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ASSESSMENT STRATEGIES FOR BUILDING INFORMATION MODELING SKILLS IN PROBLEM-BASED LEARNING PEDAGOGICS

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Abstract: Preparing students with the knowledge of Building Information Modeling (BIM) may be critical for advancing the construction industry in the future. Educational researchers have explored various pedagogical models for teaching students about BIM. One potentially promising pedagogy for BIM education is problem-based learning, as it presents BIM in a context that may effectively simulate a real-world scenario students may expect to experience in their careers. This paper explores how prior research efforts have used problem-based learning to educate students. The results will help to inform future BIM education research efforts. Specifically, this work addresses the following research questions*: (1) What can be assessed from problem-based learning modules? And (2) What are the potential assessment methods for problem-based learning modules related to BIM?* The results suggest that students' development, learning processes, and problem-based learning modules can be assessed for determining the benefits of adopting the module in BIM education. Additionally, rubrics, surveys, interviews, reflective journals and peer assessment are strategies for evaluating BIM skills. However, using a single strategy might not be adequate. Therefore, future work should adopt several of the strategies when determining the benefits of implementing problem-based learning in BIM education.

1 Introduction

The architecture, engineering, and construction (AEC) industries pursue various ways to reduce project cost, increase productivity and quality, and reduce project delivery time. These goals can be addressed by the potential benefits of implementing Building Information Modeling (BIM) in construction projects. Those potential benefits include savings in time and cost (Bryde et al. 2013). However, implementing BIM in practice can also have some possible challenges including those related to people, process, and technology (Arayici et al. 2011). Nonetheless, BIM is expected to play a central role in the AEC industry as numerous business processes and services that have been developed throughout the years (Sacks and Pikas 2013). Therefore, preparing students with the skills to mitigate or avoid the challenges that likely arise during BIM implementation may offer benefits to the building industry in the future.

Educators have tried to incorporate the issues associated with implementing BIM within the boundaries of a classroom (Becerik-Gerber et al. 2012, Ahn et al. 2013). However, those issues are being taught using more traditional pedagogies such as through lectures and assignments. With that said, there are opportunities to advance BIM education using other pedagogies, specifically in teaching BIM implementation issues. One potentially promising pedagogy for BIM education is problem-based learning, as it presents BIM in a context that may effectively simulate a real-world scenario students might expect to experience in their future careers. Determining the benefits of adopting problem-based learning in BIM education would provide helpful information to other educators. To determine those benefits, this research attempts to identify the appropriate assessment strategies for evaluating problem-based learning modules. Specifically, this research focuses on determining those benefits that are related to the BIM skills that are

recommended to be prioritized in BIM education (Rahman et al. “BIM issues: prioritizing and opportunities to integrating them into construction education,” working paper, Arizona State University). The skills identified in this prior work include communication, initiative, analytical and problem-solving, planning and organizational, and teamwork. This paper explores how prior research efforts have used problem-based learning to educate students on these topics. The results will help to inform future BIM education research efforts. Specifically, this work addresses the following research questions: *(1) What can be assessed from problem-based learning modules? And (2) What are the potential assessment methods for problem-based learning modules related to BIM?* To answer these questions, the authors analyze peer-reviewed articles to identify assessment strategies that are being used to evaluate problem-based learning modules. Then, information of identical strategies is extracted from those articles and grouped together. Finally, that information is summarized, and the strategies are reported in this paper.

2 Background

Equipping students with the appropriate BIM skills may prepare them for career success (Ku and Taiebat 2011, Uddin and Khanzode 2013) and project success (Peterson et al. 2011). Previous research has identified those skills essential for graduating students by analyzing social networking profiles and entry-level job advertisements (Rahman et al. “BIM skills: a social network and job advertisement-based comparative analysis,” submitted, Arizona State University). However, there are discrepancies between the skills, especially between those from different data sets. Therefore, the skills are validated through open-ended individual interviews with content experts (Rahman et al. “BIM issues: prioritizing and opportunities to integrating them into construction education,” working paper, Arizona State University). These skills are validated by identifying those that overlap with the skills that are perceived to be important in team members of BIM-based construction projects from the interviews. The overlapping skills are those that are recommended to be prioritized in BIM education. Skills identified from this analysis are CAD software, communication, initiative, analytical and problem-solving, planning and organizational, and teamwork.

