deployed across the firm, due to time, access limitations and with advice from senior management in the firm, the civil engineering division was selected for a detailed study. The civil engineering division also resembled best practice in terms of how the firm is deploying BIM. The aim is to provide a holistic account of BIM process standards use. The study focused on a variety of issues including how BIM users interacted and exchanged knowledge. The account offered is that of those involved in day to day practice. Therefore the data collected is that of the multiple meanings and mental constructions made by practitioners as they interact and use the BIM process standards. By examining interactions between professionals involved, the study seeks to explore the issues that arise in project based environments and how they shape interactive learning processes.

The case study design is selected because it is useful in studying the "particularity and complexity of a single case, coming to understanding its activity within important circumstances" (Stake 1995: p.xi). It provides a holistic account of human experiences (Creswell 2003). Baxter and Jack (2008: p.544) also argued that case studies "... ensure that the issue is explored through ... a variety of lenses which
allows for multiple facets of the phenomenon to be revealed and understood”. The case study design is common in studies of this nature (Gann and Salter 2000, Miozzo and Dewick 2004). The selected design is not without challenges, for instance it only captures the views of a limited group of individuals hence generalisation is to an individual’s context (Stake 1978). Despite this challenge, this method enabled rich data to be collected which appreciates the contextual issues surrounding interactions at multiple levels of analysis. In the process the research captures specific issues in localised contexts. Wider generalisations are therefore not the priority here, instead the focus is on theoretical generalisation.

Empirical evidence was collected from participants in their natural settings. In order to capture their lived experiences around BIM process standards, a decision was taken to only interview the firm’s professional pool involved in everyday BIM use. Data was collected over a period of 7 months and it involved interviews, observations and secondary documents collected from three ongoing projects and the BIM core team. The ongoing projects were selected with the advice from the firm's BIM manager. Data collection was done in: a) three hour long workshops involving the case study firm, IT suppliers and a wider industry group on three occasions, b) more than 15 observations of practice which lasted more than 80 minutes in the BIM core team and in three ongoing projects, c) 12 semi-structured interviews, each interview lasted on average 70 minutes; and d) secondary publications from the firm.

Participants were selected on the basis of their role, their availability, and through the snow balling strategy. Through examining the everyday use of BIM, it was possible to understand how users interacted. Discussions focused on what the standard meant to the participant, the effect on their work practices and whether the standards encouraged or hindered their information sharing activities or shaped their interaction patterns. The analytical model presented in Fig 1 was used to guide the discussions and probe interviewees that they cite specific examples of their interactions with the actors identified in the model. The discussions focused on how they solved problems and whether the firm had provided them training. Interviews were conducted with design engineers, site engineers, site operatives, BIM managers and consultants. A particular disadvantage of the research strategy is that it only captures the views of a limited group of individuals, at one specific time period. Despite this, it offers a rich data of the social interactions.

The interviews were recorded and transcribed by the researcher to engage deeply with the data. Although the interviews focused at the firm level, they encouraged participants to cite specific examples from their daily experiences. Data was analysed through an iterative process of identifying emergent themes, coding and continuous reviewing of the data to identify aggregate themes and central meanings. The model presented in Fig 1 was used to analyse data. Although this study is inductive, concepts established in literature were used to develop an analytical framework for data coding. To improve the research’s validity, method triangulation and interview participants were accorded an opportunity to review and revise the transcriptions and subsequent publications (Silverman 2009). Data analyses suggested that BIM process standards have influence internal and external interactive learning processes.

**FINDINGS**

**The case study firm**

The construction firm employees just over 6,000 employees in the UK and its global work force exceeds 60, 000. At the time of data collection, the firm was involved in
Interactive learning in construction practice

more than 300 projects in the UK. The civil engineering division of the firm employers approximately 3,500 people in the UK. Most of these people are based on projects located across the UK. The firm acquired the division in 2008. The UK firm’s turnover was just over £1.2 billion in 2012. The civil engineering division is currently involved in one of the largest rail project in the UK. The division is involved in the airports, education, nuclear, rail, health and roads sectors.

The civil engineering division has a long history of working with IT suppliers which dates back to the 1970s. It has championed the use of IT technologies in design and construction activities. It has also been involved through its BIM managers in BIM standards development in the UK and globally since the early 1980s. One of the widely used Xtech technology (not real name) was developed by the firm's former employees, with its support. The BIM manager was involved in trial projects which led to the development of the PAS 1192 standard. The civils division has been involved in the government sponsored COBie and PAS 1192 trial project which involve collaborating with 11 competitors, 3 standards developers and 4 IT developers. The firm remains in full support of the Xtech technology and occasionally acts as a hotbed for trialling improvements in the technology. As the manager noted:

"... we have quite a big influence over XTech because we’re quite a big user of them and they’re, they are beginning to say the right sort of things" Interview C01

IT suppliers are increasingly relied upon to support construction activities. The firm’s BIM manager is involved in a number of standards initiatives. BIM standards are fully implemented in the BIM core team but not on projects. In practice, BIM standards are embedded in digital technologies such as Xtech. As a result user interaction with the standard is invisible. A number of digital technologies are available in the market some of them are not embedded with the national standards. Implementation in the firm faces significant challenges because project managers have autonomy over the choice of what technology to use.

