MAJOR PROJECT TEAM LEARNING: EXAMINING BUILDING INFORMATION MODELLING

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The speed of technological advancement of software development drives the need for individual and team learning to exploit these developments for competitive advantage. Using a major long term redevelopment as a case study a review of learning processes and project team learning in the context of a voluntary approach to adopting of BIM prior to 2016 is examined. The speed of adoption of BIM across a large redevelopment project covering several years is variable and the differences of preparedness between team members from different organisations raises the question of how effective the project team can be in sharing learning and increasing the speed of adoption of BIM. The benefits of understanding the project environment as a formal learning context are recognised where teams are working in partnering arrangements but the focus is usually on post project review of what went wrong with little time to critically evaluate other variables. Knowledge Management has the potential to help understand and then facilitate greater participation amongst stakeholders in project team learning. The research team undertook decision mapping and knowledge elicitation techniques and applied these to the Dundee Waterfront to identify key factors relevant to successful project management, enabling the Waterfront Project Team to understand current practice. The effectiveness of project team learning in relation to BIM within this long-term major redevelopment is influenced by positive motivational drivers for individuals to learn how to use and apply BIM, the level of organisational support for learning and professional development and the project information and communication systems. In practice the current approach to sharing of knowledge within the project team indicates a fragmented approach in relation to the adoption and application of BIM to managing construction projects.

Keywords: individual learning, knowledge management, team learning.

INTRODUCTION

The construction industry is experiencing the impact of rapid technological developments in relation to both design and construction processes that demands continuous learning of the design team. Can project teams learn sufficiently quickly to keep up with the pace of change effectively and efficiently? The larger the project team and the longer the project then the more important it is to understand the complexities of how large multi-disciplinary teams can work towards sustained team performance through knowledge and skill development. Bunderson (2003) ascertained that it was essential to have a balance between learning and overall team goals for effective team performance but teams that over-emphasise learning may compromise their performance (Levinthal and March, 1993). Using the focus of the

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adoption of BIM within a large, multi-disciplinary waterfront redevelopment project the research team investigated team learning and assessed the impact in relation to project team knowledge development.

INDIVIDUAL LEARNING THEORY

The importance of learning is recognised by professionals in their individual roles within the construction process and by organisations as a part of maintaining competitive advantage (Bhargav and Koskela 2009). In each case a successful learning context was found where the individuals were personally motivated to succeed, could identify the appropriate opportunities and provided with the necessary resources (Seward 1952). The ability of individuals within a team to perform familiar tasks in more efficient ways and facilitate novel problem solving in an ever-changing environment contributed further to an individual's knowledge base (Rumbaugh *et al* 2012) and that of the team if it was shared within the team environment.

Priorities for organisational support for learning are affected by factors such as organisational strategy, in this case for engaging with BIM, requiring the development of knowledge through assessing the appropriate software and where it can be applied for effective results within an organisation, assessing the consequences and making subsequent improvements. Where the motivation for learning is not driven by a positive personal desire (a pull factor) but by fear of consequence for failing to adapt to change (a push factor) individual motivation towards learning is adversely affected. In this situation individual motivation will be present, but the approach-avoidance to learning to BIM will be adopted (Madan, 2013), indicating that whilst organisational objectives may be achieved the issue of successful learning that can be shared within teams could be limited.

There are different theories to explain individual learning (Pashler 2008), but within the context of a major project team Kolb's Experiential Learning model provides an appropriate model for explaining the learning processes of individuals, teams and organizations. Experiential Learning Theory as a structured approach to team learning has been shown to be successful in helping teams to develop the essential competencies necessary for team learning (Kayes 2005). Kolb and Kolb (2005) have demonstrated that knowledge is derived from two actions; requiring understanding which is described as 'grasping experience' and application which is described as 'transforming experience'. In examining the context of team learning it is necessary to identify the actions, events, behaviours and decision making processes that an effective team exhibits (Day, Gronn and Salasc, 2004).