Introducing new pedagogies to teaching BIM implementation issues may enhance the overall BIM education. Specifically, it would be better if the new approach has the potential to develop those prioritized BIM skills. To identify those approaches, the authors performed a literature review of articles from peer-reviewed publications (Rahman and Ayer “BIM issues: prioritizing and opportunities to integrating them into construction education,” working paper, Arizona State University). The literature review does not involve identifying pedagogies that may result in a development of technology-related skills. This consideration is taken because an analysis of issue logs from an electrical contractor’s fifty-seven BIM-based construction projects throughout the United States suggests that the common cause of issues in those projects are people or process rather than technology (Rahman and Ayer “Prevalent issues in BIM-based construction projects,” submitted, Arizona State University). Therefore, pedagogies that focus on developing technology-related skills, i.e. CAD software are not included in the literature review. The literature review suggests that collaborative learning, project-based learning, case studies, problem-based learning, simulation-based learning, inquiry-based learning, role-based learning, and game-based learning are all pedagogies that are shown to foster the development of at least one of those prioritized skills. The authors consider problem-based learning as a promising pedagogy because it has the potential to develop several of the prioritized BIM skills including communication, problem-solving, and initiative skills (Steinemann 2003). To best determine the benefits of adopting problem-based learning in teaching BIM implementation issues, this paper identifies appropriate assessment strategies for evaluating problem-based learning modules. Specifically, this research identifies those strategies that evaluate benefits related to communication, initiative, analytical and problem-solving, planning and organizational, and teamwork skills.

3 Methodology

This research analyzes information from peer-reviewed articles to answer the questions. The process of analyzing this information involves collecting articles from peer-reviewed publications. This process is followed by exploring the assessment strategies that are being used to assess or evaluate problem-based learning in those articles. Then, information of identical strategies is extracted from those articles and grouped together. Finally, this process ends by summarizing the grouped information for each assessment

strategy. The following subsections discuss the method of collecting and analyzing information from peer-reviewed articles.

3.1 Data collection

This research collects peer- reviewed articles from bibliographic databases. The databases are American Society of Civil Engineers (ASCE), Elsevier, Emerald, and Taylor and Francis. Journal of Information Technology in Construction and proceedings of Associated Schools of Construction (ASC) are also included in the list of databases. These databases are selected because they have various journal publications that highlight issues related to BIM and education. The search feature in those databases is used to identify articles that are both related to problem-based learning and any of the prioritized BIM skills. Figure 1 shows the search terms used to identify those articles. Only articles that report their method of assessing or evaluating the prioritized BIM skills are considered for data collection.

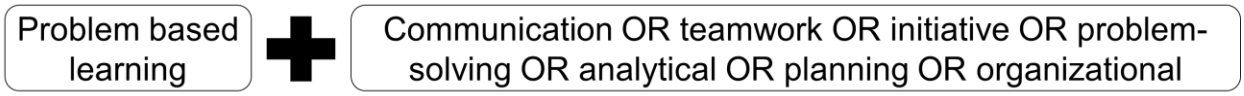

Figure 1: The search terms used to identify articles in peer-reviewed publications

Moreover, articles that are referenced in the collected papers are gathered. This method is adopted to identify articles that are outside of the designated databases, but still relevant to the topic. Figure 2 shows the process of identifying those articles. The process of identifying the articles involves going through the list of references of the collected papers. Articles with either “problem-based” or “problem based” in the titles are identified as those that are related to problem-based learning. Those titles are then collected, if available. Similar to collecting articles from the designated databases, only those that report their method of assessing or evaluating the prioritized BIM skills are collected. This process is repeated using the articles that have been collected to identify another set of articles until there are no new articles to be found.

