To cite this article:

Zou P.X.W., Xu X., Jin R., Painting N., and Li B. (2018). "Investigation of AEC Students' Perceptions towards BIM Practice-a Case Study of Swinburne University of Technology." *Journal of Professional Issues in Engineering Education and Practice*. In Press, DOI: 10.1061/(ASCE)EI.1943-5541.0000410.

Investigation of AEC Students' Perceptions towards BIM Practice-a Case Study of Swinburne University of Technology

Patrick X.W. Zou[1], Xiaoxiao Xu[2], Ruoyu Jin[3], Noel Painting[4], Bo Li[5]

Abstract

The growing BIM (i.e., Building Information Modeling) application in the construction industry worldwide has driven the research in both technological and managerial aspects. Existing managerial studies have not fully addressed individual perceptions of BIM implementation, especially AEC (i.e., architecture, engineering and construction) students' opinions related to BIM implementation or industry practice. As the future industry professionals, AEC students' perceptions and expectations have not been compared with that of industry professionals. Adopting the student population from Swinburne University of Technology as the case study, this research initiated a questionnaire-based approach followed by statistical analysis. Totally *257* AEC students were collected of their responses to four major

[1]Professor of Construction Engineering and Management, Department of Civil and Construction Engineering, Swinburne University of Technology, ATC Building, Hawthorn Campus Hawthorn Vic 3122 Australia, Phone: +61(3)92143781, Email: pwzou@swin.edu.au

[2]Ph.D. candidate, Department of Civil and Construction Engineering, Swinburne University of Technology, Hawthorn Campus Hawthorn Vic 3122 Australia, Email: xiaoxiaoxu@swin.edu.au

[3]Senior Lecturer, School of Environment and Technology, University of Brighton, Cockcroft Building 616, Brighton, UK. BN24GJ. Phone: +44(0)7729 813 629, Email: *R.Jin@brighton.ac.uk*

[4]Senior Lecturer, School of Environment and Technology, University of Brighton, Cockcroft Building 620, BN24GJ, Brighton, UK. Email:N.J.Painting@brighton.ac.uk

[5] Associate Professor, School of Civil Engineering, Wenzhou University, No.5Bldg, North Campus, Zhejiang, China, 325000. Email: libo@wzu.edu.cn

perception-based categories, namely BIM's usefulness, students' desired BIM-related jobs, and challenges during BIM implementation. The overall sample analysis revealed that students favored BIM-based jobs related to engineering design and project management, and they perceived less usefulness of BIM in assisting facility management and quantity survey. Subgroup analysis showed that certain perceptions in BIM practice would be affected by students' field of study, prior industry experience, and gender. For example, male students generally held more positive views on BIM's applicability and its usefulness. AEC students in this study showed certain discernment in identifying certain contemporary BIM-related practices. However, they also had different views on challenges compared to industry professionals due to AEC students' less industry experience. In-depth discussions were provided in how these subgroup factors affected students' perceptions. This empirical study of student perceptions in BIM practice provides insights to both BIM educators and AEC employers, in terms of optimizing the BIM education resources between industry practice and academic research, awareness of subgroup differences in their perceptions and motivations, and similarities and differences between AEC students and industry practitioners. Based on the current finding, future research could focus on cross-institutional comparison of student BIM-based perceptions by considering more subgroup factors. This study could also lead to future pedagogical research in adopting BIM in different project sectors (e.g., building and infrastructure).

Keywords: Building Information Modeling (BIM); architecture, engineering, and construction (AEC); individual perceptions; BIM education; subgroup analysis

Introduction

BIM (i.e., Building Information Modeling) studies that have high impacts in the research community are mostly focusing on technical aspects including BIM application and implementation (Yalcinkaya and Singh, 2015). In comparison, managerial part of BIM has not received the attention as it deserves (Oraee et al., 2017). However, the managerial aspect should be another core research area in BIM besides the technical aspect of BIM. (He et al., 2017). Most previous management-based studies in BIM focused on the industry, company, or project levels, without addressing the individual level (Howard et al., 2017). Perceptions have a direct effect in human behaviour (Dijksterhuis and Bargh 2001). Human behavior was further identified by Lu et al. (2015) as a key issue in adopting information and communication technologies. There have been some existing BIM-related studies addressing the individual perceptions towards BIM practice and implementation (Howard et al, 2017; Jin et al., 2017a; Jin et al., 2017b). However, these individual perception-based studies in BIM were mostly limited to AEC (i.e., architecture, engineering, and construction) industrial professionals (e.g., Ku and Taiebat, 2011; Panuwatwanich et al., 2013; Sacks and Pikas, 2013; Lucas, 2017), without sufficiently addressing AEC (i.e., architecture, engineering, and construction) students, the future employees in the industry. Further, the existing studies targeting on students' perspectives (e.g., Zhao et al., 2015; Shelbourn et al., 2017) focused more on the course or curriculum development of BIM, without further extending it to investigate students' perceptions on the industry implementation. There has also not been sufficient research addressing the individual perceptions towards BIM between students and industry professionals.

The importance of addressing AEC students' individual perceptions towards BIM lies in that they will become professionals in the industry. What they perceive BIM impact on AEC project management would also drive their learning and practical behaviors upon completing their studies and entering the job market, and even drive the industry movement in the longer-term. Therefore, AEC students' perceptions should also be considered part of BIM education. Tang et al. (2015) considered BIM education important because it worked as pre-career training for AEC students and further reduced the industry investment in employees' BIM training. One of the barriers in increasing project efficiency through BIM, as identified by XS CAD Limited (2018), was the resistance of AEC firms to switch from the traditional Computer Aided Design (CAD) to BIM. On the other hand, graduating AEC students, although new in the professional fields with limited practical experience, tended to pick up digital skillsets quicker compared to their senior peers (Jin et al., 2016). There can be subgroup differences during BIM implementation. For example, in the same AEC project, BIM practitioners from different AEC disciplines and those at various experience levels of BIM usage might hold different perceptions towards BIM adoption (Jin et al., 2017a). However, there has been so far limited BIM managerial research focusing on the subgroup analysis of AEC students or learners. Although several previous studies (e.g., Jin et al., 2018) found that with proper college education and BIM pedagogical delivery methods, AEC students could obtain similar perceptions as industry professionals towards BIM adoption, there has been so far limited investigation on how the subgroup factors (e.g., academic discipline) might cause deviations in learners' perceptions towards BIM adoption.

Aiming to address the current research gaps in terms of insufficient studies targeting on AEC students, lack of individual levels of BIM managerial studies, as well as the issue of subgroup or demographic factors in BIM-involved project management, this research is comprised of these objectives: 1) to investigate students' overall perceptions towards BIM practice; 2) to investigate the effects of subgroup factors (i.e., students' disciplines, prior experience, and gender) in their perceptions; and 3) to further compare the perceptions between AEC students and industry professionals from existing literature (e.g., Jin et al., 2017a). This study adopted a questionnaire survey approach by collecting perceptions of AEC students from multiple disciplines including construction engineering and management, other civil engineering disciplines (e.g., structural engineering), and other non-civil engineering subjects (e.g., architecture). Perceptions collected from students covered topics regarding BIM's usefulness in different AEC professions, students' interests in different BIM-related AEC jobs, as well as their perceptions towards challenges encountered in BIM practice. This research contributes to the existing body of knowledge in BIM by investigating the subgroup factors in AEC students' perceptions towards BIM implementation. The current study offer insights for AEC educators by shedding lights on the demographic factors' effect in BIM learning. The findings also provide insights for AEC employers regarding subgroup factors when they are hiring BIM-related employees. Further, the current study leads to future research in BIM pedagogy-based research, which was identified by Santos et al. (2017) as under-represented BIM research area.

