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An Alternative Project-Based Learning Model for Building Information Modelling-Using Teams

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Abstract

Adopting Building Information Modelling (BIM) is a radical challenge for Small and Medium construction enterprises (construction SMEs) and BIM-using teams. Inadequate individual BIM competences 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 their influencing attributes in projects 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: Building Information Modelling (BIM), construction innovation adoption, Project-Based Learning (PBL), and project knowledge transfer.

Introduction

Adopting Building Information Modelling (BIM) is a radical challenge for Small and Medium construction Enterprises (construction SMEs) (Dainty et al., 2017; Tulenheimo, 2015) and BIM-using teams (Migilinskas et al., 2013). BIM technologically and procedurally (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 teams is the key issue (Succar and Sher, 2014), while Project-Based Learning (PBL) is a potential solution (Hartmann and Dorée, 2015). PBL emphasises the Knowledge-Based View (KBV) of firms, where knowledge is crucial in innovation adoption (Gopalakrishnan et al., 1999). PBL answers to the project nature of constructions (Bakker et al., 2011), where innovations are constantly co-developed (Aouad et al., 2010; Lloyd-Walker et al., 2014) among team members.

PBL features the sender/receiver and social learning approaches (Hartmann and Dorée, 2015). The former focuses on processes, practices, and influences in individual learning. The latter examines attributes affecting project context. However, relations between knowledge practices used in teams and their influencing attributes can be investigated to foster BIM learning. Their discussions in literature of PBL is scarce.

The paper presents an alternative PBL model that conceptualises knowledge practices in projects and their influencing attributes for future studies and practical implementation to improve BIM learning mechanism in teams. 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 model and frameworks section investigates background of related literature. Next, the research approach section clarifies the methodology. Then, an alternative PBL model is proposed. Ensuring sections analyse the model against literature and conclude this study.

Project-Based Learning and BIM adoption

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 a dynamic human process 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). Gopalakrishnan et al. (1999) highlighted knowledge in innovation adoption, where innovation is crucial to growth in organisations (Cooper, 1998; Pichlak, 2016). In adopting construction innovation such as BIM, foci have been shifted to 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).

Project-Based Learning (PBL)

Construction industry is organised around projects (Tatum, 1987), where innovations are co-developed (Aouad et al., 2010). Projects are innovative environment where specialists constantly explore and learn (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 that arises 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 and collaborative mechanisms in teams (Bresnen et al., 2005; Hartmann and Dorée, 2015), where creativity and innovation positively resulted from (Lloyd-Walker et al., 2014). Described as the 'community approach', it is advisable for process innovation, as knowledge learned is un-codifiable (Bresnen et al., 2005). Adopting BIM for construction SMEs and BIM-using teams is a radical process innovation (Eadie et al., 2013; Migilinskas et al., 2013; Succar and Sher, 2014)

Building Information Modelling (BIM) innovation adoption

BIM emerges from the current geometric oriented Computer Aided Design (CAD) program (Ghaffarianhoseini et al., 2017). It 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). While adopting BIM is a systematic innovation for organisations (Murguia et al., 2017; Papadonikolaki, 2017), it is a radical innovation for construction SMEs (Dainty et al., 2017; Tulenheimo, 2015) and BIM-using teams (Migilinskas et al., 2013). Slaughter (2000) explained radical innovation as a breakthrough change that completely replaces existing paradigms. Construction SMEs face greater challenges than large firms in adopting BIM from inadequate resources of expertise and skills (Dainty et al., 2017; Tulenheimo, 2015). Succar and Sher (2014) referred to as

inadequate individual BIM competencies, personal capacities to perform BIM activities or deliver BIM-related outcomes.

Project-Based Learning models and frameworks

PBL models and frameworks are classified into the sender/receiver and social learning approaches (Bresnen et al., 2003). The sender/receiver approach considers processes, practices, and influences in individual learning (Hartmann and Dorée, 2015). Prencipe and Tell (2001) suggested a learning landscape framework in analysing learning abilities of project-based firms. The framework of Prencipe and Tell (2001) argued for attentions upon processes of learnings 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) also stressed workflows and knowledge practices as major contributors 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.