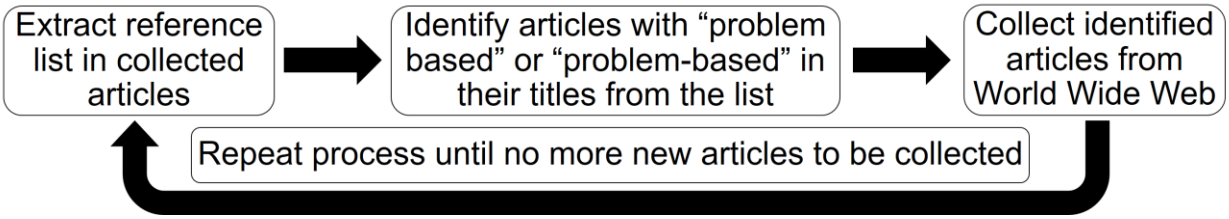

Figure 2: The process of identifying articles that are outside of the designated databases

3.2 Data analysis

The collected articles are analyzed to identify the assessment strategies that are being used to assess or evaluate problem-based learning. The process of analyzing the articles includes identifying the following information: (1) The assessment strategies; (2) The approach of implementing the strategies; (3) The elements that are being evaluated by the strategies; and (4) Other additional information that is related to the strategies.

This information is grouped based on their assessment strategies. Then, that grouped information is reviewed and compared to identify similarities and differences between them. Finally, the information of those strategies that evaluate the prioritized BIM skills is summarized and reported. Articles that do not provide new information are excluded from the summary to remove those that only validate existing information without adding any new content.

4 Results

This section reports the results of analyzing the collected peer-reviewed articles. The section starts by reporting the different aspects that can be assessed in problem-based learning. Then, the various assessment strategies that have been used to assess those aspects are reported.

4.1 What can be assessed through problem-based learning?

The results illustrate that there are different aspects that can be assessed in problem-based learning. The first aspect relates to the students themselves including assessing the development of their skills, knowledge, and performances. The skills include those prioritized BIM skills such as teamwork (Hur and Kim 2007), problem-solving (Ribeiro and Mizukami 2005), analytical (Li et al. 2013) and communication skills (Katsitkitis et al. 2002). Other skills that have been assessed in problem-based learning that were not initially identified by the authors' prior work include decision-making (Werth 2009), interpersonal (Ribeiro and Mizukami 2005), self-regulated learning, and cooperative learning skills (Yoon et al. 2014). The development of students' knowledge is those such as their knowledge building (Murray-Harvey et al. 2005) and their applied knowledge into class discussions (Katsitkitis et al. 2002). Finally, students' performances are assessed including those such as their ability to utilize relevant materials to get appropriate information effectively (Li et al. 2013) and their level of participation, effort, and sense of responsibility (McIntyre 2003).

In addition to assessing students, prior work suggests that the learning process can also be assessed in problem-based learning. The assessment includes students' observations, impressions, and reactions on the problem-based learning modules towards their learning (Williams et al. 2013). Moreover, students' perceived learning has also been assessed in problem-based learning. These perceived learnings include the effectiveness of the module in achieving the learning goals (Ribeiro and Mizukami, 2005). Other elements of perceived learning include those such as the development of competencies such as hypothesis formulation, argumentation, synthesizing, data analysis, information and time management (Carrio et al. 2011).

The third type of assessment identified relates to evaluating the developed learning modules that are aimed at presenting problem-based learning content to students. These assessments include evaluating the individual components of the module such as the quality of the instruction (Moeller et al. 2010) and the evaluation procedures of the module (Ribeiro and Mizukami 2005). In addition to assessing the individual components, the module themselves have also been assessed as a single component. The assessment includes students' learning experience (Seng Tan 2004) and their opinions on the effects of the modules on their development (Sulaiman 2010). Other assessments of the module involve evaluating feedback on the students' satisfaction (Moeller et al. 2010) and their perception of problem-based learning as a teaching approach (Werth 2009). The feedback includes their feelings about the learning process and the influence of the instructional design towards their learning (Sulaiman 2010).

4.2 How can problem-based learning in BIM education be assessed?

Table 1 shows the different aspects that can be evaluated using the various assessment strategies that are reported in this paper. The results illustrate both similarities and differences between the various assessment strategies. Rubrics are used to assess more of the prioritized BIM skills compared to other assessment strategies. Conversely, surveys and interviews are used to assess all the different aspects that can be assessed in problem-based learning. Finally, reflective journals are used to assess students' learning, communication, and problem-solving skills while peer assessments are used only to assess communication and problem-solving skills. In other words, the results illustrate that a single assessment strategy has not been used to assess all the BIM prioritized skills and different aspects of problem-based learning.

