AN ALTERNATIVE PROJECT-BASED LEARNING MODEL FOR BUILDING INFORMATION MODELLING-USING TEAMS

Prompt Udomdech[1], Eleni Papadonikolaki and Andrew Davies

The Bartlett School of Construction and Project Management, University College London, 1-19 Torrington Place, London WC1E 6BT, UK

Adopting Building Information Modelling (BIM) is a radical challenge for Small and Medium-sized construction enterprises (construction SMEs). Inadequate individual BIM competencies in BIM-using teams are among key challenges, while Project-Based Learning (PBL) could form a potential solution. An alternative PBL model that conceptualises relations between knowledge practices exercised and project influencing attributes is presented to be used further in improving BIM learning mechanisms of teams. It contains three dimensions which are: 1) project knowledge stocks; 2) project knowledge practices; and 3) project influencing attributes. A Systematic Literature Review (SLR) is performed to qualitatively synthesise attributes found from relevant literature from management and construction innovation. The model serves as a framework for future studies and investigations on how project knowledge practices and their influencing attributes in projects can assist BIM learning in construction SMEs and BIM-using teams.

Keywords: BIM, innovation, Project-Based Learning (PBL), project knowledge

INTRODUCTION

Adopting Building Information Modelling (BIM) is a radical challenge for Small and Medium-sized construction Enterprises (construction SMEs) (Dainty *et al*., 2017; Tulenheimo, 2015). BIM changes existing paradigms of construction by politically, technologically, and procedurally (Migilinskas *et al*., 2013; Puolitaival and Forsythe, 2016) incorporates geometrical and functional properties of facilities for stakeholders throughout the building lifecycle (Ding *et al*., 2014; Miettinen and Paavola, 2014). Inadequate individual BIM competencies in BIM-using teams is the major issue (Dainty *et al*., 2017; Succar and Sher, 2014), while Project-Based Learning (PBL) is a potential solution (Bartsch *et al*., 2013; Hartmann and Dorée, 2015).

PBL values project-based knowledge and focuses on learning to improve organisational performance and innovation adoption (Ashok *et al*., 2016; Gopalakrishnan *et al*., 1999; Hartmann and Dorée, 2015). It answers to the temporal nature of construction (Bakker *et al*., 2011; Davis *et al*., 2016), where innovations are constantly co-developed among team members (Aouad *et al*., 2010; Lloyd-Walker *et al*., 2014). PBL features the sender/receiver and social learning approaches (Bresnen *et al*., 2003; Hartmann and Dorée, 2015). The former directs on knowledge practices

[1] prompt.udomdech.14@ucl.ac.uk

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and attributes affecting individual learning. The latter examines influencing attributes of project context to learning. Additionally, relations between knowledge practices used in teams and influencing attributes of projects can be studied to understand BIM learning mechanisms in teams and advance individual BIM learning. The integration of both approaches in literature of PBL is scarce.

The paper presents an alternative PBL model that conceptualises knowledge practices in projects and influencing attributes of projects for future studies and practical implementation. A Systematic Literature Review (SLR) is conducted to synthesise attributes found. The structure of the paper is as follows. The background section discusses PBL and BIM theories. PBL models and frameworks section investigates background of related literature. Next, the research approach section clarifies the methodology. Then, an alternative PBL framework is proposed. Ensuring sections analyse the framework against literature and conclude this study.

BIM Adoption and Project-Based Learning

Building Information Modelling (BIM) Innovation Adoption

BIM is the common construction innovation (Bryde *et al*., 2013; Succar and Sher, 2014), the solution to fragmentation in construction (Chen *et al*., 2017; Ghaffarianhoseini *et al*., 2017; Puolitaival and Forsythe, 2016). It emerges from the current geometric oriented Computer Aided Design (CAD) program (Ghaffarianhoseini *et al*., 2017). BIM politically, technologically, and procedurally integrates facility-related geometries and functional properties for project actors throughout the building lifecycle (Miettinen and Paavola, 2014; Puolitaival and Forsythe, 2016). Adopting BIM is a systematic innovation for organisations (Murguia *et al*., 2017; Papadonikolaki, 2017), however, it is a radical process innovation for construction SMEs (Dainty *et al*., 2017; Tulenheimo, 2015) as they contain insufficient resources of expertise and skills compared to large firms. Adopting BIM will revolutionarily replace existing working paradigms. This complication is referred to as inadequate individual BIM competencies (Succar and Sher, 2014). Gained through BIM learning, individual BIM competencies are personal capacities to perform or deliver BIM-related activities and outcomes (Succar and Sher, 2014). Foci to advance this have been shifted to KBV of firms and PBL as valuable knowledge in parts of a firm is unequally dispersed (Prencipe and Tell, 2001; Szulanski, 2000) and learning is highly intensive in projects (Egbu, 2004; Hartmann and Dorée, 2015).

