Problem-Based Learning: Enhancing Students Learning of Building Information Modelling

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Abstract
Building Information Modelling (BIM) is an innovative collaborative process underpinned by digital technologies introduced to improve project performance in the Architecture, Engineering and Construction (AEC) industry. Growth in industry demands has necessitated BIM inclusion into the Higher Education (HE) curricula as both a pedagogic and practical objective to prepare and develop aspiring Built Environment (BE) professionals with the required competence for contemporary practice. However, comprehension of BIM concepts and developing the skill set required for its application can be overwhelming for students and crucial to mitigating this challenge is the adoption of appropriate learner-centred strategies. Problem-based Learning (PBL) is becoming a widespread strategy to address such concern. This paper evaluates the impact of PBL strategy on students accelerated learning of BIM based on a case study of an undergraduate BIM module. Findings from the study show PBL benefits on students' knowledge acquisition (cognitive and affective) of BIM concept and development of transferable skills (academic and disciplinary) equipping them with capabilities to become BIM competent and workplace ready for the AEC industry.

Keywords: Building Information Modelling, Problem-based learning, Built environment undergraduate students

1.0 Introduction

Building Information Modelling (BIM) is an innovative collaborative process underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining building assets (Blackwell, 2012; Eastman et al., 2012). It was introduced in the Architecture, Engineering and Construction (AEC) industry to improve project performance and encompasses a wide range of concepts, tools and workflows employed to create and manage all of the information on a project – throughout the project lifecycle (Succar, et al., 2012). This background suggests that technical competence alongside effective collaborative skills to project delivery instead of specialisation is a core employability skill set required to work in a BIM project environment successfully. Therefore potential BE graduates need to gain awareness and understanding of the required technological and organisational requirement relevant to successfully apply BIM project environment in the AEC industry.

BIM inclusion into the BE curricula is both a pedagogic and practical objective to develop and prepare future BE professionals for contemporary industry practice. Underpinned by authentic practice, it encourages learning strategies that thrive in a multidisciplinary environment (Luo and Wu, 2015). Surprisingly, the lecture-based strategy seems to be the most predominant model for teaching BIM in many Higher Education Institutions (HEI) particularly in the early years of study. This pedagogy model with linear and fragmented teaching presentations have been criticised for depriving students of the opportunities for learning the holistic nature of a discipline hence, inefficient to assist students developing the prerequisites for professional expertise (Chinowsky et al. 2006; Forsythe, et al., 2013). Models on teaching strategies such as the Learning pyramid model have highlighted teaching others and practice by doing teaching strategies as most effective, to promote 75-90 per cent of learning retention in students, while lecture and reading promote only 5 - 10 per cent, retention (Url , 2014 cited in Yildirim, et al., 2014). Therefore to improve students' learning curve on BIM, practice by doing teaching strategies such as Problem-based learning (PBL) can be explored.

This study explores the benefits of PBL as a practical and effective pedagogic strategy to cultivate student competencies and achieve learning outcomes (LOs) in line with institutional assessment requirements based on a case study of an undergraduate module on BIM and Data Management. The paper outlines the justification, procedure and benefits of PBL on student learning on BIM based on a case study of an undergraduate BIM module. The paper concludes by identifying the benefits of PBL on students' cognitive and soft skills development which is relevant to prepare them to become BIM-ready graduates. Results and findings of this research are expected to shed light on innovative teaching strategies for BIM curriculum delivery.

2.0 BIM Education Framework

BIM Education is considered a viable and sustainable approach to producing graduates equipped with the relevant knowledge and skillset required to generate BIM deliverables that satisfy defined project requirements (Succar et al., 2012). Globally, BIM Education is gaining wide acceptance and recognition in HEI. In the UK, BIM is taught in several universities at mostly at the postgraduate level although its inclusion at undergraduate levels is beginning to gain more grounds (Kocaturk and Kiviniemi, 2013; Mandhar and Mandhar, 2013). Many attempts have been made to develop frameworks for successfully integrating BIM into HE curricula across the AEC disciplines. A study by Silver Rodriguez et al. (2017) highlights some of these frameworks such as the AIACA, IMAC, Kumar's and the BIM Academic Forum (BAF) learning outcome framework. The BIM Academic Forum (BAF) learning outcome framework (Underwood et al., 2015) as shown in Figure 1 outlines expected learning outcomes for teaching BIM at the various level of HE study, and it is the most referred to in the UK.