Literature review

BIM practice and implementation worldwide

BIM practice has been extended in multiple areas, including vertical BIM, horizontal BIM, heavy BIM, and "green" BIM (Rahman et al., 2013). According to Jäväjä and Salin (2014), the diversified BIM applications and movements have created a higher demand on competent BIM professionals and college graduates with BIM skills. Practically, BIM has been investigated for its rapid growth in the global AEC industry (Both et al., 2012; Davies and Harty, 2013; Masood et al., 2013;

Juszczyk et al., 2015). Technically, BIM has been studied in its application in addressing various issues crossing different AEC disciplines or professions, such as the interoperability issue in civil engineering (Ma et al., 2015), safety management (Abolghasemzadeh, 2013), quantity take-off (Said and El-Rayes, 2014), and facility management (Lu and Olofsson, 2014). BIM practice worldwide has motivated research in both technological aspects (Yalcinkaya and Singh,2015)and managerial perspectives (He et al., 2017; Oraee et al., 2017).

Individual perceptions towards BIM practice

Collaboration has been defined by multiple studies (e.g., Eadie et al., 2013; Sacks and Pikas, 2013; Jin et al., 2017a) as the key for successful BIM implementation. Collaboration also means that multiple trades (Eadie et al., 2013), disciplines (Jin et al., 2017a) and project participants (Jin et al., 2017b) are typically included in BIM-involved projects. The effects of these subgroup factors in individual perceptions towards BIM implementation have been considered important as joint-effort from multiple subgroups is imperative for successful BIM practice (Jin et al., 2017a). Perceptions towards BIM implementation generally consist of benefits, critical factors, risks, and challenges in BIM implementation according to multiple prior studies (e.g., Eadie, et al., 2013; Ahn et al., 2015; Jin et al., 2017a; Jin et al., 2017b). These studies all addressed the challenges encountered during BIM practice, including insufficient evaluation of BIM value, cultural resistance, lack of client demand, lack of BIM training, high investment in BIM resources, lack of relevant legislation or standards, and insufficient understanding of BIM technology (He et al., 2012; Sackeyet al., 2014; Tang et al., 2015; Çıdık et al., 2017). Most of these studies (Ku and Taiebat, 2011; Panuwatwanich et al., 2013; Sacks and Pikas, 2013) focused on the individual perceptions from the industry practitioners' perspective. Although several studies (e.g., Zhao et al., 2015; Shelbourn et al., 2017) captured students' perceptions towards BIM, they focused on the BIM course or curriculum itself, but not in the practical level of BIM implementation (Jin et al., 2017a).

BIM pedagogy and training

Educational institutions play a key role in BIM adoption (Jäväjä and Salin, 2014). A review of existing studies in BIM pedagogy revealed that most studies have focused on a single discipline, for example, architecture (Livingston, 2008), construction engineering (Kim, 2011), and structural engineering (Nawari, 2015). Institutions (e.g., Sharag-Eldin and Nawari, 2010; Mathews, 2013; and Tang et al., 2015) have also adopted collaborative teamwork approach in BIM pedagogy, especially the interdisciplinary collaboration approach (Jin et al., 2018). Pikas et al. (2013) suggested that BIM education should be implemented at the program level rather than an isolated course. BIM education has been identified by both academia and industry as a necessity (Solnosky and Parfitt, 2015). However, insufficient resources and university conservations were identified by Trine (2008) as key barriers in meeting this demand. Furthermore, the effects of BIM in AEC education have not been sufficiently investigated (Solnosky and Parfitt, 2015). On the other hand, Sacks and Pikas (2013) emphasized the importance of BIM education in meeting industry needs.

Methodology

This study consisted of two main research methods, namely a questionnaire survey to AEC students, and the follow-up statistical analysis. The questionnaire survey was one of the widely recognized research approaches investigating both practical and pedagogical topics in the field of construction engineering and management (e.g., Lewis et al., 2015; Zhao et al.,2015; Jin et al., 2017a). In this study, the questionnaire was developed by the researchers by partially adapting the BIM challenge-related question items from Jin et al. (2017a). Details of the questionnaire can been seen in the Appendix. Fig. 1 describes the research framework of this BIM-learner-based study.

<Insert Fig.1 here>

Fig.1 indicates the importance of studying students' perceptions following BIM teaching and learning, as their perceptions will affect the learning and practical behaviors in adopting BIM, and further transforming themselves to be the future industry practitioners. Their perceptions also offer insights and feedback for BIM educators. This study specifically focuses on how these three influence factors (i.e., gender, academic discipline, and prior industry experience) would affect students' perceptions towards BIM. It also allows further comparison of the perceptions between BIM learners and practitioners.

Questionnaire survey

Questionnaire survey was designed to target AEC students, by aligning it to the research objectives focusing on students' perceptions towards BIM practice as well as how students' subgroup factors (e.g., AEC discipline) would affect their perceptions. The questionnaire consisted of five major sections, aiming to collect data on students' background, their perceptions of BIM's usefulness in various AEC professions (e.g., architectural design), students' desired BIM-related industry jobs (e.g., BIM project manager), and challenges encountered in BIM implementation:

- the first section was designed with questions in the multiple-choice format to collect student background information, including students' discipline (e.g., CEM), whether or not having prior industry experience, and gender. Earlier studies (e.g., Eadie et al., 2013; Jin et al., 2017a; Jin et al., 2017c) addressed individual factors (e.g., AEC profession) in affecting the industry professionals' perceptions of certain construction themes (e.g., digital technology). Demographic factors (e.g., gender) have been an ongoing concern in the AEC industry worldwide. This study was further designed to investigate whether these subgroup factors would affect students' individual perceptions of these follow-up four sections using the five-point Likert-scale format;

- multiple AEC professions were listed as another section to study students' perceptions on the usefulness of BIM in each of them. BIM practice involved multi-disciplinary collaboration (Eadie et al., 2013; Jin et al., 2017b; Santos et al., 2017). BIM-related industry jobs, such as BIM manager, BIM coordinator, and BIM engineer identified by Sacks and Pikas (2013) and Uhm et al. (2017) were listed in the questionnaire;
- a list of potential challenges encountered during BIM implementation were asked to students to collect their opinions on the ease of overcoming them. These challenges have been studied in previous managerial studies of BIM, such as insufficient evaluation of BIM value (Sebastian, 2010), and higher initial cost of BIM (Azhar, 2011), etc. Collection of students' perceptions of these challenges would allow the comparison between AEC students and practitioners.

The questionnaire was initiated from August to September 2017. Later it was peer reviewed externally by BIM educators from other institutions during October 2017. A pilot study was performed a smaller group of AEC students to make sure that these questions were clearly presented. The finalized questionnaire survey was then sent to the survey population from Faculty of Science, Engineering & Technology in

Swinburne University of Technology. The Faculty had a student enrollment of *428*. These students had either learned BIM in their curriculum, planned to learn BIM in the near future, or been with prior BIM experience. The survey population covered students crossing multiple AEC disciplines, such as general civil engineering (CE) excluding construction engineering and management (CEM), CEM, and other disciplines (e.g., building services engineering). Following the statistical procedure of *Inferences Concerning Proportions* introduced by Johnson (2005), the authors conducted the tests of proportions for genders among different disciplinary groups, as well as work experience proportions among different groups defined by BIM learning experience. Based on the level of significance at *5%*, it was found that the gender proportion was not significantly affected by students' disciplines, or vice versa. Similarly, work experience was also independent of BIM learning experience. Dividing the whole survey population into subgroups to study a single factor's effects on survey participants' perceptions can be found in several existing studies, such as work experience (Han et al., 2018) and geographic location (Xu et al., 2018).