Knowledge-Based View (KBV) of Firms

KBV of firms perceives knowledge as a strategic resource (Nonaka and von Krogh, 2009). Knowledge is defined as individual capabilities acquired through dynamic human processes of justifying personal perceptions towards truth (Nonaka, 1994; Prencipe and Tell, 2001). Nonaka (1994) distinguished knowledge into explicit and tacit. Explicit knowledge can be accessed through consciousness, codified, and externalised, while tacit knowledge is intuitive, un-codifiable, and personal (Nonaka, 1994; Seidler de Alwis and Hartmann, 2008). For knowledge-intensive and project-based organisations such as constructions (Egbu, 2004; Prencipe and Tell, 2001), learning from projects is crucial to innovation adoption (Aouad *et al*., 2010).

Project-Based Learning (PBL)

PBL highlights the management of project-based knowledge to maximise individual learning (Hartmann and Dorée, 2015; Prencipe and Tell, 2001; Yun *et al*., 2011). Constructions are organised around projects (Gann and Salter, 2000; Tatum, 1987), an innovative environment where specialists constantly explore and learn (Aouad *et al*.,

2010; Bartsch *et al*., 2013; Davis *et al*., 2016). Lindner and Wald (2011) classified project-based knowledge into: 1) project knowledge that denotes an overview of an organisational landscape; 2) intra-project knowledge within a project; 3) knowledge between upstream and downstream projects; 4) knowledge between parallel projects; and 5) knowledge between projects and their parent organisations. Zhao *et al*., (2015) added 6) knowledge between two projects with different completion time.

Individual learning occurs when routines are recreated and maintained in new settings (Hartmann and Dorée, 2015). Learning in projects is categorised into the sender/receiver and social learning approaches (Bresnen *et al*., 2003). The former expresses learning from processes of storing, retrieving, and transferring explicit knowledge that can be reverted to transmission channels such as electronics and document-based repositories (Bresnen *et al*., 2003; Hartmann and Dorée, 2015). Referred as the 'cognitive approach', it is suitable for product innovation, where learning is based on codifiable knowledge (Bresnen *et al*., 2003). The latter focuses more on tacit knowledge transfer and prioritises attributes promoting a fertile environment, a context that facilitate learning (Szulanski, 2000) and innovation from collaboration mechanism in teams (Bresnen *et al*., 2003; Hartmann and Dorée, 2015). Described as the 'community approach', it is advisable for process innovation as knowledge learned is mostly un-codifiable (Bresnen *et al*., 2005).

Project-Based Learning Models and Frameworks

PBL models and frameworks can be classified into the sender/receiver and social learning approaches (Bresnen *et al*., 2003). Within the sender/receiver approach, Prencipe and Tell (2001) suggested a learning landscape framework in analysing learning abilities of project-based firms. Prencipe and Tell (2001) argued for attentions upon processes of learning and the articulation of codifiable knowledge. Szulanski (2000) presented a process model of knowledge transfer between individuals and highlighted transfer barriers on each process. Built on Szulanski (2000), Tan *et al*., (2006) introduced a model in live-capturing and sharing of explicit knowledge among project members. Tan *et al*., (2006) stressed workflows and knowledge practices as major attributes to individual learning of codifiable knowledge. Knowledge practices were mentioned in Reich *et al*., (2012) to help generate desired business outcomes when aligned with knowledge stocks and enabling environment dimensions. Duffield and Whitty (2015) accentuated this by proposing the Systematic lessons learned knowledge (Syllk) model, encouraging the alignment of organisational elements such as people, practices, culture, and so forth.

