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6

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

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10 **Abstract**

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

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

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

#### 44 **Introduction**

45 BIM (i.e., Building Information Modeling) studies that have high impacts in the

46 research community are mostly focusing on technical aspects including BIM  
47 application and implementation (Yalcinkaya and Singh, 2015). In comparison,  
48 managerial part of BIM has not received the attention as it deserves (Oraee et al.,  
49 2017). However, the managerial aspect should be another core research area in BIM  
50 besides the technical aspect of BIM. (He et al., 2017). Most previous  
51 management-based studies in BIM focused on the industry, company, or project  
52 levels, without addressing the individual level (Howard et al., 2017). Perceptions have  
53 a direct effect in human behaviour (Dijksterhuis and Bargh 2001). Human behavior  
54 was further identified by Lu et al. (2015) as a key issue in adopting information and  
55 communication technologies. There have been some existing BIM-related studies  
56 addressing the individual perceptions towards BIM practice and implementation  
57 (Howard et al, 2017; Jin et al., 2017a; Jin et al., 2017b). However, these individual  
58 perception-based studies in BIM were mostly limited to AEC (i.e., architecture,  
59 engineering, and construction) industrial professionals (e.g., Ku and Taiebat, 2011;  
60 Panuwatwanich et al., 2013; Sacks and Pikas, 2013; Lucas, 2017), without sufficiently  
61 addressing AEC (i.e., architecture, engineering, and construction) students, the future  
62 employees in the industry. Further, the existing studies targeting on students'  
63 perspectives (e.g., Zhao et al., 2015; Shelbourn et al., 2017) focused more on the  
64 course or curriculum development of BIM, without further extending it to investigate  
65 students' perceptions on the industry implementation. There has also not been  
66 sufficient research addressing the individual perceptions towards BIM between  
67 students and industry professionals.

68 The importance of addressing AEC students' individual perceptions towards BIM  
69 lies in that they will become professionals in the industry. What they perceive BIM  
70 impact on AEC project management would also drive their learning and practical

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

91 Aiming to address the current research gaps in terms of insufficient studies  
92 targeting on AEC students, lack of individual levels of BIM managerial studies, as  
93 well as the issue of subgroup or demographic factors in BIM-involved project  
94 management, this research is comprised of these objectives: 1) to investigate students'  
95 overall perceptions towards BIM practice; 2) to investigate the effects of subgroup

96 factors (i.e., students' disciplines, prior experience, and gender) in their perceptions;  
97 and 3) to further compare the perceptions between AEC students and industry  
98 professionals from existing literature (e.g., Jin et al., 2017a). This study adopted a  
99 questionnaire survey approach by collecting perceptions of AEC students from  
100 multiple disciplines including construction engineering and management, other civil  
101 engineering disciplines (e.g., structural engineering), and other non-civil engineering  
102 subjects (e.g., architecture). Perceptions collected from students covered topics  
103 regarding BIM's usefulness in different AEC professions, students' interests in  
104 different BIM-related AEC jobs, as well as their perceptions towards challenges  
105 encountered in BIM practice. This research contributes to the existing body of  
106 knowledge in BIM by investigating the subgroup factors in AEC students'  
107 perceptions towards BIM implementation. The current study offer insights for AEC  
108 educators by shedding lights on the demographic factors' effect in BIM learning. The  
109 findings also provide insights for AEC employers regarding subgroup factors when  
110 they are hiring BIM-related employees. Further, the current study leads to future  
111 research in BIM pedagogy-based research, which was identified by Santos et al. (2017)  
112 as under-represented BIM research area.

## 113 **Literature review**

### 114 *BIM practice and implementation worldwide*

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

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

128

### 129 *Individual perceptions towards BIM practice*

130 Collaboration has been defined by multiple studies (e.g., Eadie et al., 2013; Sacks  
131 and Pikas, 2013; Jin et al., 2017a) as the key for successful BIM implementation.  
132 Collaboration also means that multiple trades (Eadie et al., 2013), disciplines (Jin et  
133 al., 2017a) and project participants (Jin et al., 2017b) are typically included in  
134 BIM-involved projects. The effects of these subgroup factors in individual  
135 perceptions towards BIM implementation have been considered important as  
136 joint-effort from multiple subgroups is imperative for successful BIM practice (Jin et  
137 al., 2017a). Perceptions towards BIM implementation generally consist of benefits,  
138 critical factors, risks, and challenges in BIM implementation according to multiple  
139 prior studies (e.g., Eadie, et al., 2013; Ahn et al., 2015; Jin et al., 2017a; Jin et al.,  
140 2017b). These studies all addressed the challenges encountered during BIM practice,  
141 including insufficient evaluation of BIM value, cultural resistance, lack of client  
142 demand, lack of BIM training, high investment in BIM resources, lack of relevant  
143 legislation or standards, and insufficient understanding of BIM technology (He et al.,  
144 2012; Sackey et al., 2014; Tang et al., 2015; Çıdık et al., 2017). Most of these studies  
145 (Ku and Taiebat, 2011; Panuwatwanich et al., 2013; Sacks and Pikas, 2013) focused

