A BIM-Enabled Learning Environment: a Conceptual Framework

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Abstract

Purpose – Creating a BIM-enabled learning space that spans both higher education and industry offers the possibility of immersive and integrated learning on the basis of real, up-to-date project data for a new generation of students who will be "BIM natives" and can "think in BIM". This paper aims to elaborate the concept of BIM as a learning environment so that it can be produced for Architecture Engineering Construction (AEC) educational purposes.

Design/Methodology/Approach – The complementary theoretical lenses of Experiential Learning, Structuration Theory and Systems Theory are adopted for conceptualising a BIM-enabled Learning Environment (BLE).

Findings – The BLE is proposed in the form of a social system embedded within both the education system and the industry system. The BLE is described in terms of its structures and component subsystems, inputs, outputs and flows at different scales.

Research Limitations/Implications – In this initial paper, the BLE is merely outlined and its constituent structures alluded to. Further investigation is required to fully detail the BLE.

Practical Implications – By describing the identified structures in still more detail, the BLE can be understood to the extent that it can be reproduced in practice for actual learning. This is the goal and expectation going forward.

Originality/Value – The derived BLE is described in social terms and this reflects the centrality of social activity to both building and learning. Technology, processes and traditional industry roles are subordinated into supporting functions. This potentially offers opportunities for learners to reflect on all of these and to consider ways of improving them.

Keywords BIM-enabled Learning Environment, Building Information Modelling, Construction, Education, Experiential Learning, Structuration Theory

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1. Introduction

The development of Building Information Modelling (BIM) education for architecture, engineering and construction (AEC) professionals has tended to lag industry BIM deployment (Forgues & Beceric-Gerber, 2013; Lee *et al.*, 2013). Underwood *et al.* (2013) conceptualise the evolution of BIM education in three progressive stages as: BIM-aware, BIM-focused and BIM-enabled. The overall aim of this research is to operationalise "BIM-enabled" learning. Creating a common learning space that spans both higher education and industry offers the possibility of immersive and integrated learning on the basis of real, up-to-date project data, a new generation of students who are "BIM natives" and who can "think in BIM" as well as continuity between degree studies and professional development.

"BIM-focused" learning, where the emphasis is on learning BIM ways of working, software skills, etc., has already been incorporated into many AEC programmes globally (Gerber *et al.*, 2015). In contrast, BIM-enabled learning assumes BIM skills and processes are already largely acquired, and it leverages them to enhance all aspects of AEC learning from fundamental concepts to systems building, management and multidisciplinary collaboration. In an earlier study reviewing the BIM education literature, it was found that existing examples of BIM-enabled education could be categorised into two groups:

(1) where traditional learning processes are enabled through the deployment of some aspect(s) of BIM – i.e. BIM as a learning tool;

(2) where learning takes place within a BIM context, e.g. in the sense of BIM providing a common platform for communication and / or where BIM work flow processes are adopted – i.e. BIM as a learning environment (Witt and Kähkönen, 2019).

The purpose of this paper is to elaborate the concept of "BIM as a learning environment" so that it can be studied and also produced and reproduced for learning to take place within it. In the following sections of the paper we provide a synopsis of the theoretical foundations and their implications for what we have termed the "BIM-enabled Learning Environment" (BLE). We then present our proposed model of the BLE at different scales together with explanatory commentary. The paper concludes with recommendations for data collection towards refining and validating the BLE.

2. Theoretical Basis

We have adopted Experiential Learning Theory, Structuration Theory and Systems Theory as theoretical lenses. However, the starting point of our argument lies in the ideas of the pragmatist philosopher and educational reformer, John Dewey who noted the following:

- Education is for social life what nutrition and reproduction are for physiological life. It is the means of transmission and conservation of (the more desirable aspects of) society through time.
- Environment is essential to education – "We never educate directly, but indirectly by means of the environment".
- This educational environment is a social environment. It may be a chance environment in everyday life, or, as society becomes more complex, and then formal education is called for where a simplified, ordered, purified and idealised special social environment deliberately regulated for its educational effect is provided to learners.