PROJECT TEAM LEARNING

Carrillo (2005) identifies the exploitation lessons learnt and experiences to improve performance on future projects, is highly desirable to construction companies offering commercial success. However, a project based industry involving multiple stakeholders and complexity provides a challenge where project memory is not integrated in to organisational memory (Ghosh *et al* 2012). Teams are complex, dynamic, and adaptive systems (McGrath, Arrow, and Berdahl, 2000) bounded by context and time variables (Ilgen *et al*. 2005). Hannes *et al*. (2013) reviewed team learning and ascertained that employees learn for different reasons and in different ways, identifying three factors required to facilitate team learning:

- Effective open multi-disciplinary communication

- Minimising power inequalities that flow from hierarchical differences within team relationships
- Stimulating commitment and devotion towards team learning, and to consider the place of reflection and action in this process

There is a hierarchy of learning, commencing with individual learning, then team learning with organisational learning (Figure 1). Research into the complexities of team learning is focused on intra-organisational teams with the result that there is limited research into how inter-organisational multi-disciplinary teams such as major construction project teams learn and share knowledge. Whilst individual and team learning is identifiable within organisations, the construction project team adds another layer of complexity to the learning process (Figure 1). Typical construction project teams involve cross-discipline working and another team context overlapping with different organisational, team learning and individual learning processes. While professionals are happy to share knowledge and learning from training and CPD events, where this knowledge has commercial value it was found there was some reluctance to share other than that absolutely necessary for operational reasons.