Statistical analysis

Multiple statistical methods were applied in this study to provide the overall sample analysis and subgroup evaluation of the four aforementioned perception-based sections. For the overall sample analysis, the relative importance index (*RII*) and Cronbach's Alpha were conducted respectively to rank the Likert-scale items and to test the internal consistency:

- the *RII* has been applied in the CEM field (e.g., Tam, 2009; Jin et al., 2017c) to rank multiple Likert-scale items. It ranges from *0* to *1*, and can be calculated according to Equation (1)

$$RII = \frac{\sum w}{A \times N} \quad (1)$$

where *w* denotes the score from *1* to *5* selected by each survey participant, *A* is the highest score which is *5* in this survey, and *N* denotes the number of responses.

- Cronbach's Alpha value (Cronbach, 1951) is the term to measure the internal consistency of Likert-scale items. With its value ranging from *0* to *1*, a higher value indicates a higher degree of consistency among items. Generally, the value from *0.70* to *0.95* is considered acceptable with high internal interrelatedness (DeVellis, 2003). A higher overall Alpha value within one section suggests that survey participants who choose one Likert-scale score to one item is more likely to assign a similar score to other items. Each item within the same section has an individual Cronbach's Alpha value. An individual value lower than the overall value shows that this item contributes to the overall internal consistency. In another word, it means that survey participants generally hold the statistically consistent or similar perceptions towards the given item as they would perceive the remaining items. Otherwise, a higher individual value than the overall Cronbach's Alpha value would suggest that survey participants have a differed view on this given item. There is also an item-total correlation corresponding to the individual Cronbach's Alpha value, which measures the correlation between the given item and the remaining items;

Surveys were then divided into subgroups according to the students' disciplines in AEC fields, industry experience, and gender. Subgroup analysis was conducted using parametric methods, including Analysis of Variance (ANOVA) and the two-sample *t*-test. Parametric methods have been adopted in earlier studies involving Likert-scale questions in the CEM field, such as Aksorn and Hadikusumo (2008), Meliá et al. (2008), and Tam (2009). Both ANOVA and the two-sample *t*-test were based on the null hypothesis that there were no subgroup differences among students' perceptions of the given Likert-scale item. Setting the level of significance at *5%*, a *F* value and a *t* value were computed respectively in ANOVA and the two-sample *t*-test. A corresponding *p* value was then generated in both parametric methods to test the null hypothesis. A *p* value lower than *0.05* would reject the null hypothesis and suggest significant differences of subgroup factors in perceiving the given item related to BIM applicability, usefulness, BIM-based jobs, or challenges.

Results and findings

The questionnaire was initiated in July 2017, peer-reviewed and revised through a pilot study in August, and finally sent out to AEC students during September and October of 2017. Totally *257* valid questionnaires were received. Students in this survey sample had an average BIM learning experience of *19* months, the median value of learning experience at *12* months, as well as the minimum and maximum learning and practical experience at *1* month and *84* months respectively. The percentages of respondents divided by their AEC disciplines, whether or not having AEC industry experience, and their gender are illustrated in Fig.2.

<Insert Fig.2 here>

CE students in this sample accounted for over 60% of total survey population. The CE subgroup excluded CEM, which was identified as a separate subgroup. Examples of CE students in this study included structural engineering. Others included a variety of different non-CE disciplines, such as building services engineering, architectural technology, and architecture, etc. The majority (i.e., *73%*) of the student population did not have prior AEC industry experience. Those with some previous experience had been working in the industry from three months to over *13* years, with the average industry experience at *23* months, and the median experience at *12* months. Fig.2 also shows that female students only accounted for *10%*

of the survey sample, indicating that females are a minority in CE or relevant subjects.

Statistical tests of individual perceptions of BIM-practice-related questions are summarized in the following sections, namely BIM applicability in different project sectors, BIM's usefulness in different AEC professions, students' motivation in various BIM-related industry jobs, as well as challenges encountered in BIM implementation. In each of these aforementioned sections, the whole student sample's overall perception was evaluated, followed by the subgroup analysis divided by these demographic factors displayed in Fig.2.

BIM usefulness in different AEC professions

Students were asked of their perceptions regarding the usefulness of BIM in various AEC professions. They were guided to select a Likert-scale score from *1* to *5*, which indicated the perception from "least useful" to "very useful". Survey participants were also given the extra option of *6* indicating that they were unsure of the perception towards the given profession. Table 1 provides the overall sample analysis.

<Insert Table 1 here>

Four items listed in Table 1 received the mean Likert scores over *4.000*, indicating students' highly positive perceptions of BIM's usefulness in these four top-ranked AEC professions, namely architectural design, structural design, building services design, and construction project management. It should be noticed that all of these four professions were either design-based or general construction management. Students were prone to perceive BIM's usefulness in the early project delivery stages (e.g., design). In comparison, other non-design-related professions (e.g., cost estimate) or post-design work (e.g., facility management) received less positive perceptions from survey respondents. Besides facility management, building energy assessment also received one of the lowest mean scores from students, inferring that there had been limited education on linking BIM to building performance.

The overall Cronbach's Alpha value in Table 1 indicates a fairly high internal consistency. Individual Cronbach's Alpha values lower than the overall value showed that each individual item in Table 1 contributes to the internal consistency. The subgroup analysis is summarized in Tables 2 to 4.

<Insert Table 2 here>

<Insert Table 3 here>

<Insert Table 4 here>

Several significant differences can be found from Tables 2 to 4, including: 1) CE and CEM students held more positive views on BIM's usefulness in cost estimate/bills of quantities compared to those from other disciplines; 2) students with prior industry experience had more positive views of BIM's usefulness in structural design; 3) male students generally held more positive perceptions compared to female peers, especially in cost estimate/bills of quantities, and construction project management.

Desired BIM-related jobs

Students were asked of their motivations in BIM-related AEC jobs by selecting a Likert-scale score ranging from *1* to *5*, representing their attitudes from "least desired" to "highly desired". An extra numerical score at *6* was also given if they were unsure of the given BIM-related job. Excluding those who were not sure of their opinion, the overall sample analysis is summarized in Table 5.

<Insert Table 5 here>

The two top-ranked BIM-related jobs were BIM project manager and BIM engineer, with the mean Likert-scale score over *4.000*. Consistent to what was found in Table 1, facility management and quantity survey-related work were one of the lowest ranked items. Other least desired BIM-related jobs included BIM technician and BIM software developer. BIM engineer received the lowest standard deviation, indicating least variation of perceptions among students. That could be due to the fact that the majority of student respondents in this study were in engineering disciplines. They tended to desire the career path within their field of study in college.

The overall Cronbach's Alpha value at *0.8999* indicated a strong internal consistency among these listed BIM-related jobs in Table 5. The majority of these listed jobs contributed to the internal consistency due to the lower individual Cronbach's Alpha values, except these top two ranked items (i.e., BIM project manager and BIM engineer), which also had the lowest item-total correlation. Students were found more likely to have higher motivations in BIM-linked engineering and project management career paths. As shown in Tables 6 to 8, the subgroup analysis was further performed investigating how students' motivations in AEC jobs would be affected by their discipline, prior experience, and gender.

<Insert Table 6 here>

<Insert Table 7 here>

<Insert Table 8 here>

Compared to the factors of gender and prior experience, it could be found from Tables 6 to 8 that disciplines played a more significant role in affecting students' motivation in BIM-based AEC jobs. Basically, students from other disciplines had significantly higher motivations in BIM-related AEC jobs compared to their peers in CE and CEM disciplines. Specifically, non-CE and non-CEM students had much higher motivation in working as BIM software developer and BIM facility manager.

These two jobs were ranked as least favored BIM-related career paths by the student population. Other significant subgroup differences were found in that: 1) these with prior industry experience had higher motivation in working as BIM manager; 2) female students displayed a higher motivation in working as BIM coordinator.