Table 1: The different aspects that can be evaluated by each assessment strategy

Aspects vs. Assessment strategy	Rubrics	Surveys	Interviews	Reflective journals	Peer assessments
Student's development	Yes	Yes	Yes	Yes	Yes
Problem-solving	Yes	Yes	Yes	Yes	Yes
Communication	Yes	Yes		Yes	Yes
Teamwork	Yes	Yes	Yes		
Analytical	Yes				
Learning process	Yes	Yes	Yes	Yes	
Problem-based learning module		Yes	Yes		

4.2.1 Rubrics

Rubrics allow assessment based on the complexity and structural organization of a student's answer (Roca et al. 2016). In regards to the prioritized BIM skills, rubrics have been used to assess teamwork (Hur and Kim 2007), analytical (Li et al. 2013), communication (Katsitkitis et al. 2002) and problem-solving skills (Hur and Kim 2007). Furthermore, rubrics have been used to assess the ability of students to demonstrate viewpoints of initiative and curiosity, utilize relevant materials to get appropriate information effectively and propose hypotheses and issues (Li et al. 2013). Rubrics are also used to assess other elements such as applying knowledge into class discussions, contributing to class discussions, interacting orally, and students' overall performance (Katsitkitis et al. 2002). Rubrics are used by either the instructor of the course (Tarmizi et al. 2010) or selected content experts such as experienced educators of the subject (Abdullah et al. 2010) and often involve Likert-scale questions to gauge levels of agreement among evaluators.

4.2.2 Surveys

Surveys are used to assess students' development of their skills. The skills include those prioritized BIM skills such as communication (Ribeiro and Mizukami 2005, Carrio et al. 2011), problem-solving (Murray-Harvey et al. 2005, Werth 2009), and teamwork (Ribeiro and Mizukami 2005, Moeller et al. 2010). Skills other than those prioritized BIM skills have also been assessed through surveys, including decision making (Werth 2009) and interpersonal skills (Ribeiro and Mizukami 2005). Additionally, surveys are also used to assess other elements. These elements include those such as knowledge building (Murray-Harvey et al. 2005) and the development of students' competencies such as hypothesis formulation, argumentation, synthesizing, data analysis, information and time management (Carrio et al. 2011). Additionally, other elements that have been assessed using surveys include how problem-based learning help them remember information that they have learned previously and how to use that information in reality (Werth 2009).

Surveys are also used to collect feedback including on students' satisfaction, the role of the tutor, the quality of the instruction and the realism of the module (Moeller et al. 2010). Surveys are also used to gather opinions about the module, centering on the accomplishment of the general course goals, as well as those about knowledge, and attitudes, and the evaluation procedure. (Ribeiro and Mizukami 2005). Other opinions include those such as what are the most beneficial about the module, what could be done to make the module more effective in the future, and should the module be used in the future (Werth 2009). Likert-scale questions are used to elicit quantitative responses (Werth 2009, Murray-Harvey et al. 2005). Conversely, qualitative responses are elicited by using open-ended questions (Werth 2009) or providing room for write-in comments (Moeller et al. 2010).

4.2.3 Interviews

Individual and focus groups interviews have been used for assessing problem-based learning. Focus group interviews are useful for obtaining several perspectives on the same topic (Herron and Major 2004). Conversely, individual interviews explore the topic in-depth (Seng Tan 2004). The prioritized BIM skills that were determined through interviews are teamwork (Herron and Major 2004, Seymour 2013) and problem-solving (Seng Tan 2004, Sulaiman 2010).

Interviews involve students sharing their learning experience (Seng Tan 2004) and other topics related to problem-based learning (Seymour 2013). Those topics include what skills that are needed to work as part of a team, which aspects of the module helped students develop the skills, and how they think their skills are developed (Seymour 2013). Students have also discussed their confidence to do problem-based learning tasks, their feelings about the learning process, their views of the content after finishing the module, and the influence of the pedagogy towards their learning process (Sulaiman 2010). The interviews are adopted as either semi-structured (Sulaiman 2010) or open-ended (Herron and Major 2004).

4.2.4 Reflective journal

Reflective journals allow the capture of rich and complex data that would provide an opportunity for researchers to explore students' problem-based learning experiences and emotions (Joham and Clarke 2012). Reflective journals should include students' observations, impressions, and reactions to their learning in the unit (Williams et al. 2013).These journals have determined that problem-based learning develops several of prioritized BIM skills including communication (Williams et al. 2003, Joham and Clarke 2012) and problem-solving (Joham and Clarke 2012, Kong 2014). Other skills that were determined through this strategy include critical thinking and life-long learning (Kong 2014).