LEVEL	Undergraduate			Post graduate
	4	5	6	7
Knowledge & understanding	• Importance of collaboration. • The business of BIM.	• BIM concepts – construction processes. • Stakeholders' business drivers. • Supply chain integration.	• BIM across the disciplines. • Contractual and legal frameworks/regulation. • People change management	• Collaborative working, BIM, information management and its application in the built environment. • Commercial implications – contractual/legal, etc. • De-risking projects through BIM and risk management. • Understanding nature of current industry practice. • Client value – soft landings. • Business value – RoI /value proposition. • Understanding supply chain management. • Lifecycle management of BIM – asset, performance in use, etc
Practical skills	• Introduction to technology used across disciplines.	• Use of visual representations. • BIM tools and applications. • Attributes of a BIM system.	• Technical know-how. • Structures and materials. • Sustainability.	• Demonstrate ability to adopt different platforms. • Critically judge/evaluate various BIM tools applications. • Protocols/interoperability/standards. • Capability evaluation. • Change in way projects are to be delivered. • Visualisation of large data sets. • Lean principles and links to BIM. • Use of BIM enabled technology, e.g. palm devices.
Transferable skills	• BIM as a process/ technology/people/poli cy.	• Value, lifecycle and sustainability. • 'Software-as-a-service' platforms for projects. • Collaborative working. • Communication within interdisciplinary teams.	• Process/management. • How to deliver projects using BIM. • Information and data flows. • BIM protocols/EIR.	• Project level application. • Cross discipline and team working. • Importance of effective communication and decision making – human interaction! • Process mapping and BPR. • Change management and cultural gap. • Masters level thinking – strategic/technical/ managerial. • Ability to assess barriers to BIM at various levels, e.g. corporate/project.

Figure 1: BIM Academic forum learning outcomes framework

Source: Underwood et al. (2015)

However, the content and procedure (what, when and how) for delivery are not clearly defined (Kocaturk and Kiviniemi, 2013). This vagueness posed unique challenges in BIM pedagogy (Boton et al., 2018) especially to BE students who argue in the light of BIM relevance to their disciplines (Leite, 2016). Consequently, studies by Shelbourn, et al., (2017), Barison et al., (2013) on BIM education, have espoused the need to adopt pedagogical practices effective for teaching BIM. They all share the ideology by Koltich and Dean (1999 cited in Shelbourn, et al., 2017), on the engaged critical model of teaching rather than the transmission model in BIM pedagogy. They argued that the engaged critical model allows students to develop a deeper level of understanding on a subject/topic by engaging in what is being studied. This engaged critical model promotes the use of teaching methods such as problem-based learning. This finding corroborates the Learning pyramid model. Therefore, it is important that BIM educators adopt practice by doing teaching strategies such as PBL in the delivery of introductory modules on BIM as it could significantly enhance students learning retention at the level required.

3.0 Problem-based Learning

In practice, young professionals need to possess the ability to analyse problems and provide potential solutions to them without losing sight of the whole picture (Yew and Goh, 2016). PBL is an approach to professional education that emphasises the use of real-life problems as a stimulus for teaching and learning bridging the gap between academia and practice (Smith, 2005). PBL is a model for classroom activity that shifts away from teacher-centred instruction to student-centered projects and promotes a learning environment where the problem drives the learning (Klegeris and Hurren 2011). It employs collaborative peer group work and problem-solving, as a vital tool for critical thinking and self-directed learning in a scenario that reflects real life situational settings (Loyens, et al., 2015; Fukuzawa and Boyd, 2016).