Challenges in BIM

The last section of student perceptions was related to challenges encountered in BIM implementation. These challenges listed in Table 9 were adapted from the study of Jin et al. (2017a) to a survey sample of *94* industry professionals. Students were asked to rank their opinions on the given challenges with the standard Likert-scale items, from *1* being "very easy to overcome" to *5* meaning "very difficult to overcome", plus the extra numerical option at *6* for those who were unsure of their opinion. Excluding these who selected *6*, the overall sample analysis is summarized in Table 9.

<Insert Table 9 here>

The overall Cronbach's Alpha value at *0.7504*, although relatively lower compared to these in other sections, is still considered fairly high internal consistency. All the individual Cronbach's Alpha values lower than the overall value mean that all the challenges listed in Table 9 contribute to the internal consistency. Compared to the investigation of industry professionals' perceptions conducted by Jin et al. (2017a), more differences than similarities can be found in that: 1) students considered the cost of BIM software the top challenge, but industry professionals perceived it one of the least challenging issues in BIM implementation; 2) industry professionals selected the challenge of insufficient evaluation of the ratio of input to output in adopting BIM as the highest-ranked challenge, while students did not rank it as a major challenge; 3) similarly, compared to students, industry professionals ranked higher regarding the challenge coming from the attitudes or acceptance from AEC companies in implementing BIM; 4) students perceived more challenges from government guidelines/standards/regulations. Subgroup analysis of students' perceptions of these challenges is further analyzed in Tables 10 to 12.

<Insert Table 10 here>

<Insert Table 11 here>

<Insert Table 12 here>

It can be found from Tables 10 to 12 that students' perceptions were generally not affected by these subgroup factors, except the factor regarding the acceptance of AEC companies towards BIM adoption, which was perceived more challenging by students from non-CE and non-CEM programs, as well as female students. It has been previously identified that male students generally held a more optimistic view on BIM's applicability and its usefulness.

Discussions

Compared to disciplines and prior experience, the demographic factor (i.e., gender) seemed playing a more significant role in affecting students' perceptions in BIM's usefulness. Male students' more positive perceptions on BIM's usefulness in cost estimate and construction project management could be due to the fact that there is usually a much higher percentage of males in the construction industry and they tend to have more site experience including BIM's site application. However, the disciplinary factor was found with a more significant effect in impacting students' motivation in deciding BIM-related AEC jobs. Specifically, students other than CE or

CEM were more motivated in working as BIM facility manager or BIM software developer. They also had higher overall motivation in BIM-related industry jobs. This could be due to the fact these students defined as “others” came from disciplines of electrical and mechanical engineering, manufacturing, and architectural technology. They might have more exposure of information technology in their field of studies. For example, compared to CE or CEM, 3D visualization and other information technology generally had a wider application in manufacturing and mechanical engineering. These students might also have more practice in programming and be more interested in facility management, compared to CE and CEM students, who tended to be more interested in engineering design or construction project management.

Students were found with more positive perceptions of BIM’s usefulness in AEC professions involved in early project stages (i.e., architectural, structural, and building services design), and holding less positive views on non-design-based professions (e.g., bills of quantities) or professions in later project stages (e.g., facility management). Students’ perceptions happened to be consistent with the finding of Eadie et al.(2013), who conducted the industry survey and found out that BIM had been mostly applied in early project stages. Eadie et al. (2013) also indicated that BIM had not fully displayed its potential in facility management. Student participants in this study and industry professionals from the investigation of Eadie et al. (2013) showed consistent views in terms of the professions or project stages where BIM has shown its usefulness. It is further implied that though without sufficient industry experience, AEC students could still have some similar consistent views with industry professionals according to Jin et al. (2018).

However, the discrepancy between students and industry professionals can be found in that students generally perceived more challenges encountered in BIM practice. For example, students perceived it more challenging the high cost of BIM software and lack of industry legislations. It was discussed by Jin et al. (2017a) that gaining more practical experience could change individuals' mindset by perceiving less challenge in BIM practice, such as the insufficient BIM training. The different perceptions between students and industry professionals could be due to the less practical experience that students had. It was also identified that students' perceptions might counteract with the cutting-edge academic research. Using the building energy assessment as the example, although BIM integration with building energy performance (Kim and Anderson, 2013; Chou et al., 2017; Gourlis and Kovacic, 2017) has been an emerging research direction in recent years, students perceived less usefulness of BIM in being adopted in this direction.

The mean score, *RII* value, item-total correlation, and individual Cronbach's Alpha value all suggested that BIM engineer and BIM project manager were the two mostly desired AEC jobs. Student survey participants tended to have differed views on these two BIM-related jobs as they did with other jobs. This conveyed the information that AEC students perceived more positively of BIM potentials in earlier project stages, especially those related to engineering design and construction project management. In contrast, consistently perceived between the question of BIM's usefulness in AEC professions and the question of desired BIM jobs, facility management and quantity survey were the lowest-ranked items. This could be due to the fact that BIM has not been widely applied in the real-world context related to facility management and quantity take-off. Instead, academic research is being carried out addressing the issues within these two areas, for example, data collection of building maintenance to identify the building condition leading to the further development of preventive actions (Motawa and Almarshad, 2013), and adoption of BIM as the link to monitor material flow for automatic calculation of material quantities (Babič et al., 2010). Nevertheless, it could take a long period of time for a scientific research to be fully implemented in real-world practice. Therefore, students were more likely to show lower motivation or less positive perceptions.

It was indicated that students in this survey showed their discernment in the cutting-edge BIM's site application when deciding their desired AEC jobs. This could be due to the education that they had received in college. It was further inferred that more mature BIM-based technology would lead to more positive perceptions from students. As a result, students tended to have a higher motivation in gaining an industry job related to engineering design and project management. In contrast, a less-ready technological or managerial BIM-based application (e.g., facility management) would lead to more scientific research but less positive perceptions among AEC students. Based on the these findings focusing on the similarities and differences of perceptions between AEC students and industry professionals, future research could provide more solid strategies to address the gap between college education and the industry needs, especially in how to optimize exposing the site practice and scientific research in BIM pedagogy. Future research could continue from the current study by extending the survey sample to other institutions and to enable the cross-institutional comparative analysis, which could lead to the investigation of certain external subgroup factors' effects in students' perceptions, for example, how the local BIM industry practical culture or how the BIM pedagogical method would affect students' perceptions.

Similar to many other previous pedagogical studies (e.g., Amekudzi et al., 2010; Lewis et al., 2014; Dancz et al., 2018) , the student survey sample in the current study is limited to one institution. Future work could expand the research framework as shown in Fig.1 to other institutions and allow the cross-institutional comparison of influencing factors to students' BIM learning and perceptions.

Conclusions

Major findings

This study aimed to address the insufficient research of investigating individual perceptions of BIM industry practice from AEC students' perspective, specifically in terms of BIM's usefulness in multiple AEC professions, desired BIM-related industry jobs, and challenges encountered in BIM practice. Besides the overall sample analysis targeting on the student population from multiple AEC disciplines, subgroup factors were also studied of their impact on AEC students' perceptions in these BIM implementation categories. Adopting the questionnaire survey followed by statistical analysis, consistent findings were generated from different Likert-scale questions in that: 1) AEC students perceived BIM highly applicable in the areas of engineering design (e.g., structural engineering) and construction project management, and they favored BIM-based jobs related to engineer or project manager; 2) facility management and quantity survey were two professions that received lowest positive perceptions from student respondents. It was inferred that students' perceptions on BIM usefulness and their desired BIM-related jobs reflected the contemporary industry practice despite of their lack of industry experience. They were more likely to notice the state-of-the-art application of BIM and demonstrate their discernment in deciding their desired industry jobs. However, they were less likely to notice the state-of-the-art academic research in BIM-related directions, such as BIM-assisted building performance analysis and BIM application in facility management. Therefore, it is fair to claim that AEC students' perceptions on BIM functions were more affected by the real-world practice than the scientific research. It would be a general rule that BIM application in the real world would lead to students' more positive perceptions of BIM function. In contrast, academic research which tends to address contemporary technological or managerial issues, generally contradicts with students' perceptions of BIM capacity.