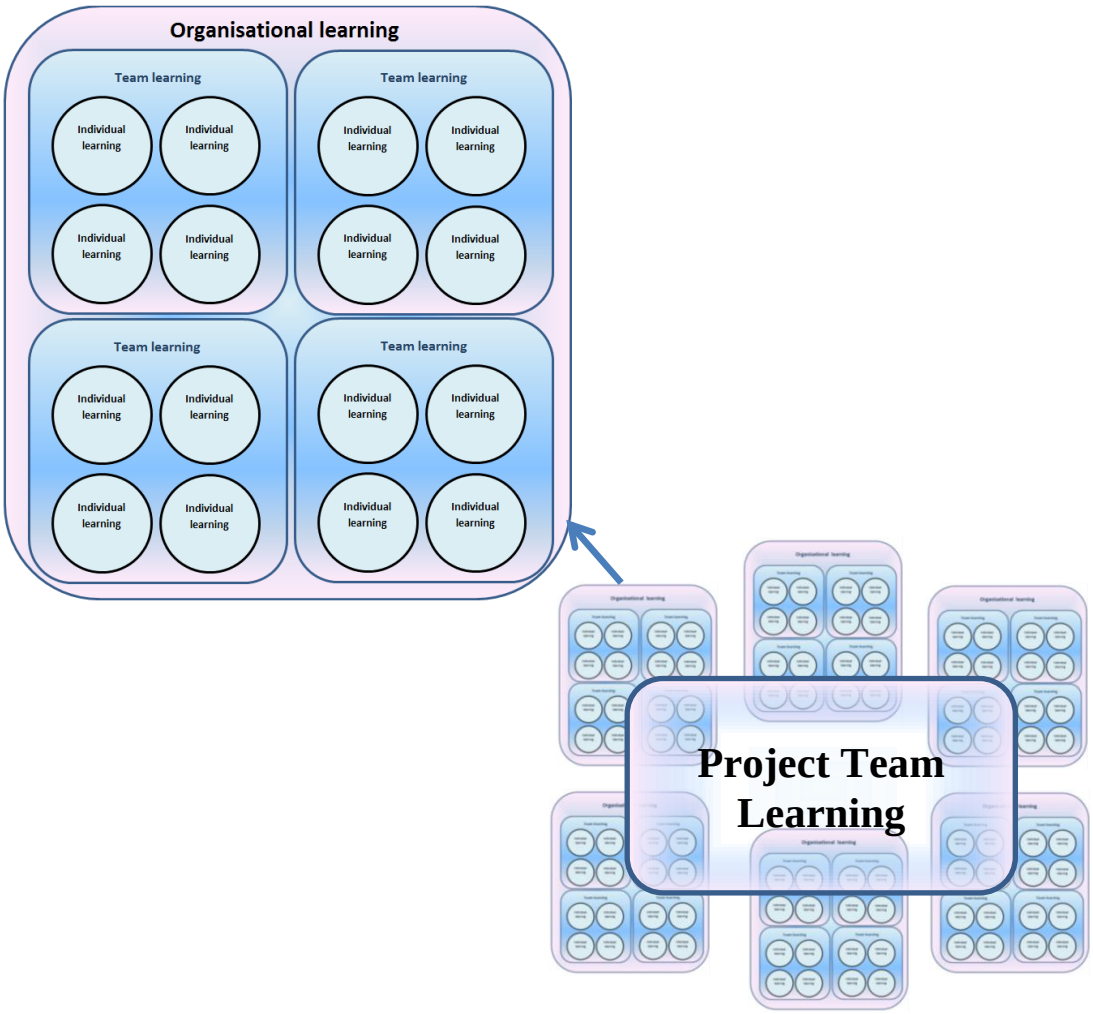

Figure 1: Project team learning

This multi-disciplinary and inter-organisational level of team learning is an additional level of complexity to organisational learning but important for corporate memory (Fruchter and Demian, 2002). For example, specialist mechanical and electrical sub-contractors with the ability to use BIM will do so but they indicate that there are limited benefits to sharing this knowledge outwith the organisation beyond operational requirements.

METHODOLOGY

Mapping Organisation Current Practice

Decision mapping and knowledge elicitation techniques were developed and applied to the Dundee Waterfront to identify key factors relevant to successful project management, enabling the Waterfront Project Team to understand current practice. A number of authors have effectively used decision mapping or knowledge mapping to document, understand organisation knowledge management and decision making (Snowden 2000; Driessen 2007; Yasin and Egbu 2010). The knowledge elicitation and mapping methodology utilised a combination of techniques drawn from the information technology, knowledge management and business process mapping fields. The detailed knowledge elicitation and process mapping methodology to identify and classify knowledge and identify Knowledge Disclosure Points has been reported previously in Gilmour *et al*. (2013)

In this study an Organic Knowledge Management approach (Snowden 2000) was adopted to elicit and categorise knowledge. This approach recognises that one cannot map knowledge without understanding of the process (Egbu 2006; Yoo 2007). Snowden (2000) terms these as Knowledge Disclosure points (KPDs) such as decisions, judgements, problem resolution or learning. The process mapping concepts have been used, together with Snowden's Organic Knowledge Management linguistic framework, to develop a technique which allows the Knowledge Disclosure Points to be identified during each process of all stages in infrastructure development.

Mapping was undertaken by interviewing key individuals responsible for a task or process. These individuals are termed 'process owners' and have a deep understanding of the phase of infrastructure or process under investigation. Process Maps were developed with the process owners during the interviews which were tape recorded for accuracy of the records. Maps were developed and subsequently verified through a series of interviews with each participant. Each of the interviews built up a set of process maps and associated Knowledge Objects based on Knowledge Disclosure Points.

The outputs of 12 interviews provided an understanding of the flow of information between the Waterfront Team and the City Engineer which is not only important in reporting and approvals but also for sharing knowledge and project learning. The interviews identified that project feedback, design reviews and experience sharing are ways where project learning is activated. The monitoring and reporting of sustainability provides the mechanism for project learning through KPI and Benchmark Indicators. These indicators feed into contract KPI and Service plan KPI at divisional level. They also feed into the Environmental Management System for the division. Experience is shared between team members but also with the City Engineer who has an understanding across all contracts and activities at the divisional level. The project learning process is illustrated together with the sustainability knowledge flow through project and management and reporting structure in Figure 2.