The social learning approach prioritises attributes promoting a fertile environment, an environment that facilitate learning (Szulanski, 2000). Innovation is a collaborative outcome of people with different knowledge (Lloyd-Walker et al., 2014). 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 learning in projects. 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 learnings 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.

Problem identification

Current theories of PBL cast attentions upon the sender/receiver and the social learning approaches. The sender/receiver approach, suitable for product innovation emphasises processes and knowledge practices in transferring codifiable knowledge. The social learning approach, advisable for process innovation accentuates learning of un-codifiable knowledge and attributes influencing fertile projects such as transfer capabilities, relationships, context, and tasks context. Notwithstanding, relations between knowledge practices and their influencing attributes can be challenged to facilitate BIM learning. This paper addressed the research question of "how can relations between project knowledge practices and their influencing attributes be conceptualised to foster BIM learning in teams?"

Research approach

The model proposed in this paper advanced from the SLR of PBL, project knowledge transfer, and construction innovation adoption. SLR is known to be efficient for identifying and evaluating extensive literature (Tranfield et al., 2003). This paper started by determining relevant keywords to the research question. Searches were made through academic sources such as the International Journal of Project Management, Journal of Knowledge Management, Proceedings of ARCOM (Association of Researchers in Construction Management) Annual Conferences, Construction Innovation Journal, and Building Research & Information. Insights and theories from different knowledge bodies mentioned were integrated and built upon one another. Qualitatively, attributes found were synthesised and developed into a model using an inductive reasoning approach, where conclusions are built on known premises (Quinlan et al., 2011).

An alternative Project-Based Learning model

This alternative PBL model conceptualises knowledge practices used by project members and their influencing attributes to a fertile project. It 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* represents individuals with cognitive capacities and potentials to increase such knowledge. The *project knowledge stocks* sorted individuals into a sender and a receiver. Relating 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, who is learning from previous projects.

Project knowledge practices

Referring to Reich et al. (2012), *project knowledge practices* are activities exercised to learn. Attributing practices from the SLR are classified into: 1) *codifiable approach*; 2) *un-codifiable approach*; and 3) *mixed approach* and explained in Table 1.

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

Approaches	Attributing practices	Cited references
Codifiable approach (explicit knowledge-related)	Project documentations	Hartmann and Dorée (2015)
	External knowledge sources	Tan et al. (2006)
	Standardised operations and manuals	Tan et al. (2006)
	Shared knowledge repositories	Egbu (2004) and Tan et al. (2006)
	Research and development	Tan et al. (2006)

Un-codifiable approach (tacit knowledge-related)	Recruitment and reassignment of project members	Tan et al. (2006)
	Mentoring	Duffield and Whitty (2015) and Egbu (2004)
	Partnership	Tan et al. (2006)
	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)
Mixed approach (includes both knowledge types)	Trainings	Tan et al. (2006)
	Professional networks	Egbu (2004) and Tan et al. (2006)
	Promotion of knowledge sharing culture	Duffield and Whitty (2015)
	Assignment of knowledge management personnel	Duffield and Whitty (2015)
	Post project reviews	Hartmann and Dorée (2015) and Tan et al. (2006)

Project influencing attributes

Project influencing attributes incorporates both technological and social aspects of PBL. They can be enabling and hindering attributes, based on perceptions of teams. Attributes found are classified into topics, then categorised into different themes of the *project influencing attributes* which include: 1) *qualities of a sender*; 2) *qualities of a receiver*; 3) *project team relationships*; 4) *project team context*; and 5) *project operational context*. The *project influencing attributes* are 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 value and purpose of knowledge, and 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 knowledges, and apply it to commercial ends)Bakker et al., 2011; Bartsch et al., 2013; Bresnen et al., 2003; Lloyd-Walker et al., 2014).
	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).
	Knowledge quality	Usefulness (Hartmann and Dorée, 2015), expiration, and fragmentation of knowledge (Zhao et al., 2015).
Project team relationships	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 from previous projects of team members (Bakker et al., 2011; Bresnen et al., 2005).
	Cognitive aspects	Shared representations, interpretations, and system of meanings among team members (Bakker et al., 2011; Bartsch et al., 2013; 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) learning in projects is structured (Duffield and Whitty, 2015; Egbu, 2004; Lindner and Wald, 2011).
	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 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 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 reasoning allows attributes found to be developed into a model. The *project knowledge practices* are means through which the receiver learns from the sender. 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*. The *qualities of senders and receivers* respectively affect them in learning. The alternative PBL model is proposed in Figure 1.