For the social learning approach, Bresnen *et al*., (2005) proposed a framework of structural, relational, and cognitive dimensions of social capital in PBL. Chen and Huang (2007) argued for less formalisation, more decentralisation, and high individual integration structure and climate. Bakker *et al*., (2011) presented temporal dimension instead of the structural dimension, stressing influences the temporal nature of constructions have to learning. Bakker *et al*., (2011) also highlighted absorptive capacities and motivations of individuals as major contributors to project learning. Respectively to the cognitive, relational, and temporal dimensions, Lindner and Wald (2011) posed three supporting attributes of culture and leadership, organisation and process, and technological system. Bartsch *et al*., (2013) investigated the relational dimension further and suggested advocating attributes of social ties and shared system of meanings among colleagues. Additionally, Hartmann and Dorée (2015) linked individual learning to social and organisational context in which projects are formed.

Zhao *et al*., (2015) re-classified project influential attributes into transfer capabilities, relationships, context, and task context of project teams.

RESEARCH APPROACH

The theoretical body of the sender/receiver approach explores upon processes and knowledge practices in learning codifiable knowledge in projects. The knowledge body of the social learning approach accentuates learning of un-codifiable knowledge and influencing attributes of a fertile project. Additionally, relations between knowledge practices and influencing attributes of a fertile project can be challenged to advance individual BIM learning. Their affiliations in BIM-using teams can be formulated to understand BIM learning mechanisms in teams to advance individual BIM learning. The paper addresses the research question of "how can relations between project knowledge in practices and their influencing attributes be conceptualised to advance individual BIM learning in teams?"

This research exercises a constructivist ontology and an interpretive epistemology of PBL and BIM adoption in construction SMEs. It suggests that the integration of both theoretical bodies potentially yield a new perspective to the practical problem of BIM adoption in construction SMEs and therefore needs to be interpreted or formulated. The research proposes a model that conceptualises knowledge practices used by project members and influencing attributes to a fertile project. The model advances from the SLR of PBL, project knowledge transfer, and construction innovation adoption. SLR is known to be efficient for identifying and evaluating extensive literature (Crossan and Apaydin, 2010; Tranfield *et al*., 2003). This paper starts by determining relevant keywords to the research question. Searches are made through academic sources such as the International Journal of Project Management, Journal of Knowledge Management, Journal of Management Studies, Construction Innovation Journal, Automation in Construction Journal, Building Research and Information Journal, and Proceedings of ARCOM (Association of Researchers in Construction Management) Annual Conferences. Qualitatively, insights from the secondary data are synthesised and built upon one another through an inductive approach.

An Alternative Project-Based Learning Model

This alternative PBL model incorporates several insights from the SLR and includes three dimensions which are: 1) project knowledge stocks; 2) project knowledge practices; and 3) project influencing attributes.

Project knowledge stocks

Similar to Reich *et al*., (2012), project knowledge stocks represent individuals with cognitive capacities and potentials to increase such knowledge. The project knowledge stocks sort individuals into a sender and a receiver. Referring to Lindner and Wald (2011) and Zhao *et al*., (2015), the sender and receiver can be two different individuals within a project, between upstream and downstream projects among parallel projects, and between two projects within different completion time. The receiver can also be the sender, learning from previous projects.

Project knowledge practices

Project knowledge practices are activities exercised to learn (Reich *et al*., 2012). They act as mechanisms to translate, transfer, and share knowledge from one entity to another (Liyanage *et al*., 2009). Attributing practices from the SLR are classified into: 1) codifiable approach; 2) un-codifiable approach; and 3) mixed approach in Table 1 as follows.

Table 1: Approaches of project knowledge practices and their attributing practices.

Approaches	Attributing practices	Cited references
Codifiable approach (concerns explicit knowledge)	External knowledge sources	Tan *et al*., (2006)
	Project documentations	Hartmann and Dorée (2015)
	Research and development	Tan *et al*., (2006)
	Standardised operations and manuals	Tan *et al*., (2006)
	Shared knowledge repositories	Egbu (2004) and Tan *et al*., (2006)
Un-codifiable approach (concerns tacit knowledge)	Creation of a knowledge team	Egbu (2004) and Tan *et al*., (2006)
	Incentive schemes	Duffield and Whitty (2015) and Egbu (2004)
	Informal meetings	Duffield and Whitty (2015) and Tan *et al*., (2006)
	Mentoring	Duffield and Whitty (2015) and Egbu (2004)
	Partnership	Tan *et al*., (2006)
	Recruitment and reassignment of project members	Tan *et al*., (2006)
Mixed approach (concerns both explicit and tacit knowledge)	Assignment of knowledge management personnel	Duffield and Whitty (2015)
	Post project reviews	Hartmann and Dorée (2015) and Tan *et al*., (2006)
	Professional networks	Egbu (2004) and Tan *et al*., (2006)
	Promotion of knowledge sharing culture	Duffield and Whitty (2015)
	Trainings and workshops	Tan *et al*., (2006)