PBL, unlike other student centred instructional strategies, is more directed to the acquisition of knowledge because it does not define the expected outcomes of an investigation but promotes the learner's role in setting the goals and solutions for the set problem. Several studies have employed PBL in the delivery of modules in Civil Engineering, Construction Management, and Architecture disciplines (Ahern, 2010; Jefferies et al., 2012; Yildirim et al., 2014; Bridges, 2007). However, its use in teaching BIM modules, especially in BE disciplines, is rare. The ability to define the problem and develop or range of possible solutions is important in real-world context. Many undergraduate BE students undertaking a BIM module are not familiar with BIM. Hence, rather than imposing the knowledge it would be more effective to allow them to inquire into the cause of the problem and what could be the potential solutions. After that, the proposed solutions are discussed and linked with the purpose and benefit of BIM. The specific feature of the PBL displays its appropriateness to teaching introductory courses or levels where acquisition and not application based knowledge is required. Given that introductory modules are acquisition centric, the PBL appears most appropriate to support introductory modules on BIM learning outcomes which are aligned to the BIM education framework at the required undergraduate level.

The PBL procedure involves the tutor acting as a facilitator of the learning process; stimulating group discussions and monitors the level of engagement of the students in the groups. A PBL process as reflected by (Klegeris and Hurren, 2011 and Pastirik, 2006) involves:

- Tutor presents a problem scenario (often ill-defined and complex) to each group Students identify learning issues and possible sources of information.
- group formulate the best approach to research solutions
- Students engage in an independent study by gathering and analysing essential scenario information.
- Students meet in their small group to critically discuss the practical application of the information to the scenario.
- Groups share the findings of their research

- Finally, students critically reflect on the work undertaken (both contents learned and process).

This process empowers learners to conduct a constructive investigation, integrating theory and practice, and applying knowledge and skills to develop a viable solution to a defined problem (Savery, 2006; Yildirim et al., 2014). Consequently, students' cognitive elaboration, critical thinking, and collaborative skills are developed in the process. The remaining sections detail the PBL methodology and benefits in the delivery of an undergraduate introductory BIM module.

4.0 Case

This case study describes an undergraduate BIM module taught in the BE department at a university in the west midlands region of the United Kingdom. This introductory module on BIM was integrated into the BE curricula in 2016 and offered to Level four undergraduate students. Up to 90 students studying on construction management, building studies, quantity surveying, building surveying, property and real estate course where enrolled on the module. The multidisciplinary environment and the co-location of these disciplines allow optimisation of multi-disciplinary teaching and engagement requiring group collaboration to achieve learning outcomes (Wu and Luo, 2015; Glanz, et al., 2016). This module was designed to introduce students to:

- BIM concepts and tools,
- The rationale for BIM integration in construction project delivery
- Overview of BIM benefits for multi-disciplinary project professionals in the project environment
- Application of measurement principles using BIM tools.

By undertaking this introductory module, students are expected to be able to:

- (L1) Demonstrate an understanding of the generic concept of BIM and highlight commonly used tools
- (L2) Understand the benefits of BIM for multi-disciplinary project professionals in the construction project environment
- (L3) apply principles of measurement using a BIM tool
- (L4) demonstrate improved analytical, communication and collaborative skills which are relevant to work in a BIM project environment.

The module was initially designed to be delivered using lectures, tutorial and demonstration exercises. However, following the evaluation of past student performances suggested the need to improve students understanding especially on two key content areas:

- BIM as a collaborative process and not software,
- BIM relevance and benefits to their professional discipline within the construction environment.

As a way of improvement, the PBL model (based on its benefit) was introduced to deliver those topics aligned to learning outcome L1, L2 and L4. It was anticipated that the integration of the PBL model would help address these inherent issues identified. This case study is concerned with the development of context-dependent understanding on how PBL can accelerate students' learning curve on BIM at the required level. As espoused by Yin (2009) and Blaikie (2010) a case study allows an empirical inquiry on a contemporary phenomenon within some real-life context with the aim of developing some level of analytical generalisations. In this context, the impact of PBL teaching strategy on students understanding of BIM is examined as the unit of analysis.