Interactive learning process within the firm’s innovation system

BIM process standards allow engineers to integrate information to create a single 3D digital object. The 3D object provides a single source of information required to perform different activities. Through 3D simulations presented to construction teams, problems can be addressed collectively through talking around the 3D model. Data shows the use of a common 3D model allows professionals to share knowledge about the design and its delivery. Engineers were able to communicate effectively with operatives performing different tasks at once. Skilled operatives shown a 3D model over lunch could appreciate their tasks. Teams could comment on one 3D model and advise engineers on the practicalities of delivery than before. The 3D model could be shared with subcontractors. Engineers were able to learn from operatives who are at the fore front of delivery. They described how Xtech has improved their communication activities. They can now access project information from a single source and circulate a variety of information with ease. Despite the benefits, some participants were unclear of their interaction with the standard nor its importance to their activities. Some were not even aware of BIM standards.

External interactive learning processes

Externally, the firm participates in trial and pilot projects involving other construction firms, government agencies, universities and suppliers. The firm engages with and provides feedback to researchers from universities. Through its BIM manager, the firm provides feedback to standards developers and information technology suppliers.
This helps shape the standard to the extent that specific issues could be addressed in
the next version of the standard and also the technology. However, participants
complained that clients were inconsistent, resistant to embrace BIM process standards
and they tended to use their own process standards. This meant that the firm's
employees had to forget and learn anew each time they had to interact with a different
client. This limited the firm's ability to exploit user and producer relations.

**DISCUSSION**

In the theoretical background, the context specificity, the dynamic nature and role of
the environment on interactive learning activities was noted. Types of interactive
learning suggested by some scholars were identified as imprinting, rote, learning by
feedback and searching (Lundvall 2010). Findings from the research suggests that
process standards supported interactive learning. Both internal and external
interactions were supported by the use of standards. Experiential learning occurred
through 3D modelling which required in-depth knowledge of the digital technologies
in which the standards are embedded. While internal searching and feedback occurred
through interactions between engineers and operatives, workshops, seminars and
training sessions were also seen as important. Lundvall and Johnson (1994) suggests
that common codes of communication provide access to a wide variety of information.
In the construction firm, the use of Xtech provided a common information facility
which could be used by users irrespective of their geographic location. This allowed
engineers to access a wide variety of information.

Literature suggests that face to face interactions are important for internal learning
activities (Salter and Gann 2003). However, the use of BIM process standards suggest
interactions are focusing more on the common 3D object. The BIM manager acts as a
champion (Nam and Tatum 1997) and assists in collecting and disseminating
knowledge from external sources into the firm. Literature suggests that external
interactive learning occurs through feedback between users and producers. In the
construction firm, findings suggest that the BIM manager facilitates interactive
learning through his involvement in national bodies and taking leading role in BIM
standards initiatives. Despite this, implementation in the firm is the result of extensive
and complex negotiations. The invisible effects of embedded standards, together with
the technical requirements might be contributing to implementation challenges.

Scholars suggest that interactive learning occurs through collectives (Gregersen and
Johnson 1997). The construction firm participated in BIM trial projects. It was
possible for the firm to simultaneously access knowledge from its competitors.
Participation provided a collective voice to influence the direction of the technology
and standard. However, findings reveal a deeper problem which stems from a limited
understanding of standards. Even though the firm through the BIM manager
contributes to BIM standards, implementation in projects is slow due to resistance
from project managers. This could also explain the lack of consistency in the
implementation approach considered by the whole firm. As a result, it may be
impossible for the standard to be fully exploited to support interactive learning.

**CONCLUSION**

The research investigated the interactions between professionals involved in
construction practice. It sought to understand the relationship between BIM process
standards and interactive learning. Interactive learning in construction firms involves
exploiting communication and social networks to develop knowledge essential for the
Interactive learning in construction practice

firm. BIM process standards are used to structure information sharing activities. Through their use, participants were able to make use of a single source of information. Construction firms interact with a diverse source involving clients, suppliers, universities, regulatory authorities and other firms. Empirical evidence suggests that BIM process standards enhance interactive learning process because they facilitate internal and external interactions with sources of knowledge. The use of common 3D objects supports talking between professionals. Participation in trial project improves the firm’s chances on engaging with a diverse source. BIM process standards support user and producer interactions, however they are not as yet understood. BIM process standards are increasingly influencing and shaping the construction process. Such change in the process of construction could be beneficial to achieving efficiencies in construction and improve quality. However this was not specifically examined in this research and could form part of future research. Further research could examine the wider implications on innovation in construction.

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