Project influencing attributes

Project influencing attributes incorporate both technological and social aspects of PBL. They can be enabling and hindering attributes to a fertile project, based on perceptions of teams. Project influencing attributes facilitate project knowledge practices and form a unique learning mechanism in teams. Attributes found are classified into topics, then categorised into different themes which are: 1) qualities of a sender; 2) qualities of a receiver; 3) project team relationships; 4) project team context; and 5) project operational context presented in Table 2.

Table 2: Themes and topics of project influencing attributes and their supporting attributes

Themes	Topics	Supporting attributes
Qualities of a sender	Transferring capacities	Existing abilities of an individual to realise values and purposes of knowledge, as well as take opportunities to accurately document and store such knowledge (Bresnen *et al*., 2003; Hartmann and Dorée, 2015; Tan *et al*., 2006)
	Willingness to share	Resources such as time in capturing knowledge (Hartmann and Dorée, 2015), workloads of the sender, and legal issues associated to knowledge captured (Tan et al., 2006).

Qualities of a receiver	Absorptive capacities	Abilities to identify the value of new knowledge, assimilate it with existing knowledge, and apply it to commercial ends (Bakker *et al*., 2011; Bartsch *et al*., 2013; Bresnen *et al*., 2003; Lloyd-Walker *et al*., 2014).
	Knowledge quality	Usefulness (Hartmann and Dorée, 2015), expiration, and fragmentation of captured knowledge (Zhao *et al*., 2015).
	Motivation to absorb	Resources such as time in learning (Hartmann and Dorée, 2015), workloads of the sender, and legal issues associated to knowledge captured (Tan *et al*., 2006).
Project team relationships	Cognitive aspects	Shared representations, interpretation, and system of meanings among team members (Bakker *et al*., 2011; Bartsch *et al*., 2013; Bresnen *et al*., 2005).
	Relational aspects	Network ties with current and former project team members based on trust, cooperation, and communication (Bakker *et al*., 2011; Bartsch *et al*., 2013; Chen and Huang, 2007)
	Temporal aspects	Disruptive experience and connection of team members from previous projects (Bakker *et al*., 2011; Bresnen *et al*., 2005).
Project team context	Project climate	Senior management support, knowledge sharing culture, and no-blame culture where social barriers in learning are blurred (Duffield and Whitty, 2015; Lloyd-Walker *et al*., 2014) and learning in projects is structured (Duffield and Whitty, 2015; Egbu, 2004; Lindner and Wald, 2011).
	Project resources	Costs and investment made by a project to capture and transfer knowledge, and modify existing business processes (Lloyd-Walker *et al*., 2014; Tan *et al*., 2006).
	Project structure	Formalisation, centralisation, integration, and stratification of a project (Chen and Huang, 2007; Egbu, 2004) and clearly defined roles and responsibilities (Bresnen *et al*., 2003).
Project operational context	Project similarities	Similarities of projects, tasks, and problems found (Zhao *et al*., 2015).
	Time urgencies	Differences in timescale of projects, tasks, and urgencies of problems encountered (Duffield and Whitty, 2015; Zhao *et al*., 2015).

The alternative Project-Based Learning (PBL) model

Inductive approach allows attributes found to be developed into a model (Figure 1). The project knowledge practices are means through which the receiver learns from the sender.