4.1 PBL Integration in the Module Delivery

The PBL design of the topics was constructively aligned with the learning outcomes of the module. Two PBL learning scenarios were developed to encompass these topics. The problem scenarios were designed to be inclusive and relevant to all disciplines and mirror real professional practice in BIM project environment**.** Students were encouraged to draw from their diversity and disciplinary knowledge in the task. The incorporation of these multiple perspectives was used to inspire them to take ownership of their learning process. The students were divided into eight groups of seven members each and given autonomy to determine their own grounds rules and allocate member roles. Each team was required to maintain a communication platform, available to them but upload their findings via the school website platform which should be updated weekly. This was set up to promote better management of documentation and information exchange within the groups. Each learning scenario took two weeks to complete. The session for the four weeks was designed to have a 40-minute lecture, 20-minute class discussion and 2-hour group discussion and one hour for groups to present their findings and progress to the class. The PBL specific design for the session is depicted in Figure 2.

Session	**Design**		
Methods	Lecture	Class discussion	Problem-solving
Main facilitator	Tutor	Tutor and students	Students
Purpose	Provide a basic knowledge of the principles and concepts understudy	Provide a platform for questions and answer to clarify any queries	Engage in the problem solving and proffer a potential solution to the problem scenario
Outcome	Overview of basic principles and concepts understudy	Comprehension of information provided	Demonstrate acquisition of knowledge

Figure 2: PBL model

Students were orientated on the PBL process and assessment criteria. The study employed formative, summative and survey to assess the impact of PBL on students learning of BIM in the module. The PBL methodology as detailed in section 2 was adopted, and the approaches employed to assess the impact of PBL on students' level of knowledge of BIM in line with the learning outcomes are summarized in Table 1.

Table 1: Assessment design

	Learning outcomes	**Teamwork (interaction and Presentation)**	**Technical report**	**Survey**
L1	Demonstrate an understanding of the concept of BIM and highlight commonly used tools	√	√	√
L2	Understand the benefits of BIM for multi-disciplinary project professionals in the construction project environment	√	√	√
L4	Demonstrate improved analytical, communication and collaborative skills in an appropriate format	√	√	√

Source: Compiled by Authors

4.2 Assessment Outcomes and Discussion

Students understanding of BIM concepts, relevance to their professional discipline and development of skill set (communication, collaboration and analytical skills) at the level required where measured using the assessment design detailed in Table 1. The study reveals that PBL has a positive impact on students learning the process as evident in the team interactions, technical reports and survey results.

4.3 Teamwork (interactions and presentation)

This theme assessed the level of teamwork employed in the process of arriving at the group results presented to the class. It assesses students' ability to collaborate and communicate the findings of their research. During the PBL process, students were involved in a series of discussions and brainstorming exercises in class and through online group chats which gave room for constructive criticisms from both team and disciplinary perspectives. These interdisciplinary and interactive features fostered team spirit within the groups which was evident in their final presentation and reflections. An understanding of the importance of collaborative skill is a key threshold concept underpinning BIM which the students could now readily embrace. Findings from this case validate previous findings on the benefit of PBL on the development of collaborative and communication skills espoused in previous studies (Klegeris and Hurren, 2011; Pastirik, 2006).

4.4 Technical reports

Their technical report submissions demonstrated high-performance competence in students understanding of BIM and relevance to discipline at the level required. Assessment outcome from their submission showed a 98 per cent pass rate and with students' average performance above 80 per cent in comparison with previous years. This performance indicates that the level of engagement and delivery was much enriched using the PBL. These findings agree with previous studies (Klegeris and Hurren, 2011; Fukuzawa, and Boyd, 2016; Loyens, et al., 2015) on the benefit of PBL in the student learning process.

