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

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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

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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 (Precipe 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; Precipe 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; Precipe 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; Precipe 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.,
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.

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Attributing practices</th>
<th>Cited references</th>
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</thead>
<tbody>
<tr>
<td>Codifiable approach</td>
<td>External knowledge sources</td>
<td>Tan et al., (2006)</td>
</tr>
<tr>
<td>(concerns explicit knowledge)</td>
<td>Project documentations</td>
<td>Hartmann and Dorée (2015)</td>
</tr>
<tr>
<td></td>
<td>Research and development</td>
<td>Tan et al., (2006)</td>
</tr>
<tr>
<td></td>
<td>Standardised operations and manuals</td>
<td>Tan et al., (2006)</td>
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<td></td>
<td>Incentive schemes</td>
<td>Duffield and Whitty (2015)</td>
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<td></td>
<td>Informal meetings</td>
<td>Duffield and Whitty (2015)</td>
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<td></td>
<td>Mentoring</td>
<td>Duffield and Whitty (2015)</td>
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<td></td>
<td>Partnership</td>
<td>Tan et al., (2006)</td>
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<td></td>
<td>Assignment of knowledge management personnel</td>
<td>Duffield and Whitty (2015)</td>
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<tr>
<td>Mixed approach</td>
<td>Post project reviews</td>
<td>Hartmann and Dorée (2015)</td>
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<td>tacit knowledge)</td>
<td>Promotion of knowledge sharing culture</td>
<td>Duffield and Whitty (2015)</td>
</tr>
<tr>
<td></td>
<td>Trainings and workshops</td>
<td>Tan et al., (2006)</td>
</tr>
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</table>

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 categorized 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

<table>
<thead>
<tr>
<th>Themes</th>
<th>Topics</th>
<th>Supporting attributes</th>
</tr>
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<tbody>
<tr>
<td>Qualities of a sender</td>
<td>Transferring capacities</td>
<td>Existing abilities of an individual to realize 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)</td>
</tr>
<tr>
<td></td>
<td>Willingness to share</td>
<td>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).</td>
</tr>
</tbody>
</table>
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](image)

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 a 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.

REFERENCES


An Alternative Project-Based Learning Model


Ding, L, Zhou, Y and Akinci, B (2014) Building Information Modeling (BIM) application framework: The process of expanding from 3D to computable nD. *Automation in Construction*, 46, 82-93.