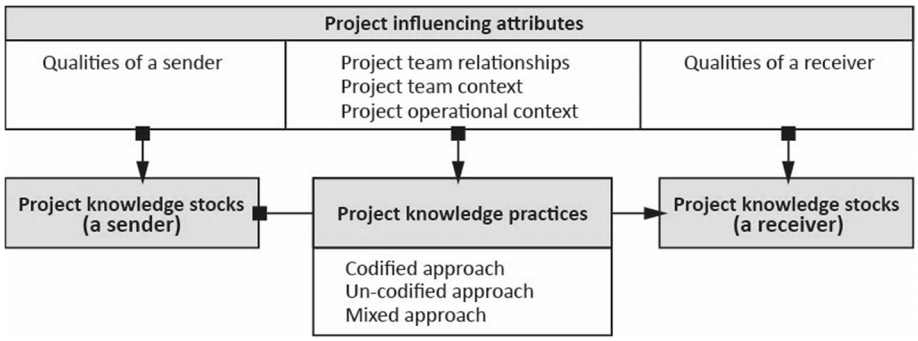

Figure 1: The alternative Project-Based Learning (PBL) model

A project can contain several attributing practices from different approaches of the project knowledge practices. The project team relationships, project team context, and project operational context directly influence the project knowledge practices and

form the learning mechanism of a team. The qualities of senders and receivers respectively affect each project knowledge stocks in learning.

DISCUSSION

The model resonated with theories about knowledge as a strategic resource (Nonaka and von Krogh, 2009), highlighted the importance of individual knowledge and competencies (Nonaka and von Krogh, 2009; Seidler de Alwis and Hartmann, 2008), and addressed relations of knowledge practices and their influencing attributes to individual BIM learning in teams.

The dimensions in the proposed model were developed from knowledge practices, knowledge stocks, and enabling environment dimensions of Reich *et al*., (2012). The project knowledge stocks were categorised based on different types of project-based knowledge in Lindner and Wald (2011) and Zhao *et al*., (2015). The codifiable and un-codifiable approaches of the project knowledge practices were based on knowledge types focused in the sender/receiver and social learning approaches (Bresnen *et al*., 2003; Hartmann and Dorée, 2015), as well as the general classification of knowledge in Nonaka (1994). The mixed approach was proposed based on how some knowledge practices practically include the learning of both types of knowledge. Themes of project influencing attributes were extended from Zhao *et al*., (2015). The transfer capabilities of individuals from Zhao *et al*., (2015) were sorted into the qualities of senders and receivers to match the project knowledge stocks dimension. The project team relationships include the temporal, relational, and cognitive aspects from Bakker *et al*., (2011). This contradicted to Bresnen *et al*., (2005), who presented the structural aspect together with the relational and cognitive aspects in assessing the social capital of firms. This paper classified the structural aspect with project climate (Chen and Huang, 2007) and project resources (Tan *et al*., 2006) as they are significant in forming a fertile project team context. The project operational context held affinities to task context of a project in Tan *et al*., (2006) as it contained task similarities and time urgencies.

Practically, construction SMEs adopting BIM and BIM-using teams can employ this model to reflect, assist, and improve upon existing BIM learning mechanisms and advance individual BIM competencies. It allows construction SMEs and BIM-using teams to select best practices to suit their existing project context or alter their context to fit practices exercised in the firm. It also fosters greater understanding on managerial challenges in construction innovation adoption and offers opportunities to challenge such issue.

Theoretically, with the constructivist ontology and interpretivist epistemology, this model consolidates related literature, question the current theoretical body of PBL, and additionally suggests a new perspective of the under-studied relations between project knowledge practices and project influencing attributes to advance individual BIM learning and BIM adoption in construction SMEs. It combines and builds on current theories of PBL with different rationale from project knowledge transfer and construction innovation adoption literature. Further studies and practical implementations are needed in exploring, refining, and validating the alternative perspective presented and the proposed model, as well as populating with empirical data.

CONCLUSIONS

BIM adoption is a radical innovation for construction SMEs due to the lack of individuals with adequate BIM competencies in BIM-using teams. PBL is suggested as potential solution. This paper challenges current theories of PBL by presenting an alternative PBL model that conceptualises relations between knowledge practices and influencing attributes of projects. The model formulates from attributes synthesised from the SLR of PBL, project knowledge transfer, and construction innovation adoption. It contains three dimensions which are: 1) project knowledge stocks; 2) project knowledge practices; and 3) project influencing attributes. The model allows construction SMEs and BIM-using teams to evaluate and improve their learning mechanisms to advance BIM learning. This paper consolidates existing literature and introduced an alternative approach to PBL to support BIM and innovation adoption in general. Future studies are needed to refine all variables and investigate how project knowledge practices and project influencing attributes can assist BIM adoption in construction SMEs and individual BIM learning in BIM-using teams.

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