Subgroup analysis revealed that the gender-based demographic factor had a more significant effect in influencing students' perceptions on BIM's applicability and its usefulness. Basically, male students generally had more positive views on BIM being applied in various project sectors and in multiple AEC professions. In contrast, the AEC disciplinary factor was found more significant in affecting students' motivations in choosing their desired jobs. Specifically, students from non-CE and non-CEM disciplines (e.g., manufacturing and mechanical engineering) were more motivated in jobs related to BIM software development and BIM facility management.

Pedagogy recommendations

Both the overall sample analysis and subgroup evaluation in this research provide insights for BIM educators based on students' overall perceptions of BIM implementation and effects from individual factors, specifically: (1) as BIM education in college is becoming more interdisciplinary crossing AEC subjects, educators should be aware of the individual differences depending on students' AEC disciplines, their prior industry experience, and even their gender; (2) the BIM education needs for students in infrastructure subjects (e.g., transportation) may be raised as so far most students still perceive BIM application mainly in the building industry; (3) students could also be introduced to the state-of-the-art BIM research in several areas, including but not limited to BIM linked to building performance analysis, quantity survey, and facility management; and (4) in order to bridge the gap of perceptions towards BIM between students and industry professionals, innovative pedagogical delivery methods could be implemented, such as project-based interdisciplinary teamwork.

Practical implications

This research also provides suggestions for AEC employers and practitioners that AEC students, with proper college education, are able to capture the cutting-edge BIM practice despite of their lack of industry experience. AEC employers may also be aware of AEC graduates' job preference, for example, BIM jobs related to technician and quantity take-off may be less-favored by CE and CEM students, and jobs related to facility management and software development might be favored more by students from disciplines other than CE or CEM. AEC employers should also be informed of both the similarities and differences between AEC graduates and professionals. For example, AEC graduates tend to perceive the lack of BIM legislation more challenging. The more effective collaboration between entry-level BIM employees and their senior peers could be a concern. Establishing the interrelation framework among BIM pedagogy, BIM academic research, and BIM industry practice would remain ongoing work to address gaps among educators, learners, and practitioners.

Future research directions

It should be noticed that students' strong desire in BIM engineer could be partly due to fact that they were mostly enrolled in the engineering program. Future research could expand the student survey population from engineering to other AEC disciplines, such as architecture, and even business management, etc. More demographic factors affecting AEC students' perceptions towards BIM practice will be investigated, including students' learning experience of BIM, years of study in college, and the differences between undergraduate and graduate students. Another research direction in the near future will be expanding the current study from Australia to other countries including U.S., China, and U.K to enable the continental comparison of AEC students in BIM learning and practice.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request.

Acknowledgement

The authors would like to thank everyone who has helped in filling and collecting the survey questionnaires, and the support provided by the School of Engineering Swinburne University of Technology. The authors would also like to acknowledge the Writing Retreat Fund provided by University of Brighton and the collaboration provided by Wenzhou University.

Supplemental Data

The questionnaire is available on-line in the ASCE Library (ascelibrary.org).

References

Abolghasemzadeh, P. (2013). "A comprehensive method for environmentally sensitive andbehavioral microscopic egress analysis in case of fire in buildings." *Saf. Sci.,* 59, 1–9, http://dx.doi.org/10.1016/j.ssci.2013.04.008.

Ahn, Y. H., Kwak, Y. H., and Suk, S. J. (2015). "Contractors' transformationstrategies for adopting building information modeling." *J. Manage.Eng.*, 10.1061/(ASCE)ME.1943-5479.0000390, 05015005.

Aksorn, T., and Hadikusumo, B.H.W. (2008). "Critical success factors influencing safety program performance in Thai construction projects." *Safety Sci.*, 46 (4), 709-727.

Amekudzi, A., Li, L., and Meyer, M. (2010). "Cultivating research and information skills in civil engineering undergraduate students"*J. Prof. Issues Eng. Educ. Pract.*,136(1), 24-29

Azhar, S. (2011). "Building information modeling (BIM): Trends, benefits,risks and challenges for the AEC industry." *Leadership Manage Eng*.,10.1061/(ASCE)LM.1943-5630.0000127, 241–252.

Babič, N.C.,Podbreznik, P., andRebolj,D. (2010)."Integrating resource production and constructionusing BIM."*Autom. Constr.*, 19 (5), 539–543.

Both, P., Koch, V., and Kindsvater, A. (2012). “Potentials and barriers forimplementing BIM in the German AEC market.” *Proc., 30th eCAADe Conf.*, Vol. 2, Czech Technical Univ., Prague, Czech Republic.

Chou, C.C., Chiang, C.T., Wu, P.Y., Chu, C.P., and Lin, C.Y. (2017). “Spatiotemporal analysis and visualization of power consumption data integrated with building information models for energy savings.”*Resour. Conserv. Recycl.,* 123, 219-229.

Çıdık, M.S., Boyd, D., and Thurairajah, N. (2017). “Ordering in disguise: digital integration in built-environment practices.” *Build. Res. Inf.*, 45 (6), 665-680, DOI: 10.1080/09613218.2017.1309767

Cronbach, L. J. (1951). “Coefficient alpha and the internal structure of tests.”*Psychometrika.*,16 (3), 297-334.

Dancz, L.A., Bilec, M.M., and Landis, A.E. (2018). “Active experiential sustainable engineering module for engineering education”*J. Prof. Issues Eng. Educ. Pract.*,144(1),04017011.

Davies, R., and Harty, C. (2013). “Measurement and exploration of individualbeliefs about the consequences of building information modellinguse.” *Constr. Manage. Econ.,* 31(11), 1110–1127.

DeVellis, R. F. (2003). “Scale development: theory and applications.”2nd Ed., SAGE Publications, Inc., Thousand Oaks, CA.

Dijksterhuis, A., and Bargh, J. A. (2001). “The perception-behavior expressway: Automatic effects of social perception on social behavior.” *Adv. Exp. Social. Psychol.*, 33, 1–40.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., and McNiff, S. (2013). “BIM implementation throughout the UK construction project lifecycle: an analysis.” *Autom. Constr.*, 36,145-151.

Gourlis, G., andKovacic, I. (2017)“Building Information Modelling for analysis of energy efficient industrial buildings – A case study.”*Renew. Sust. Energ. Rev.*, 68, 953-963.

Han, Y., Feng, Z., Zhang, J., Jin, R., and Aboagye-Nimo, E. (2018). “Employees’ Safety Perceptions of Site Hazard and Accident Scenes.” *J. Cons. Eng. Manage.*, In Press, DOI: 10.1061/(ASCE)CO.1943-7862.0001590.

He, Q., Qian, L., Duan, Y., & Li, Y. (2012). “Current situation and barriers of BIM implementation.” *Journal of Engineering Management,* 26 (1), 12-16 (in Chinese).

He, Q., Wang, G., Luo, L., Shi, Q., Xie, J., and Meng, X., 2017. “Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis.” *Int. J. Proj. Manag*. 35, 670–685.

Howard, R., Restrepo, L., and Chang, C.Y. (2017). “Addressing individual perceptions: an application of the unified theory of acceptance and use of technology to building information modelling.” *Int. J. Proj. Manag*.,35, 107–120.