146 on the individual perceptions from the industry practitioners' perspective. Although  
147 several studies (e.g., Zhao et al., 2015; Shelbourn et al., 2017) captured students'  
148 perceptions towards BIM, they focused on the BIM course or curriculum itself, but  
149 not in the practical level of BIM implementation (Jin et al., 2017a).

### 150 *BIM pedagogy and training*

151 Educational institutions play a key role in BIM adoption (Jävämä and Salin, 2014).  
152 A review of existing studies in BIM pedagogy revealed that most studies have  
153 focused on a single discipline, for example, architecture (Livingston, 2008),  
154 construction engineering (Kim, 2011), and structural engineering (Nawari, 2015).  
155 Institutions (e.g., Sharag-Eldin and Nawari, 2010; Mathews, 2013; and Tang et al.,  
156 2015) have also adopted collaborative teamwork approach in BIM pedagogy,  
157 especially the interdisciplinary collaboration approach (Jin et al., 2018). Pikas et al.  
158 (2013) suggested that BIM education should be implemented at the program level  
159 rather than an isolated course. BIM education has been identified by both academia  
160 and industry as a necessity (Solnosky and Parfitt, 2015). However, insufficient  
161 resources and university conservations were identified by Trine (2008) as key barriers  
162 in meeting this demand. Furthermore, the effects of BIM in AEC education have not  
163 been sufficiently investigated (Solnosky and Parfitt, 2015). On the other hand, Sacks  
164 and Pikas (2013) emphasized the importance of BIM education in meeting industry  
165 needs.

### 166 **Methodology**

167 This study consisted of two main research methods, namely a questionnaire survey to  
168 AEC students, and the follow-up statistical analysis. The questionnaire survey was  
169 one of the widely recognized research approaches investigating both practical and  
170 pedagogical topics in the field of construction engineering and management (e.g.,

171 Lewis et al., 2015; Zhao et al.,2015; Jin et al., 2017a). In this study, the questionnaire  
172 was developed by the researchers by partially adapting the BIM challenge-related  
173 question items from Jin et al. (2017a). Details of the questionnaire can be seen in  
174 the Appendix. Fig. 1 describes the research framework of this BIM-learner-based  
175 study.

176 <Insert Fig.1 here>

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

#### 185 *Questionnaire survey*

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

- 193 • the first section was designed with questions in the multiple-choice format to  
194 collect student background information, including students' discipline (e.g., CEM),

195 whether or not having prior industry experience, and gender. Earlier studies (e.g.,  
196 Eadie et al., 2013; Jin et al., 2017a; Jin et al., 2017c) addressed individual factors  
197 (e.g., AEC profession) in affecting the industry professionals' perceptions of  
198 certain construction themes (e.g., digital technology). Demographic factors (e.g.,  
199 gender) have been an ongoing concern in the AEC industry worldwide. This study  
200 was further designed to investigate whether these subgroup factors would affect  
201 students' individual perceptions of these follow-up four sections using the  
202 five-point Likert-scale format;

- 203 • multiple AEC professions were listed as another section to study students'  
204 perceptions on the usefulness of BIM in each of them. BIM practice involved  
205 multi-disciplinary collaboration (Eadie et al., 2013; Jin et al., 2017b; Santos et al.,  
206 2017). BIM-related industry jobs, such as BIM manager, BIM coordinator, and  
207 BIM engineer identified by Sacks and Pikas (2013) and Uhm et al. (2017) were  
208 listed in the questionnaire;
- 209 • a list of potential challenges encountered during BIM implementation were asked  
210 to students to collect their opinions on the ease of overcoming them. These  
211 challenges have been studied in previous managerial studies of BIM, such as  
212 insufficient evaluation of BIM value (Sebastian, 2010), and higher initial cost of  
213 BIM (Azhar, 2011), etc. Collection of students' perceptions of these challenges  
214 would allow the comparison between AEC students and practitioners.