The findings of the mapping supports the literature in relation to the potential for knowledge management to demonstrate current practice, improve decision making and support sustainability enhancement. The wider implications of the findings of knowledge map can be related to the current work that emphasises the requirement for an effective mechanism to manage and reuse the knowledge created in projects such as discussed in Tan *et al*. (2012) and Leblanc and Thompson (2012). The case study has also illustrated the use of knowledge management in accelerating learning to develop expertise and improve processes affecting planning and design development, construction and operational aspects as discussed in work by Robinson *et al*. (2011).

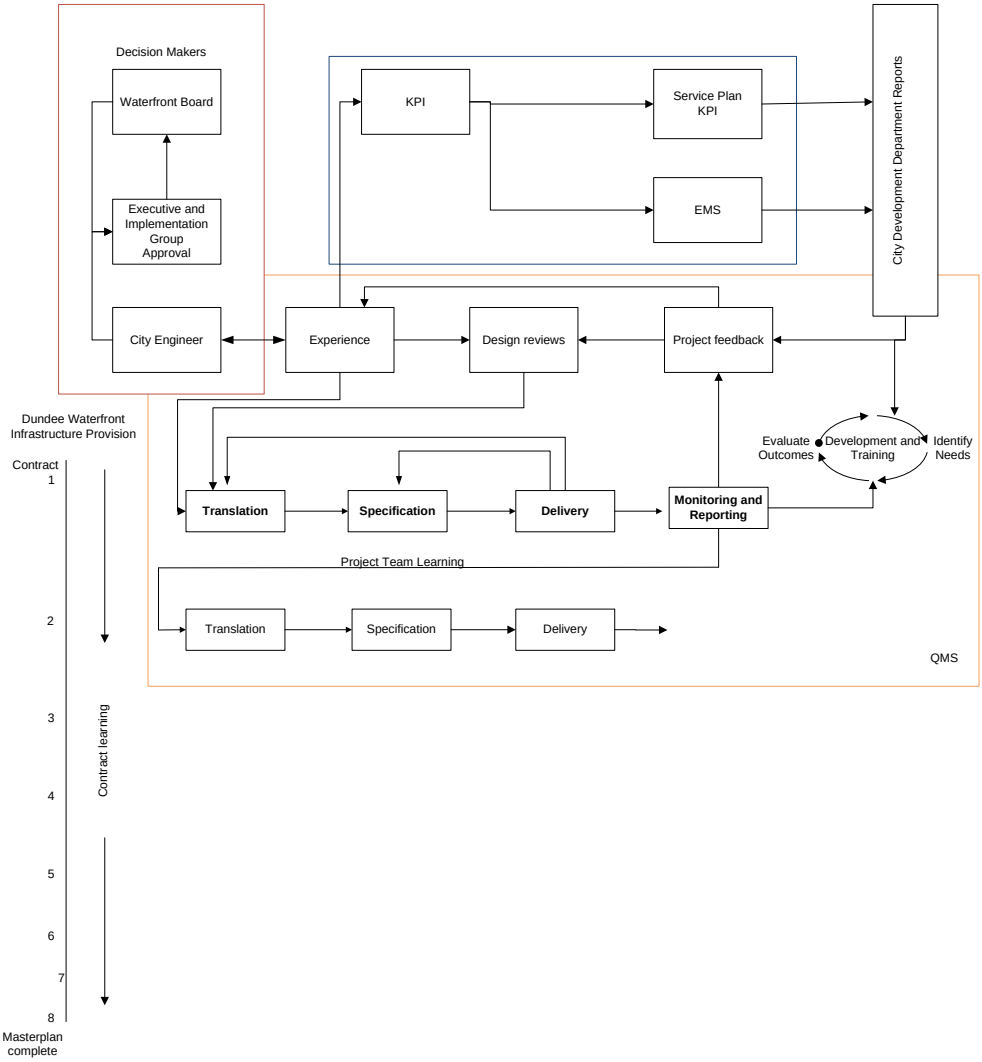

Figure 2: Project learning process of a major long term development

Contractor Interviews

Six further interviews were undertaken to establish the experience of design team participants contractors and subcontractors in relation to developing their BIM knowledge and skills. The team used thematic analysis (Braun and Clarke 2006) as a method for identifying, analysing, and reporting patterns (themes) within data based on a sample of semi-structured interviews covering an experienced client rep; an experienced contract manager with responsibility for contracts across Scotland for a large contractor, a very experienced project manager who is close to retirement, a groundworks sub-contractor, and two different mechanical and electrical sub-contractors. The main themes identified during the interviews are shown in Table 1.