Jäväjä, S.S.P., and Salin, J. (2014). “BIM Education: Implementing and Reviewing “OpeBIM” – BIM for Teachers.” *Computing in Civil and Building Engineering*, 2151-2158.

Jin, R., Hancock C.M., Tang, L., Chen, C., Wanatowski, D., and Yang, L. (2017a). “An empirical study of BIM-implementation-based perceptions among Chinese practitioners.” *J. Manage. Eng.,* 33(5), DOI: 10.1061/(ASCE)ME.1943-5479.0000538.

Jin, R., Hancock C.M., Tang, L., & Wanatowski, D. & Yang, L. (2017b). “Investigation of BIM Investment, Returns, and Risks in China's AEC

Industries."*J. Constr. Eng. Manage.*, 143(12), DOI: 10.1061/(ASCE)CO.1943-7862.0001408.

Jin R., Li B., Zhou T., Wanatowski D., and Piroozfar P. (2017c). "An empirical study of perceptions towards construction and demolition waste recycling and reuse in China." *Resour. Conserv. Recycl.*, 126, 86-98. ISSN 0921-3449

Jin, R., Tang, L., Hancock, C.M., and Allan, L. (2016). "BIM-based multidisciplinary building design practice-a case study." *The 7th International Conference on Energy and Environment of Residential Buildings*, November 20-24, Brisbane, Australia.

Jin R., Yang T., Piroozfar P., Kang B.G, Wanatowski D., and Hancock C.M. (2018). "Project-based pedagogy in interdisciplinary building design adopting BIM." *Engineering, Construction, and Architectural Management.* In Press, https://doi.org/10.1108/ECAM-07-2017-0119.

Johnson, R.A. (2005). "Probability and Statistics for Engineers." pp. 292-317. Miller&Freund's. New Jersey, U.S.

Juszczyk, M., Výskala, M., and Zima, K. (2015). "Prospects for the use ofBIM in Poland and the Czech Republic—Preliminary research results."*Procedia Eng.,* 123, 250–259.

Kim, H., and Anderson, K. (2013). "Energy modeling system using building information modeling open standards."*J. Comput. Civil. Eng.*, 27 (3), 203-211.

Kim, J. (2011). "Use of BIM for effective visualization teaching approach in construction education." *J. Prof. Issues Eng. Educ. Pract.*, 138(3), 214-223.

Ku, K. D., and Taiebat, M. (2011). "BIM Experiences and Expectations: The Constructors' Perspective." *International Journal of Construction Education and Research*, 7:3, 175-197, DOI: 10.1080/15578771.2010.544155.

Lewis A.M., Valdes-Vasquez R., Clevenger C., and Shealy T. (2015). "BIM energy modeling: Case study of a teaching module for sustainable design and construction courses." *J. Prof. Issues Eng. Educ. Pract.,* 141(2), C5014005.

Livingston, C. (2008). "From CAD to BIM: constructing opportunities in architectural education." *AEI 2008*: *Building Integration Solutions*, 1-9.

Lu, W., and Olofsson, T. (2014). "Building information modeling and discrete event simulation: towards an integrated framework." *Autom. Constr.,* 44, 73–83, http://dx.doi.org/10.1016/j.autcon.2014.04.001.

Lucas, J. D. (2017). "Identifying Learning Objectives by Seeking a Balance between Student and Industry Expectations for Technology Exposure in Construction Education." *J. Prof. Issues Eng. Educ. Pract.*, 143(3), 5016013.

Ma, L., Sacks, R., andZeibak-Shini,R. (2015). "Information modeling of earthquake-damaged reinforcedconcrete structures."*Adv. Eng. Inform.,* 29 (3), 396–407, http://dx.doi.org/10.1016/j.ael.2015.01.007.

Masood, R., Kharal, M. K. N., and Nasir, A. R. (2013). "Is BIM adoptionadvantageous for construction industry of Pakistan?" *Procedia Eng.*, 77,229–238.

Mathews, M. (2013). "BIM collaboration in student architectural technologist learning." *AEI 2013*, 1-13.

Meliá, J. L., Mearns, K., Silva, S. A., and Lima, M. L. (2008). "Safety climate responses and the perceived risk of accidents in the construction industry." *Safety Sci.*, 46 (6), 949-958.

Motawa, I., and Almarshad,A. (2013). "Knowledge-based BIM system for building maintenance." *Autom. Constr.*, 29, 173–182.

Nawari, N.O. (2015). “The role of BIM in teaching structural design.” *Structures Congress,* 2622-2631.

Oraee, M., Hosseini, M.R., Papadonikolaki, E., Palliyaguru, R., and Arashpour, M. (2017). “Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review.” *Int. J. Proj. Manag.,* 35, 1288–1301.

Panuwatwanich, K., Wong, M., Doh, J., Stewart, R. A., and McCarthy, T. J. (2013). “Integrating building information modelling (BIM) into engineering education: an exploratory study of industry perceptions using social network data.” In C. Lemckert, G. Jenkins & S. Lemckert (Eds.), AAEE2013: *Australasian Association for Engineering Education Conference*, 1-9.

Pikas, E., Sacks, R., and Hazzan, O. (2013). “Building information modeling education for construction engineering and management. II: procedures and implementation case study.” *J. Constr. Eng. Manage.,*139(11).

Rahman, M.A., Suwal, S., and Jäväjä, P. (2013). “Diverse approach of BIM in AEC industry: a study of current knowledge and practice.” *Proceedings of the CIB W78 2013: 30th International Conference*– Beijing, China, 9–12 October, 2013.

Sackey, E., Tuuli, M., and Dainty, A. (2014). “Sociotechnical systems approach to BIM implementation in a multidisciplinary construction context.” *J. Manage. Eng.,* 31(1), DOI: 10.1061/(ASCE)ME.1943-5479.0000303.

Sacks, R., and Pikas, E. (2013). “Building information modeling education for construction engineering and management. I: industry requirements, state of the art, and gap analysis.” *J. Constr. Eng. Manage*.,139(11).

Said, H., and El-Rayes, K. (2014). “Automated multi-objective construction logistics optimization system.” *Autom. Constr.,* 43, 110–122, http://dx.doi.org/10.1016/j.autcon.2014.03.017.

Santos, R., Costa, A.A., and Grilo, A. (2017). “Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015.”*Autom. Constr.*, 80, 118–136.

Sebastian, R. (2010). “Breaking through business and legal barriers of opencollaborative processes based on building information modelling(BIM).” *Proc., W113 Special Track, 18th CIB World Building Congress,* International Council for Building, Delft, Netherlands.

Sharag-Eldin, A., and Nawari, N.O. (2010). “BIM in AEC education.” *Structures Congress,* 1676-1688.

Shelbourn, M, Macdonald, J, McCuen, T, and Lee, S. (2017). “Students' perceptions of BIM education in the higher education sector: a UK and US perspective.” Industry & Higher Education, 31 (5), 293-304.

Solnosky, R.L., and Parfitt, M.K.(2015). “A curriculum approach to deploying BIM in Architectural Engineering.” *AEI 2015*, 651-662.

Tam, V.W.Y. (2009). “Comparing the implementation of concrete recycling in the Australian and Japanese construction industries.” *J. Clean. Prod.*, 17(7), 688-702.

Tang, L., Jin, R., and Fang, K. (2015). “Launching the innovative BIM module for the architecture and built environment programme in China.” *WIT Transactions on The Built Environment*. 149, 145-156.

Trine, R. (2008). “Engineering education: quality and competitiveness from the European perspective.” TREE-disclosing conference – a report, TREE – teaching and research in engineering in Europe, 2008.

Uhm, M., Lee, G., and Jeon, B. (2017). “An analysis of BIM jobs and competencies based on the use of terms in the industry.”*Autom. Constr*.,81, 67-98.