215 The questionnaire was initiated from August to September 2017. Later it was  
216 peer reviewed externally by BIM educators from other institutions during October  
217 2017. A pilot study was performed a smaller group of AEC students to make sure that  
218 these questions were clearly presented. The finalized questionnaire survey was then  
219 sent to the survey population from Faculty of Science, Engineering & Technology in

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

### 235 *Statistical analysis*

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

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

$$244 \quad RII = \frac{\sum w}{A \times N} (1)$$

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

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

263 Surveys were then divided into subgroups according to the students' disciplines in  
264 AEC fields, industry experience, and gender. Subgroup analysis was conducted using  
265 parametric methods, including Analysis of Variance (ANOVA) and the two-sample  
266  $t$ -test. Parametric methods have been adopted in earlier studies involving Likert-scale  
267 questions in the CEM field, such as Aksorn and Hadikusumo (2008), Meliá et al.  
268 (2008), and Tam (2009). Both ANOVA and the two-sample  $t$ -test were based on the  
269 null hypothesis that there were no subgroup differences among students' perceptions

270 of the given Likert-scale item. Setting the level of significance at 5%, a  $F$  value and a  
271  $t$  value were computed respectively in ANOVA and the two-sample  $t$ -test. A  
272 corresponding  $p$  value was then generated in both parametric methods to test the null  
273 hypothesis. A  $p$  value lower than 0.05 would reject the null hypothesis and suggest  
274 significant differences of subgroup factors in perceiving the given item related to BIM  
275 applicability, usefulness, BIM-based jobs, or challenges.

## 276 **Results and findings**

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

285 <Insert Fig.2 here>

286 CE students in this sample accounted for over 60% of total survey population.  
287 The CE subgroup excluded CEM, which was identified as a separate subgroup.  
288 Examples of CE students in this study included structural engineering. Others  
289 included a variety of different non-CE disciplines, such as building services  
290 engineering, architectural technology, and architecture, etc. The majority (i.e., 73%)  
291 of the student population did not have prior AEC industry experience. Those with  
292 some previous experience had been working in the industry from three months to over  
293 13 years, with the average industry experience at 23 months, and the median  
294 experience at 12 months. Fig.2 also shows that female students only accounted for 10%

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

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

### 303 *BIM usefulness in different AEC professions*

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

310 <Insert Table 1 here>

311  
312 Four items listed in Table 1 received the mean Likert scores over 4.000,  
313 indicating students' highly positive perceptions of BIM's usefulness in these four  
314 top-ranked AEC professions, namely architectural design, structural design, building  
315 services design, and construction project management. It should be noticed that all of  
316 these four professions were either design-based or general construction management.  
317 Students were prone to perceive BIM's usefulness in the early project delivery stages  
318 (e.g., design). In comparison, other non-design-related professions (e.g., cost estimate)  
319 or post-design work (e.g., facility management) received less positive perceptions  
320 from survey respondents. Besides facility management, building energy assessment

321 also received one of the lowest mean scores from students, inferring that there had  
322 been limited education on linking BIM to building performance.

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

327 <Insert Table 2 here>

328 <Insert Table 3 here>

329 <Insert Table 4 here>

330  
331 Several significant differences can be found from Tables 2 to 4, including: 1) CE  
332 and CEM students held more positive views on BIM's usefulness in cost  
333 estimate/bills of quantities compared to those from other disciplines; 2) students with  
334 prior industry experience had more positive views of BIM's usefulness in structural  
335 design; 3) male students generally held more positive perceptions compared to female  
336 peers, especially in cost estimate/bills of quantities, and construction project  
337 management.

### 338 *Desired BIM-related jobs*

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

344 <Insert Table 5 here>

345

346 The two top-ranked BIM-related jobs were BIM project manager and BIM

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

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

363 <Insert Table 6 here>

364 <Insert Table 7 here>

365 <Insert Table 8 here>

366  
367 Compared to the factors of gender and prior experience, it could be found from  
368 Tables 6 to 8 that disciplines played a more significant role in affecting students'  
369 motivation in BIM-based AEC jobs. Basically, students from other disciplines had  
370 significantly higher motivations in BIM-related AEC jobs compared to their peers in  
371 CE and CEM disciplines. Specifically, non-CE and non-CEM students had much  
372 higher motivation in working as BIM software developer and BIM facility manager.