Table 1: Themes

	Individual benefits	Organisational benefits	Influence other team members	Uncertainty
Client rep	X	X		X
Contract Manager	X	X		X
Project Manager		X		X
Groundworks SC	X	X		X
M&E SC 1	X	X	X	X
M&E SC 2	X		X	X

RESULTS

The theme of individual benefit through continuous learning and career development was recognised by the professionals interviewed and by organisations within their staff development processes as a part of maintaining competitive advantage, confirming previous studies (Bhargav and Koskela 2009). Due to the fragmented nature of the industry and the nature of project team formation with each unique construction project creating knowledge for individuals any knowledge, even explicit knowledge, does not automatically transfer to future projects. Information and communication technologies offer potential solutions (Bhargav and Koskela 2009; Ruikar *et al*. 2007) and the thematic analysis results identified expectations that BIM can provide organisations with a partial solution to capturing explicit project knowledge with the potential to access tacit knowledge as a project develops (Zhao *et al* 2013), indicating that tools used to capture corporate memory such as BIM may be effective (Demian and Fruchter, 2006). Ho, Tserng and Jan (2013) proposed a BIM-based Knowledge Sharing Management (BIMKSM) system for project managers and engineers that they applied in Taiwan. Their research identified a number of limitations within their single case study, including the time required to extract and codify knowledge within the model and the inability to keep the model updated. Lin (2014) also identified BIM within a case study as having the potential to capture tacit knowledge with similar results. A common feature of both studies was that mechanical, electrical and plumbing design engineers demonstrated a leading role in sharing their use and knowledge of BIM. This was replicated within the Dundee Waterfront at this time with BIM being used by the mechanical, electrical and plumbing design engineers, having a positive impact on the projects within which they work and engaging others with their practice in relation to, for example, clash detection. Such evidence reinforces the assertion that project team learning will be successful in making more tacit knowledge visible in practical situations where BIM can be applied throughout the entire team.

The individuals and the knowledge they create are critical features for improving business performance and ultimately for collective learning; organisational culture, the application of technology and leadership are the three most important factors for influencing the success of Knowledge Management (Loforte Ribeiro 2009). Whilst Knowledge Management is important in the construction industry there is an unrecognised gap between rhetoric and reality in relation to expectations of technology (Esmi and Ennals 2009). This may be partially explained by the fact that

the culture of the construction industry is still predisposed to providing protection of knowledge (Keeble Kululanga 2009) and this creates uncertainty in relation to level of involvement and knowledge sharing with others as well as their organsiation. Knowledge Management is not only a technical problem but a socio-cultural problem involving motivating people to make them willing to give up knowledge for organisational or project use (Robinson *et al*. 2005).

Using a Communities of Practice (CoPs) approach through BIM, project participants and engineers have the opportunity to get an overview of available knowledge in core project areas and take appropriate management in tacit and explicit knowledge (Lin and Lee 2012). CoPs are intra-organisational and an investigation of 57 CoPs from major European and US organisations identified the factors affecting success and failure in relation to sharing of knowledge (Probst and Borzilla 2008). The failure factors can explain why it is so difficult for a project team to achieve shared learning. The relevant failure factors included the low level of one-to-one interaction between team members and, where members trust their own competences they can be less willing to integrate practices originating from other CoP members into their daily work. These are typical features of the large waterfront redevelopment project. Project leaders have to deal with the challenges presented by the fast pace of not just organisational change but the project environment requiring skills to help them and their teams to interact more from shared experience emerging out of collective engagement (Vince 1998).