- Education primarily entails transmission through communication but telling and being told, while important, are insufficient, as education is ultimately an active and constructive process. Thus, the educational environment must also be equipped with the necessary agencies, tools and materials for doing (Dewey, 1916).

2.1. Experiential Learning Theory

Kolb's Experiential Learning Theory draws on the work of Dewey (as well as others), and it emphasizes the primacy of real, concrete experiences in the learning process (Kolb, 1984). In focusing on experience, Kolb embraces the importance of environment to learning: "Experiential learning is...the central process of human adaptation to the social and physical environment" (Kolb, 1984).

Experiential Learning introduces the concept of "Learning Space" which elaborates the transactions between learner and environment and Kolb & Kolb (2005) note that "the enhancement of experiential learning ... can be achieved through the creation of learning spaces that promote growth-producing experiences for learners". "Learning Spaces" appear to be physical, i.e. they exist in physical space-time (particularly in the sense of "allowing time for"). However, they also extend beyond physical space–time and are closely bound with Dewey's ideas of simplification, ordering, purification, idealisation and regulation of the learning environment as we can infer from the following list of Learning Space categories delineated by Kolb & Kolb (2005):

- creating and holding a hospitable space for learning and
- making space for
  - conversational learning;
  - development of expertise;
  - acting and reflecting;
  - feeling and thinking;
  - inside-out learning (by linking educational experiences to the learner's interests); and
  - learners to take charge of their own learning.

In the context of a learning environment, such as our proposed BLE, Learning Space allows for the mediation of the "real world" environment (that can be experienced) to enhance the learning process.

2.2. Structuration Theory

Structuration Theory is Anthony Giddens' social science meta-theory aimed at understanding social systems. (Orlikowski, 1992) In *The Constitution of Society: Outline of the Theory of Structuration*, Giddens explains the theory as follows:

Social systems are the "reproduced relations between actors or collectivities, organized as regular social practices". *Structures*, in relation to social systems, are the systems' enduring aspects. They are the properties, the rules and resources or sets of transformational relations, which allow similar social practices to be reproduced across time and space and which give them the form of systems. *Structuration* refers to the "conditions governing the continuity or transmutation of structures, and therefore the reproduction of social systems" (Giddens, 1984 p.16–25).

A key proposition of Structuration Theory is the *duality of structure* - that the rules and resources drawn upon to produce and reproduce social systems are, at the same time, the means of system reproduction (Giddens, 1984 p.19). In other words, the structural properties of social systems are both the medium of the social activities they organise and also their outcome. Structure does not only constrain social activity but always also enables it (Giddens, 1984 p.25).

We have already established (from Dewey [1916], above) that our BLE is a social environment. A Structuration Theoretical perspective suggests that we can describe this environment in terms of the structures which allow it to be produced and reproduced in social activity. By adopting this perspective, we consider our BLE to be a social system with both BIM and learning as fundamentally social activities, and we seek to identify and understand the nature of the structures which are associated with it through both the fragmentary accounts of participant actors as well as our own observations in order to better define / describe the BLE and understand how learning can take place within it.

Giddens distinguishes between three structural dimensions of social systems – structures of signification, domination and legitimation. Consideration of these, in turn, illustrates the (considerable) scope of the social system that is the BLE.

Examples of structures relevant to the BLE:

Structures of *signification* give meaning to the system. They relate to the symbols and codes of the system and allow human actors to make sense of interactions (Rose and Scheepers, 2001). Examples applicable to the BLE include the following:

- learning rules and resources – education institutions' organisational structures, learning outcomes, assessment strategies, credit system, professional qualifications standards, time / space / staff / equipment allocations, etc.;
- BIM rules and resources – BIM workflows, BIM communication protocols, industry project data, model view definitions, levels of development, IFC, etc.; and
- industry rules and resources – industry needs for graduates, ways of working, etc.