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

### 377 *Challenges in BIM*

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

386 <Insert Table 9 here>

387  
388 The overall Cronbach’s Alpha value at  $0.7504$ , although relatively lower  
389 compared to these in other sections, is still considered fairly high internal consistency.  
390 All the individual Cronbach’s Alpha values lower than the overall value mean that all  
391 the challenges listed in Table 9 contribute to the internal consistency. Compared to the  
392 investigation of industry professionals’ perceptions conducted by Jin et al. (2017a),  
393 more differences than similarities can be found in that: 1) students considered the cost  
394 of BIM software the top challenge, but industry professionals perceived it one of the  
395 least challenging issues in BIM implementation; 2) industry professionals selected the  
396 challenge of insufficient evaluation of the ratio of input to output in adopting BIM as  
397 the highest-ranked challenge, while students did not rank it as a major challenge; 3)

398 similarly, compared to students, industry professionals ranked higher regarding the  
399 challenge coming from the attitudes or acceptance from AEC companies in  
400 implementing BIM; 4) students perceived more challenges from government  
401 guidelines/standards/regulations. Subgroup analysis of students' perceptions of these  
402 challenges is further analyzed in Tables 10 to 12.

403 <Insert Table 10 here>

404 <Insert Table 11 here>

405 <Insert Table 12 here>

406

407

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

#### 414 **Discussions**

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

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

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

447 However, the discrepancy between students and industry professionals can be

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

460 The mean score, *RII* value, item-total correlation, and individual Cronbach's  
461 Alpha value all suggested that BIM engineer and BIM project manager were the two  
462 mostly desired AEC jobs. Student survey participants tended to have differed views  
463 on these two BIM-related jobs as they did with other jobs. This conveyed the  
464 information that AEC students perceived more positively of BIM potentials in earlier  
465 project stages, especially those related to engineering design and construction project  
466 management. In contrast, consistently perceived between the question of BIM's  
467 usefulness in AEC professions and the question of desired BIM jobs, facility  
468 management and quantity survey were the lowest-ranked items. This could be due to  
469 the fact that BIM has not been widely applied in the real-world context related to  
470 facility management and quantity take-off. Instead, academic research is being carried  
471 out addressing the issues within these two areas, for example, data collection of  
472 building maintenance to identify the building condition leading to the further

473 development of preventive actions (Motawa and Almarshad, 2013), and adoption of  
474 BIM as the link to monitor material flow for automatic calculation of material  
475 quantities (Babič et al., 2010). Nevertheless, it could take a long period of time for a  
476 scientific research to be fully implemented in real-world practice. Therefore, students  
477 were more likely to show lower motivation or less positive perceptions.

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

496 Similar to many other previous pedagogical studies (e.g., Amekudzi et al., 2010;  
497 Lewis et al., 2014; Dancz et al., 2018), the student survey sample in the current study

498 is limited to one institution. Future work could expand the research framework as  
499 shown in Fig.1 to other institutions and allow the cross-institutional comparison of  
500 influencing factors to students' BIM learning and perceptions.

## 501 **Conclusions**

### 502 *Major findings*

503 This study aimed to address the insufficient research of investigating individual  
504 perceptions of BIM industry practice from AEC students' perspective, specifically in  
505 terms of BIM's usefulness in multiple AEC professions, desired BIM-related industry  
506 jobs, and challenges encountered in BIM practice. Besides the overall sample analysis  
507 targeting on the student population from multiple AEC disciplines, subgroup factors  
508 were also studied of their impact on AEC students' perceptions in these BIM  
509 implementation categories. Adopting the questionnaire survey followed by statistical  
510 analysis, consistent findings were generated from different Likert-scale questions in  
511 that: 1) AEC students perceived BIM highly applicable in the areas of engineering  
512 design (e.g., structural engineering) and construction project management, and they  
513 favored BIM-based jobs related to engineer or project manager; 2) facility  
514 management and quantity survey were two professions that received lowest positive  
515 perceptions from student respondents. It was inferred that students' perceptions on  
516 BIM usefulness and their desired BIM-related jobs reflected the contemporary  
517 industry practice despite of their lack of industry experience. They were more likely  
518 to notice the state-of-the-art application of BIM and demonstrate their discernment in  
519 deciding their desired industry jobs. However, they were less likely to notice the  
520 state-of-the-art academic research in BIM-related directions, such as BIM-assisted  
521 building performance analysis and BIM application in facility management. Therefore,  
522 it is fair to claim that AEC students' perceptions on BIM functions were more

523 affected by the real-world practice than the scientific research. It would be a general  
524 rule that BIM application in the real world would lead to students' more positive  
525 perceptions of BIM function. In contrast, academic research which tends to address  
526 contemporary technological or managerial issues, generally contradicts with students'  
527 perceptions of BIM capacity.