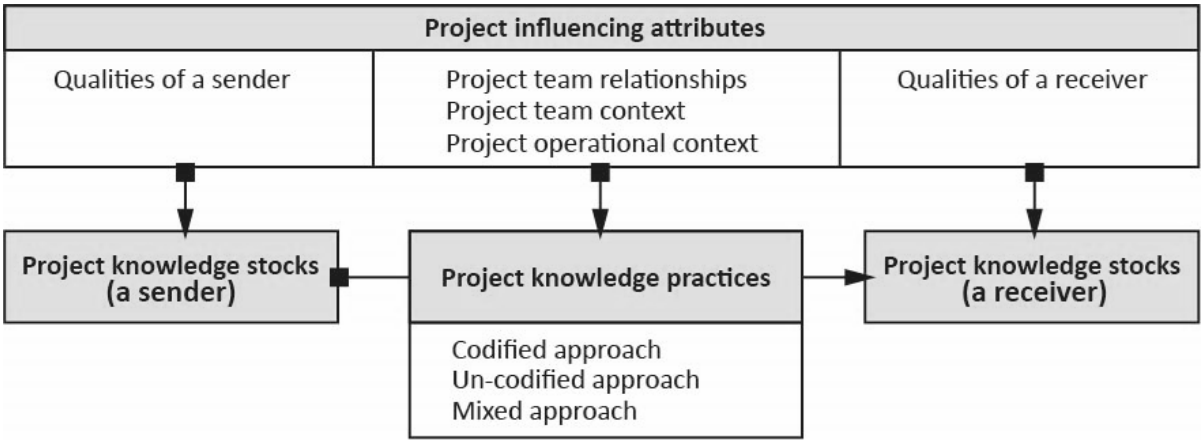

Figure 1: The alternative Project-Based Learning (PBL) model.

Discussion

The model resonated with theories about knowledge as a strategic resource (Nonaka and von Krogh, 2009), highlighted the importance of individual knowledge (Nonaka and von Krogh, 2009; Seidler de Alwis and Hartmann, 2008), and addressed relations of knowledge practices and their influencing attributes to 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, and general classification of knowledge in Nonaka (1994). The *mixed approach*, however, was proposed based on how some knowledge practices practically include both types of knowledge. Themes of the *project influencing attributes* were extended from the model of Zhao et al. (2015). The transfer capabilities of a project team 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 alternative PBL model to reflect, assist, and improve upon existing BIM learning mechanisms and individual BIM competencies. It also fosters greater understanding of managerial challenges in construction innovation adoption and offers opportunities to challenge such issues. Theoretically, this model consolidates existing related literature and alternatively explores the under-studied relations of knowledge practices to their influencing attributes in

projects. It built 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 refining and validating the proposed model as well as populating with empirical data.

Conclusion

BIM adoption is a radical innovation for construction SMEs and BIM-using teams due to the lack of individuals with adequate BIM competencies. PBL is suggested here as a potential solution. This paper challenged current theories of PBL by presenting an alternative PBL model that conceptualises relations between knowledge practices and their influencing attributes within projects. This model formulated from attributes synthesised from the SLR of PBL, project knowledge transfer, and construction innovation adoption. It contained three dimensions which are: 1) *project knowledge stocks*; 2) *project knowledge practices*; 3) *project influencing attributes*. The model allowed construction SMEs and BIM-using teams to evaluate and improve their learning mechanisms for BIM learning. This paper consolidated existing literature and introduced an alternative approach to PBL to support BIM and innovation adoption in general. The proposed model will serve as a framework for future studies to refine all variables and investigate how knowledge practices and their influencing attributes can assist in BIM learning of construction SMEs and BIM-using teams in developed and developing countries.

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