Structures of *domination* relate to hierarchies and the power to allocate resources within the system

- professional roles;
- instructor / learner roles;
- curriculum / module / learning outcomes / learning activity structures; and
- procurement and contractual arrangements including their principal / agent roles in industry.

Structures of *legitimation* relate to the regulation of that which is and isn't acceptable within the system:

- educational and professional ethics, codes of conduct; and
- legislation, regulation, building codes, etc.

2.3. Adaptive Structuration Theory

The power of Anthony Giddens' Structuration Theory in the analysis of empirical situations of information technology adoption in organisations has been thoroughly demonstrated (Rose and Scheepers, 2001). Orlikowski (1992), DeSanctis and Poole (1994) and others have extended Structuration Theory in this particular empirical context and formulated Adaptive Structuration Theory (AST). Reflecting Giddens' duality of structure concept, Orlikowski (1992) also advances a "duality of technology" proposition – that technology is both

- created and changed by human action; and
- used by humans to accomplish some action.

In AST, structures are considered identifiable in both organisations (in human actions as people interact with technology) and in technologies as structures that are embedded within the technologies themselves (i.e. in their design). AST considers how these two types of structures shape each other in the mutual influence of social and technological processes (DeSanctis and Poole, 1994).

2.4. Systems Theory

We have broadly established that our BLE is a social system that can be understood and described in terms of structures. Its constituents are people, activities and resources and it combines BIM and learning processes, "real" BIM-based experiences and "learning space". "Systems thinking" helps us to articulate this BLE as it provides a framework for identifying interrelationships rather than objects, and patterns rather than snapshots in time (Senge, 1990). From the systems viewpoint, emphasis is on the relationship between the system under consideration and its external environment. System inputs are drawn from the external environment, are processed, and the resulting outputs are sent back to the environment. In exploring this relationship, the main inputs, processes, outputs and feedback are contemplated (Kefalas, 2011).

In a way similar to the depiction of the built environment by Moffatt and Kohler (2008) as a socio-ecological system in the zone where nature and culture overlap, we can conceive of our BLE as a system in relation to the overlap between the educational system and the AEC/Real Estate industry system on the other (Figure 1). As is typical of systems, this macro-level BLE system is comprised of numerous, nested subsystems (Kefalas, 2011).

3. Conceptualisation of the proposed BLE

3.1. Overview of the BLE at the macro scale

The BLE is a system embedded within both the wider education system and the AEC and real estate (AEC+RE) industry system. The "experiential learning subsystem" is

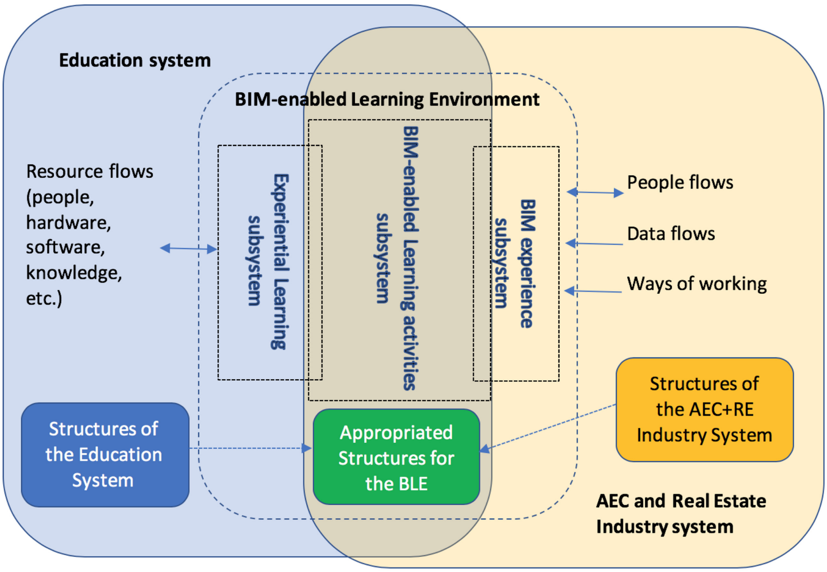

Figure 1. The BIM-enabled Learning Environment (BLE) within the Education and Industry Systems

predominantly influenced by the structures of the education system (e.g. curriculum requirements, qualification standards, resource allocations, etc.), whereas the "BIM experience subsystem" mainly reflects the structures of industry (in terms of its real project data, work flows, roles, etc.).