One study required students to write at least one entry per week in a reflective journal for twelve weeks. (Williams et al. 2003) The students' writing had to reflect their understanding of the problem-based learning process. Students received marks after submitting their completed journal at the end of the problem-based learning module. The mark was based on the level of reflection demonstrated in the journal.

4.2.5 Peer assessment

Peer assessment allows students to rate the performance of other groups and individuals (McIntyre 2003). The prioritized BIM skills that were assessed through peer assessment are communication (Chin and Chia 2004, Panpinczak et al. 2007) and problem-solving (Yoon et al. 2014). Other elements that have been assessed include others' sense of responsibility, information processing, critical analysis, and self-awareness (Yoon et al. 2014). Knowledge application and independent learning have also been assessed using peer assessment in problem-based learning (Chin and Chia 2004). Additionally, the assessment of other individuals includes evaluating each individual's level of participation, effort, and sense of responsibility (McIntyre 2003). Students' presentations have also been assessed using this strategy (Panpinczak et al., 2007)

Additionally, peer assessment can be modified for self- and tutor assessment (Panpinczak et al. 2007). Results from the peer-, self-, and tutor assessments can be compared to identify any common consensus between the different individuals (Panpinczak et al. 2007). Self-assessment has been used to evaluate students' self-regulated and cooperative learning skills (Yoon et al. 2014). There are those that use 5-point Likert-scale (Yoon et al. 2014) and 4-point Likert-scale (Chin and Chia 2004).

5 Discussion

These results suggest that the benefits of implementing problem-based learning modules can be assessed from other aspects besides the development of students' skills. Additionally, the results illustrate that rubrics, surveys, interviews, journal reflections and peer assessment are the strategies that evaluate the prioritized BIM skills. However, no single assessment strategy has been used to assess all the BIM prioritized skills and different aspects of problem-based learning. Some may argue that survey- and interview-based strategies can assess all aspects of problem-based learning, but these methods rely primarily on perception-based responses. Therefore, they may be further supported by the inclusion of other, observation-based, data to support their findings.

In addition to some of the beneficial aspects of the identified assessment strategies, several disadvantages were also identified. For example, developing rubrics requires a lot of effort and time because they should be interpreted consistently, not only by the researcher but also other individuals. Interviews often have limitations related to small sample sizes that make generalizations of findings challenging (Seng Tan 2004). Journal reflections may require students to conduct the activity for weeks. Otherwise, the activity would be

similar to open-ended questions surveys. In regards to peer assessment, this strategy may also have challenges related to students assessing others unjustly by providing higher marks to others in exchange for higher marks for themselves (Ahern 2010). Moreover, although there are students who can assess others fairly, there are also those that have difficulty in assessing others (Ahern 2010). Because each assessment method has certain advantages, but also fundamental limitations, it is difficult to conclude that there is a single assessment strategy that is appropriate for evaluating all aspects of problem-based learning in BIM education. Therefore, using several assessment strategies for evaluating problem-based learning modules might be the best method to determine the benefits of implementing the module in BIM education.

6 Conclusion

This research reports the assessment strategies used in problem-based learning for evaluating high potential value BIM skills, including communication, initiative, analytical and problem-solving, planning and organizational, and teamwork skills. Those strategies are identified by analyzing information from articles in peer-reviewed publications. The results suggest that problem-based learning modules can be used to assess the high potential value BIM skills as well as others that were not originally identified through prior research. The results also suggest that rubrics, surveys, interviews, reflective journals and peer assessment are the strategies that have been used for evaluating several of those BIM skills. However, there are no assessment strategies that evaluates all of these different aspects nor the prioritized BIM skills together at once. Therefore, using several assessment strategies for evaluating problem-based learning modules might be the best method to determine the benefits of implementing the module in BIM education.

Future work should consider these findings when developing assessments for problem-based learning modules that teach BIM implementation issues related to people and process. Preparing students with the skills to mitigate or avoid those issues may offer benefits to the AEC industry in the future. These findings should also be considered when developing problem-based learning modules for other topics in BIM education that focus on those prioritized BIM skills.

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