The difficulty for the Dundee Waterfront Redevelopment is that not all project participants or organisations are currently using BIM. Construction project teams do not transfer team learning to the organisational level as a collective body because the construction project team setting does not facilitate such a formal relationship between the project team and the organisation (Seneratne and Malewana 2011). There are examples, within the Dundee Waterfront Redevelopment where members of the client organisation, a major mechanical and electrical contractor and some contractors have experience and are currently using BIM, the adoption is for each organisation's own benefits. In examining the reasons why the mechanical and electrical contractor is taking a lead in BIM it became evident that this international organisation had a strategy of adopting BIM and had internal case studies demonstrating the benefits to the organisation of using BIM where possible. This specialist contractor had identified sound commercial reasons for adopting BIM where possible irrespective of contractual requirements. Until contractual requirements for all the team organisations to engage with BIM are in place the project team is currently limited to no more than a fragmented approach to shared learning on BIM as shown in Figure 3.

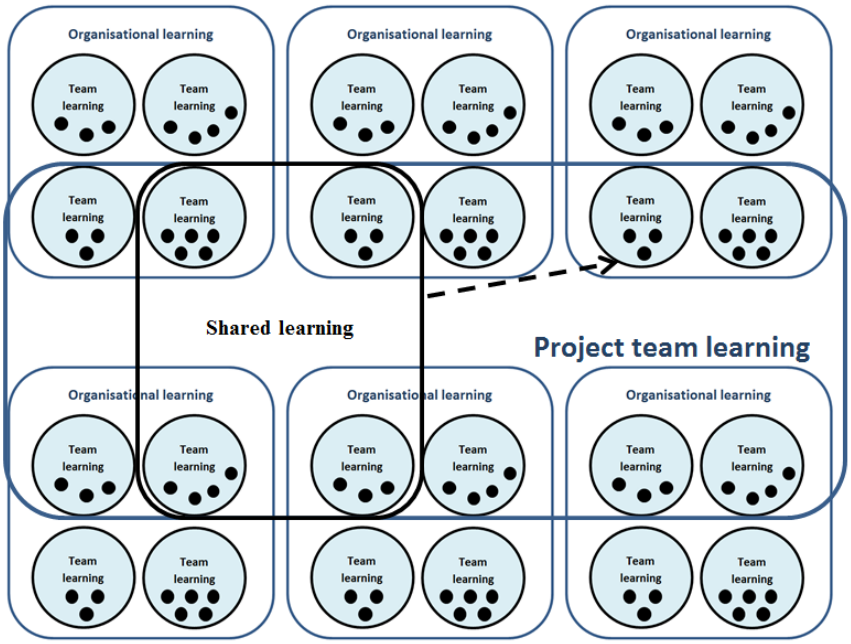

Figure 3: Fragmented project team learning

CONCLUSIONS

Project team learning is a complex process involving the interaction of numerous factors influencing individual learning, team learning and organisational learning. Capturing explicit knowledge is considered achievable through recognised organisational processes and procedures; capturing tacit knowledge has proven to be elusive although there is evidence that BIM may be one approach to address this issue. Knowledge Management has the potential to help understand and then facilitate greater participation amongst stakeholders in project team learning. The research team undertook decision mapping and knowledge elicitation techniques and applied these to the Dundee Waterfront and knowledge mapping techniques successfully identified current practice. The effectiveness of project team learning in relation to BIM within this long-term major redevelopment is influenced by positive motivational drivers for individuals to learn how to use and apply BIM, the level of organisational support for learning and professional development and the project information and communication systems. In practice the current approach to sharing of knowledge within the project team indicates a fragmented approach in relation to the adoption and application of BIM to managing construction projects. Within large project teams with constantly changing participants the adoption of BIM within the Dundee Waterfront redevelopment has had limited impact on encouraging learning of BIM across the project team. At the current time, where choice permits, those organisations leading the use of BIM have identified commercial benefits and are encouraged in the adoption and use of BIM by strategies for developing the individual skills and knowledge of their staff with the intent of providing the organisation some competitive advantage.

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