Structures of both education and industry must be appropriated to create the BLE. The emergent structures of the BLE combine both. For example, BLE roles must make sense both from the BIM work flow / industry point of view (e.g. construction manager, BIM coordinator and architect) and also from the education point of view (e.g. learner and instructor).

The "BIM-enabled learning activity subsystem" overlaps both the BIM experience subsystem and the experiential learning subsystem. It adopts the work flows, real project data, etc. from industry and it provides the necessary learning space for reflection, discussion, context simplification, acquisition of requisite knowledge and skills, etc. to ensure that the focus is on learning, not just on doing.

Resources flow between the BLE and the systems in which it is embedded. These include

- people flows, e.g., subject specialists, learners, instructors move in and out of the BLE from the education system, mentors and graduates between the BLE and industry;
- data flows, e.g., subject and learning data flow between the BLE and education system, project data flows in from industry; and
- other flows, e.g., educational resources from the education system, ways of working from industry.

3.2. The BLE at the meso scale

If we "zoom in" on the BIM-enabled learning activities subsystem in Figure 1 to reveal additional detail, the central feature is a series of learning activities (Figure 2).

An idealised BIM work flow (from industry and shown in grey) provides the basis for the learning activities. The learning activities are "real" industry tasks informed by both educational and industry system needs and carried out in a simulated "real" context. Learning activities are both "experienced" and "used for learning" (reflected upon, etc.), and they are sequential in that they build upon each other incrementally. Learning activities' later usefulness as inputs into subsequent activities should inform their assessment.

Learning space (for experiential learning) is provided in the sense of time and resources for reflection, discussion, etc. in relation to the learning activities so that task execution within the learning environment is (efficiently) transformed into knowledge.

At this level of detail, we can consider input data flows from both the educational system (assessment criteria, learning objectives, etc.) and the industry system (real project data, ways of working, etc.). The learning activities themselves also generate data (in the course of doing) and knowledge (in the course of learning) – so data and knowledge resources are progressively developed as activities are performed.

With regard to people, learners work in groups and roles with support from instructors (education system) and mentors (industrial system).

3.3. The BLE at the micro scale

Further magnification of the BLE concept to the scale of a single learning activity is shown in Figure 3.

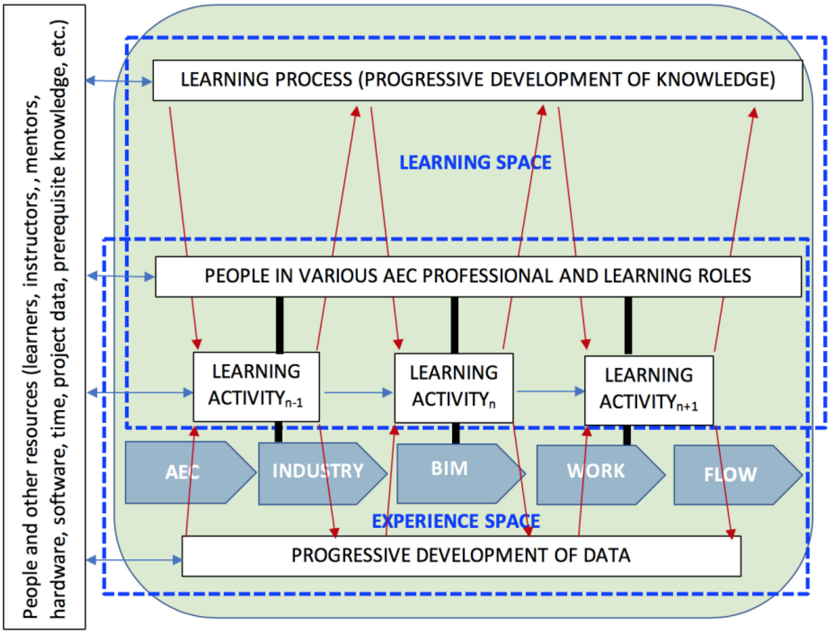

Figure 2.
The BIM-enabled Learning Activity Subsystem (BLE Meso Level)