XS CAD Limited (2018). “Issues affecting the adoption of 3D BIM modeling.” Available via < https://www.ukconstructionmedia.co.uk/press-releases/issues-affecting-the-adoption-of-3d-bim-modelling-xs-cad/>, accessed on October 19th, 2018.

Xu, J., Jin, R., Piroozfar, P., Wang, Y., Kang, B.G., Ma, L., Wanatowski, D., and Yang, T. (2018). “An Initiated BIM Climate-based Framework Incorporating Regional Comparison.” *J. Cons. Eng. Manage.,* 144(11): 04018105.

Yalcinkaya, M., and Singh, V. (2015). “Patterns and trends in building information modeling (BIM) research: a latent semantic analysis.”*Autom. Constr.*, 59, 68–80.

Zhao, D., McCoy, A. P., Bulbul, T., Fiori, C., and Nikkhoo, P. (2015). “Building collaborative construction skills through BIM-integrated learning environment.” *International Journal of Construction Education and Research*, 11(2), 97-120.

Table 1. Overall sample analysis in the question of BIM usefulness in different AEC professions (Overall Cronbach's Alpha = *0.8779*)

AEC profession	**Mean**	**Std**	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
Architectural design	4.154	0.838	0.831	2	0.4799	0.8755
Structural design	4.213	0.940	0.843	1	0.5446	0.8708
Building services design	4.071	0.949	0.814	3	0.6469	0.8629
Construction project management	4.012	0.988	0.802	4	0.6183	0.8469
Cost estimate/Bills of quantities	3.858	1.130	0.772	5	0.6488	0.8621
Quality control/quality assurance	3.769	1.113	0.754	6	0.6965	0.8576
Quantity surveying	3.722	1.080	0.744	7	0.6900	0.8583
Facility management	3.391	1.235	0.678	9	0.6898	0.8584
Building energy assessment	3.680	1.217	0.736	8	0.5806	0.8693

Table 2. ANOVA results for subgroup analysis of students divided by disciplines responding to the question of BIM usefulness in different AEC professions

AEC profession	**CE students**		**CEM students**		**Others**		**Statistical comparison**	
	Mean	Std	Mean	Std	Mean	Std	*F* value	*p* value
Architectural design	4.169	0.916	4.070	0.863	4.059	0.814	0.36	0.695
Structural design	4.193	0.996	4.397	0.793	3.971	0.985	2.26	0.107
Building services design	4.053	0.947	4.176	0.974	4.000	0.791	0.44	0.642
Construction project management	3.867	1.138	4.259	0.915	3.939	0.827	2.73	0.067
Cost estimate/Bills of quantities	3.970	1.077	3.878	1.301	3.364	1.220	**3.66**	**0.027***
Quality control/quality assurance	3.683	1.164	3.750	1.297	3.500	1.164	0.44	0.641
Quantity surveying	3.713	1.071	3.648	1.276	3.533	1.252	0.30	0.738
Facility management	3.331	1.267	3.377	1.244	3.600	1.102	0.57	0.567
Building energy assessment	3.545	1.238	3.776	1.327	3.677	1.194	0.62	0.537
Overall	3.841	0.790	3.941	0.752	3.691	0.764	1.15	0.318

* A *p* value lower than *0.05* indicates the significant differences of perceptions for students from different disciplines

Table 3. Two-sample *t*-test results for subgroup analysis of students categorized by industry experience regarding BIM's usefulness

AEC profession	**Students with industry experience**		**Students without prior experience**		**Statistical comparison**	
	Mean	Std	Mean	Std	*t* value	*p* value
Architectural design	4.016	0.924	4.171	0.868	-1.14	0.255
Structural design	4.415	0.748	4.130	1.010	**2.35**	**0.020***
Building services design	4.108	0.921	4.060	0.936	0.35	0.729
Construction project management	4.030	1.050	3.950	1.060	0.52	0.601
Cost estimate/Bills of quantities	3.800	1.340	3.880	1.100	-0.41	0.680
Quality control/quality assurance	3.640	1.200	3.680	1.200	-0.25	0.804
Quantity surveying	3.660	1.200	3.670	1.130	-0.07	0.945
Facility management	3.460	1.230	3.350	1.240	0.58	0.564
Building energy assessment	3.780	1.270	3.560	1.240	1.10	0.274
Overall	3.872	0.825	3.831	0.760	0.35	0.728

* A *p* value lower than 0.05 indicates the significant difference for students with or without prior industry experience

Table 4. Two-sample *t*-test results for subgroup analysis of students of different genders regarding BIM's usefulness

AEC profession	**Female students**		**Male students**		**Statistical comparison**	
	Mean	Std	Mean	Std	*t* value	*p* value
Architectural design	3.947	0.970	4.144	0.878	-0.85	0.406
Structural design	3.900	1.210	4.240	0.922	-1.22	0.234
Building services design	3.890	1.230	4.091	0.899	-0.68	0.504
Construction project management	3.330	1.320	4.040	1.000	**-2.39**	**0.026***
Cost estimate/Bills of quantities	3.290	1.350	3.920	1.130	**-2.07**	**0.050***
Quality control/quality assurance	3.500	1.280	3.690	1.190	-0.64	0.532
Quantity surveying	3.470	1.430	3.690	1.120	-0.64	0.530
Facility management	3.280	1.530	3.390	1.210	-0.31	0.760
Building energy assessment	3.630	1.450	3.620	1.240	0.01	0.993
Overall	3.500	1.140	3.877	0.728	-1.50	0.148

* A *p* value lower than *0.05* indicates the significant difference between male and female students

Table 5. Overall sample analysis in the question of desired BIM-related AEC jobs (Overall Cronbach's Alpha = *0.8999*)

BIM-related job titles	**Mean**	**Std***	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
BIM manager	3.806	1.055	0.761	3	0.5354	0.8962
BIM engineer	4.056	0.998	0.811	2	0.4474	0.9002
BIM coordinator	3.419	1.163	0.684	5	0.7620	0.8838
BIM technician	3.212	1.305	0.642	9	0.7557	0.8835
BIM modeler/operator/draughtsman	3.362	1.271	0.672	6	0.6724	0.8887
BIM quantity surveyor	3.237	1.261	0.647	8	0.7092	0.8865
BIM project manager	4.063	1.044	0.813	1	0.4467	0.9004
BIM leader/director	3.775	1.104	0.755	4	0.5909	0.8933
BIM software developer	2.962	1.326	0.592	11	0.6614	0.8895
BIM consultant	3.269	1.272	0.654	7	0.6452	0.8904
BIM facility manager	3.131	1.239	0.626	10	0.7152	0.8861

Table 6. ANOVA results for subgroup analysis of students divided by disciplines responding to the question of desired BIM-related AEC jobs

BIM-related job titles	**CE students**		**CEM students**		**Others**		**Statistical comparison**	
	Mean	Std	Mean	Std	Mean	Std	*F* value	*p* value
BIM manager	3.644	1.188	3.887	0.913	3.871	1.056	1.13	0.324
BIM engineer	4.060	1.045	3.765	0.815	4.188	0.965	2.28	0.105
BIM coordinator	3.365	1.266	3.510	1.138	3.813	0.859	1.84	0.162
BIM technician	3.068	1.369	3.122	1.166	3.606	1.116	2.31	0.102
BIM modeler / operator / draughtsman	3.284	1.401	3.239	1.119	3.633	1.159	1.00	0.372
BIM quantity surveyor	3.205	1.399	3.178	0.886	3.581	1.089	1.23	0.295
BIM project manager	4.035	1.096	4.265	0.836	3.906	1.027	1.36	0.259
BIM leader/director	3.702	1.159	3.740	0.965	3.903	1.044	0.41	0.662
BIM software developer	2.701	1.410	2.580	1.295	3.633	0.999	**6.92**	**0.001***
BIM consultant	3.145	1.397	2.920	1.338	3.667	1.093	2.95	0.055
BIM facility manager	2.868	1.334	2.952	1.125	3.806	1.046	**7.05**	**0.001***
Overall	3.333	0.902	3.435	0.667	3.785	0.856	**3.84**	**0.023***