4.5 Survey

Survey exercises were conducted during and upon completion of the module. During the module delivery, students were requested to identify the key things that were positive about the module and offer constructive feedback on potential areas of improvement. Many corroborated that the style of teaching (PBL) was very interesting and engaging which significantly helped in understanding the relevance of BIM from a disciplinary and a construction industry perspective.

Upon completion of the module, 37 students agreed and participated in a questionnaire survey. The respondents were requested to rate on a five-point Likert scale, ranging from "very high impact " to "no impact", the level of impact of PBL on questions related to their understanding of BIM and development of analytical, communication and collaborative skills. Prior to the study, ethical approval was granted through a University ethics board.

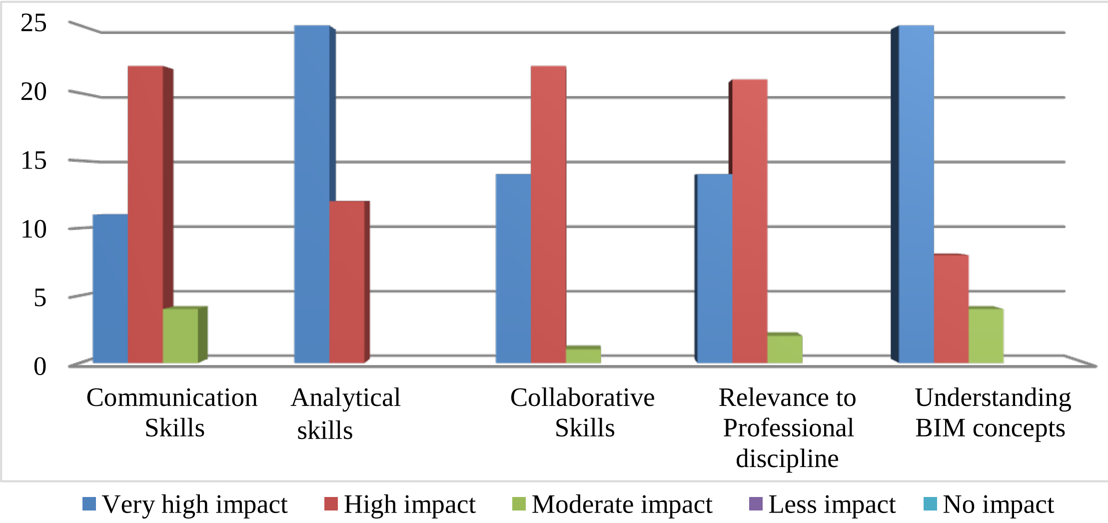

Figure 3: Results on the Impact of problem based learning on student learning curve

The results show that over 85 per cent of the students agreed that PBL significantly impacted on their learning process. The outcomes of the analysis indicated that PBL was very significant in helping students develop understanding in the subject area of BIM and develop cognitive, communication and collaborative skills relevant to prepare them to become BIM-ready graduates for practice.

Conclusion

Accelerating the learning curve for the development of relevant knowledge, skills and competencies required to operate successfully in a BIM project environment is essential integrated HE curricular for BE disciplines, and PBL is often advocated as an appropriate strategy in this regards. This study employed the PBL pedagogical principles and methodology to examine its impact on students learning of BIM and developing the cognitive and required skill set relevant to function in a BIM project environment. The study creatively positioned the learning outcomes in alignment with the model assessment design. The results of this research showed significant growth in students' knowledge and understanding (cognitive and affective) of BIM as well as the practical and transferable skills (presentation and communication and collaborative skills) at the required level in comparison to previous years. This study provided a timely example of the potential benefits accrued from applying PBL in BIM modules to enhance student learning and skill development to function within a BIM project environment. Future studies will seek to integrate PBL holistically in the delivery of the undergraduate BIM module to measure its effectiveness. Finally, the research findings have several implications for BIM educators in HEI to cultivate desired BIM competency (Knowledge and Skills) of the future BE graduates. It is recommended that future studies adapt the methodology as applied as a platform to investigate PBL benefits using a case study of postgraduate BIM modules.

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