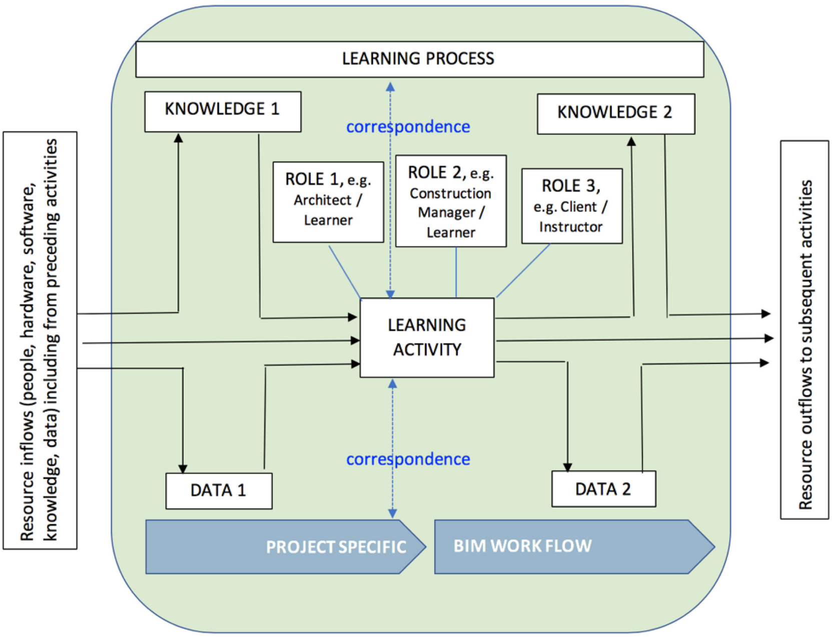

Figure 3.
The BLE at the Scale of a Single Learning Activity

The learning activity corresponds with (i.e. is drawn from, is relevant to, etc.) both the industry BIM process and the overall learning process (which is bound up with the education system).

Being able to successfully carry out this activity reflects on the adequacy of the inputs and preceding activities and provides a means of assessing the preceding activities. Individuals' roles in carrying out the activity reflect those in the industry BIM process and in the experiential learning process.

Knowledge acquired from preceding activities and other prerequisite knowledge is input. Data generated from preceding activities and any other required data (e.g. project data) is also input into the activity along with all other resources (hardware, software, time, etc.) necessary to carry out the activity.

In terms of outputs, carrying out the activity furthers the learning process and thus generates knowledge. Data generated in the course of carrying out the activity is used in subsequent activities and the utility (usefulness) of the information generated for future activities feeds into the assessment of this activity's success.

6. Conclusions

We have tentatively outlined a BLE describing it in terms of Experiential Learning Theory, Structuration Theory and Systems Theory as a social system embedded within the education and AEC+RE industry systems. Using this theoretical perspective and conceptualisation, we can describe it in detail in terms of its structures. These structures emerge as we appropriate the structures of the education system and the AEC+RE industry system into the BLE. They provide us a means by which we can create the BLE.

To further our enquiry, we propose to systematically

- identify and describe the structures of the AEC+RE industry system that are relevant to the BLE (i.e. the system properties that provide the authentic, industry "BIM experience"); and
- identify and describe the structures of the education system that are relevant to our BLE (i.e. the system properties which are required for the BLE to provide a legitimate learning experience).

We can then attempt to combine these structures to describe an initial version of the BLE and, thereafter, use the defined structures as variables for continuously improving the BLE as it is produced and reproduced.

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