* A *p* value lower than *0.05* indicates the significant differences of perceptions among students from different disciplines

Table 7. Two-sample *t*-test results for subgroup analysis of students categorized by industry experience regarding BIM-based AEC jobs

BIM-related job titles	**Students with industry experience**		**Students without prior experience**		**Statistical comparison**	
	Mean	Std	Mean	Std	*t* value	*p* value
BIM manager	4.000	0.809	3.640	1.180	**2.44**	**0.016***
BIM engineer	3.891	0.994	4.048	0.981	-1.00	0.318
BIM coordinator	3.360	1.260	3.520	1.150	-0.85	0.400
BIM technician	3.000	1.330	3.240	1.270	-1.14	0.255
BIM modeler / operator / draughtsman	3.110	1.220	3.410	1.330	-1.50	0.137
BIM quantity surveyor	3.360	1.070	3.220	1.320	0.76	0.449
BIM project manager	4.107	0.966	4.060	1.050	0.32	0.753
BIM leader/director	3.840	1.010	3.710	1.120	0.78	0.439
BIM software developer	2.850	1.470	2.800	1.330	0.24	0.812
BIM consultant	3.060	1.390	3.210	1.340	-0.70	0.486
BIM facility manager	2.960	1.300	3.070	1.280	-0.53	0.594
Overall	3.474	0.748	3.416	0.891	0.48	0.632

* A *p* value lower than *0.05* indicates the significantly different perceptions for students with or without prior industry experience

Table 8. Two-sample *t*-test results for subgroups analysis of students of different genders regarding desired BIM-based AEC jobs

Project sectors	**Female students**		**Male students**		**Statistical comparison**	
	Mean	Std	Mean	Std	*t* value	*p* value
BIM manager	3.889	0.963	3.730	1.120	0.66	0.513
BIM engineer	3.780	1.110	4.027	0.972	-0.92	0.371
BIM coordinator	4.000	1.080	3.420	1.180	**2.14**	**0.045***
BIM technician	3.390	1.140	3.150	1.310	0.84	0.413
BIM modeler / operator / draughtsman	3.390	1.200	3.320	1.320	0.22	0.825
BIM quantity surveyor	3.060	1.250	3.280	1.250	-0.69	0.497
BIM project manager	4.000	1.030	4.080	1.030	-0.31	0.759
BIM leader/director	3.760	1.300	3.740	1.070	0.07	0.944
BIM software developer	3.440	1.380	2.750	1.350	2.04	0.055
BIM consultant	3.760	1.350	3.110	1.340	1.91	0.071
BIM facility manager	3.330	1.460	3.01	1.270	0.90	0.379
Overall	3.414	0.856	3.621	0.809	-1.03	0.314

* A *p* value lower than *0.05* indicates the significant difference between male and female students

Table 9. Overall sample analysis in the question of challenges encountered in BIM implementation (Overall Cronbach's Alpha = *0.7504*)

Challenges	**Mean**	**Std***	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
Insufficient BIM education resource or training	3.300	1.079	0.660	7	0.4497	0.7239
High cost of BIM software tools	3.527	1.001	0.705	1	0.3134	0.7483
Upgrading of existing hardware	3.413	0.876	0.683	4	0.2942	0.7491
Attitudes of AEC companies towards BIM adoption	3.347	1.049	0.669	5	0.4787	0.7180
Lack of client demand for using BIM	3.213	0.945	0.643	8	0.5298	0.7096
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	3.347	1.010	0.669	5	0.5119	0.7118
Lack of legislation or incentives from government or authority	3.480	1.015	0.696	2	0.4689	0.7200
Lack of industry standards in BIM applications	3.427	1.038	0.685	3	0.5169	0.7104

Table 10. ANOVA results for subgroup analysis of students divided by disciplines responding to the question of challenges encountered in BIM practice

Challenges	**CE students**		**CEM students**		**Others**		**Statistical comparison**	
	Mean	Std	Mean	Std	Mean	Std	*F* value	*p* value
Insufficient BIM education resource or training	3.341	1.165	3.073	1.034	3.600	0.894	2.39	0.095
High cost of BIM software tools	3.552	1.111	3.528	0.973	3.621	1.049	0.07	0.931
Upgrading of existing hardware	3.325	1.020	3.453	0.952	3.615	0.941	1.03	0.358
Attitudes of AEC companies towards BIM adoption	3.425	1.097	3.137	1.077	3.806	0.910	**3.82**	**0.023***
Lack of client demand for using BIM	3.297	1.040	3.240	0.894	3.276	0.882	0.06	0.943
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	3.441	1.050	3.386	0.920	3.276	0.996	0.31	0.731
Lack of legislation or incentives from government or authority	3.432	1.125	3.523	0.952	3.355	1.018	0.23	0.793
Lack of industry standards in BIM applications	3.393	1.085	3.283	1.167	3.394	1.144	0.17	0.843
Overall	3.411	0.674	3.382	0.559	3.461	0.694	0.15	0.858

* A *p* value lower than *0.05* indicates the significantly different opinions of students from various disciplines

Table 11. Two-sample *t*-test results for subgroup analysis of students categorized by industry experience regarding challenges in BIM practice

Challenges	**Students with industry experience**		**Students without prior experience**		**Statistical comparison**	
	Mean	Std	Mean	Std	*t* value	*p* value
Insufficient BIM education resource or training	3.240	1.050	3.330	1.130	-0.56	0.580
High cost of BIM software tools	3.530	1.070	3.570	1.060	-0.26	0.799
Upgrading of existing hardware	3.448	0.958	3.380	1.010	0.48	0.629
Attitudes of AEC companies towards BIM adoption	3.330	1.150	3.440	1.060	-0.67	0.504
Lack of client demand for using BIM	3.237	0.989	3.297	0.977	-0.39	0.697
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	3.300	1.000	3.450	1.010	-0.92	0.359
Lack of legislation or incentives from government or authority	3.558	0.895	3.400	1.120	1.03	0.306
Lack of industry standards in BIM applications	3.360	1.110	3.370	1.110	-0.02	0.982
Overall	3.438	0.684	3.400	0.633	0.38	0.705

Table 12. Two-sample *t*-test results for subgroup analysis of students of different genders regarding challenges in BIM practice

Challenges	**Female students**		**Male students**		**Statistical comparison**	
	Mean	Std	Mean	Std	*t* value	*p* value
Insufficient BIM education resource or training	3.440	1.040	3.290	1.110	0.58	0.569
High cost of BIM software tools	3.760	1.090	3.540	1.060	0.83	0.419
Upgrading of existing hardware	3.650	1.220	3.373	0.970	0.90	0.381
Attitudes of AEC companies towards BIM adoption	3.824	0.636	3.370	1.110	**2.58**	**0.016***
Lack of client demand for using BIM	3.647	0.996	3.244	0.972	1.60	0.128
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	3.667	0.900	3.380	1.020	1.17	0.256
Lack of legislation or incentives from government or authority	3.353	0.996	3.450	1.070	-0.38	0.709
Lack of industry standards in BIM applications	3.180	1.190	3.390	1.100	-0.70	0.495
Overall	3.593	0.636	3.394	0.647	1.30	0.206

* A *p* value lower than *0.05* indicates the significant difference between male and female students