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

#### 536 *Pedagogy recommendations*

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

548 towards BIM between students and industry professionals, innovative pedagogical  
549 delivery methods could be implemented, such as project-based interdisciplinary  
550 teamwork.

551 *Practical implications*

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

565 *Future research directions*

566 It should be noticed that students' strong desire in BIM engineer could be partly  
567 due to fact that they were mostly enrolled in the engineering program. Future research  
568 could expand the student survey population from engineering to other AEC  
569 disciplines, such as architecture, and even business management, etc. More  
570 demographic factors affecting AEC students' perceptions towards BIM practice will  
571 be investigated, including students' learning experience of BIM, years of study in  
572 college, and the differences between undergraduate and graduate students. Another

573 research direction in the near future will be expanding the current study from  
574 Australia to other countries including U.S., China, and U.K to enable the continental  
575 comparison of AEC students in BIM learning and practice.

#### 576 **Data Availability Statement**

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

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#### 585 **Supplemental Data**

586 The questionnaire is available on-line in the ASCE Library ([ascelibrary.org](http://ascelibrary.org)).

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

<b>AEC profession</b>	<b>Mean</b>	<b>Std</b>	<b><i>RII</i></b>	<b>Ranking</b>	<b>Item-total Correlation</b>	<b>Cronbach's Alpha</b>
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

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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	<i>F</i> value	<i>p</i> 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	<b>3.66</b>	<b>0.027*</b>
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

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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	<i>t</i> value	<i>p</i> 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	<b>2.35</b>	<b>0.020*</b>
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

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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	<i>t</i> value	<i>p</i> 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	<b>-2.39</b>	<b>0.026*</b>
Cost estimate/Bills of quantities	3.290	1.350	3.920	1.130	<b>-2.07</b>	<b>0.050*</b>
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

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

<b>BIM-related job titles</b>	<b>Mean</b>	<b>Std*</b>	<b>R/I</b>	<b>Ranking</b>	<b>Item-total Correlation</b>	<b>Cronbach's Alpha</b>
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

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993 Table 6. ANOVA results for subgroup analysis of students divided by disciplines  
 994 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	<i>F</i> value	<i>p</i> 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	<b>6.92</b>	<b>0.001*</b>
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	<b>7.05</b>	<b>0.001*</b>
Overall	3.333	0.902	3.435	0.667	3.785	0.856	<b>3.84</b>	<b>0.023*</b>

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

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1029 Table 7. Two-sample *t*-test results for subgroup analysis of students categorized by  
 1030 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	<i>t</i> value	<i>p</i> value
BIM manager	4.000	0.809	3.640	1.180	<b>2.44</b>	<b>0.016*</b>
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

1031 \* A *p* value lower than 0.05 indicates the significantly different perceptions for students with or  
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1064 Table 8. Two-sample *t*-test results for subgroups analysis of students of different  
 1065 genders regarding desired BIM-based AEC jobs

Project sectors	Female students		Male students		Statistical comparison	
	Mean	Std	Mean	Std	<i>t</i> value	<i>p</i> 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	<b>2.14</b>	<b>0.045*</b>
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

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1100 Table 9. Overall sample analysis in the question of challenges encountered in BIM  
 1101 implementation (Overall Cronbach's Alpha = 0.7504)

Challenges	Mean	Std*	<i>RII</i>	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

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1132 Table 10. ANOVA results for subgroup analysis of students divided by disciplines  
 1133 responding to the question of challenges encountered in BIM practice

Challenges	CE students		CEM students		Others		Statistical comparison	
	Mean	Std	Mean	Std	Mean	Std	<i>F</i> value	<i>p</i> 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	<b>3.82</b>	<b>0.023*</b>
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

1134 \* A *p* value lower than 0.05 indicates the significantly different opinions of students from various  
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1163 Table 11. Two-sample *t*-test results for subgroup analysis of students categorized by  
 1164 industry experience regarding challenges in BIM practice

Challenges	Students with industry experience		Students without prior experience		Statistical comparison	
	Mean	Std	Mean	Std	<i>t</i> value	<i>p</i> 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

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1201 Table 12. Two-sample *t*-test results for subgroup analysis of students of different  
 1202 genders regarding challenges in BIM practice

Challenges	Female students		Male students		Statistical comparison	
	Mean	Std	Mean	Std	<i>t</i> value	<i>p</i> 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	<b>2.58</b>	<b>0.016*</b>
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

1203 \* A *p* value lower than 0.05 indicates the significant difference between male and female students  
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