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Comparisons of Students' Perceptions on BIM Practice among Australia, China and U.K.

Abstract

Purpose –University students are the future driving forces in and leaders ofthe AEC industry advancement. Although BIM pedagogical studies have been performed in different institutions, there has not been sufficient research providing a global perspective of BIM education and students' perceptions towards BIM practice and application following their learning progress. This study adopted student samples from Swinburne University of Technology (SUT, Australia), Wenzhou University (WZU, China), and University of Brighton (UoB, U.K.) as three case studies to investigate the BIM practice and application-related perceptions and motivations.

Design/Methodology/Approach – Based on the thorough understanding of the BIM pedagogical delivery including teaching contents and assessment methods among the three institutions, a questionnaire survey approach was adopted to collect AEC students' perceptions of BIM.Within each selected case,statistical analysis was conducted to investigate both the overall sample and subgroup differences regarding students' opinions on BIM's functions (e.g. as a 3D visualization tool) and BIM usefulness in various industry professions, their motivation in BIM-related jobs, and their perceptions of challenges encountered in BIM practice and application. Multiple factors influencing BIM learners' perceptions were discussed, such as pedagogical assessment approach, and individual factors (e.g. disciplines).

Findings –The results showed that students were able to discern the latest industry practices and critical thinking in BIM movements. For example, SUT students perceived more challenges from the government legislation or incentive policies, which was consistent with Australia's BIM policy movement. WZU students tended to have less positive views on BIM usefulness. The results also indicated fewer differences regarding perceived challenges among students from these three institutions.

Originality/value –This study contributed to the body of knowledge in managerial BIM by focusing on learners' perceptions from the perspective of students' understanding, motivation, and individual views of BIM, which were insightful to both BIM educators and employers. By initiating the framework of BIM learning process and its influence factors, the current study serves as a point of reference to continue the future work in strengthening the connection between institutional BIM education and industry practical needs worldwide.

Keywords: Building InformationModelling (BIM); Pedagogy; Education;Comparative Analysis;Subgroup analysis; Individual perceptions

1. Introduction

BIM, or Building Information Modelling, which is the digital technology that enables creations of accurate virtual models and supports the project delivery process, was viewed by Eastman et al. (2011) as one of the most promising developments in the architectural, engineering, and construction (AEC) industry. The movement of BIM in the global AEC market has driven practical, academic research, and educational activities worldwide. Much academic research of BIM has focused on technical aspects referring to BIM application and implementation (Yalcinkaya and Singh, 2015), but less on the managerial part of BIM which is also a key critical factor for successful BIM practice (Oraee et al., 2017). One important aspect within managerial BIM is the collaboration among project team members (Eadie et al., 2013; Tang et al., 2015). It was further indicated by Jin et al. (2016) that there could be a complementary relationship between new college graduates with BIM skillsets and senior professionals with more industry experience. The study of perceptions towards BIM practice between AEC students and industry professionals is needed because: 1) perceptions would have a direct impact on individual behavior(Dijksterhuis and Bargh, 2001); and 2) BIM-based projects would involve team members from different background and experience levels (e.g., entry-level and senior employees), and their shared perceptions towards BIM could be a driver towards multi-disciplinary and cross-experience-levelcollaboration in the BIM environment (Jin et al., 2017a).

A review of existing literature revealed the following knowledge gaps: 1) most existing managerial BIM studies focused on the industry, company, or project levels, without sufficiently addressing the individual level (Howard et al., 2017); 2) most existing BIM studies of individual perceptions (e.g., Eadie et al., 2013; Ding et al., 2015; Howard et al, 2017;) targeted industry professionals, without sufficiently addressing perceptions from AEC students or graduates; 3) compared to other BIM-related studies (e.g., interoperability), the education, training, and pedagogy of BIM have not been sufficiently studied (Santos et al., 2017); 4) existing BIM-pedagogy-based studies focus mainly on case studies of individual institutions or a single discipline (e.g., Sacks and Barak, 2010; Nawari, 2015; Jin et al. 2017c). There have been various BIM pedagogical delivery and assessment methods acrossinstitutions which could lead to different student perceptions and behaviors in BIM practice, and there have been limited comparative studies of BIM education focusing on AEC students' perceptions across differentinstitutions worldwide.

Addressing these gaps is important due to the following facts: 1) the global BIM movement (Jin et al., 2017b) has driven educational institutions to establish or promote their BIM programs in order to update themselves in the AEC education; 2) AEC students or college graduates are the future employees of the industry and they play a significant role in the AEC market (Zou et al., 2018). There is a need to study their perceptions towards BIM practice following their BIM learning; 3) the knowledge gap identified between industry needs and BIM institutional education (Wu and Issa, 2014) requires more effective coping strategies from the perspective of BIM pedagogy; and 4) there is a need to bridge BIM educators, leaners, and industry practitioners to enhance college graduates' readiness in the job market, and to reduce AEC employers' investment in training BIM competent employees (Sacks and Pikas, 2013;;Solnosky and Parfitt, 2015).

By adopting student survey samples from three universities located in different continents (i.e., Swinburne University of Technology (SUT) Australia, Wenzhou University (WZU) China, and the University of Brighton (UoB) UK, this study aims to achieve the following objectives: 1) to study the overall perception of students towards BIM practice; 2) to analyze the sub-sample perceptions of students from the three selected case study universities; and 3) to discuss potential factors that lead to different perceptions among students (e.g., local BIM practice and BIM assessment methods). Students' perceptions towards BIM were categorized into their opinions of BIM functions (e.g., as a digital platform for cross-disciplinary collaboration), BIM's usefulness in various AEC professions (e.g., architectural design), their desire for BIM-related industry jobs (e.g., BIM engineer), and challenges encountered in BIM practice. The sampling strategy for choosing these three universities was Simple Random Sampling (SRS) and the only criteria used were that chosen samples should represent the mainstream higher education institutions in their country of origin and should not be considered as leading universities, orbelong in the bottom of the academic league table in their respected countries. It was believed that following these simple inclusion/exclusion criteria within the SRS strategy, will increase the validity, reliability and in return the generalisability of the knowledge claim of this study. The findings from this case study further address the connection between institutional education and industry practice in

BIM. The study provides insights to BIM educators in a global perspective of how students from different institutions perceive BIM after a certain period of BIM learning and practice. AEC employers could also gain information from this study on how students (i.e., their potential future employees) view BIM practice and students' motivation in BIM-related jobs. The study also leads to future studies to evaluate the perceptions between BIM learners and BIM industry practitioners.

2. Background

2.1. BIM movement in Australia, China, and U.K.

BIM has enjoyed fast growth in the AEC global market, such as Australia (Hong et al., 2018), China (Zhao et al., 2018), UK (Khosrowshahi and Arayici, 2012), USA (Oraee et al., 2018), Canada (Poirier et al., 2017), and Scandinavia (Jensen and Jóhannesson, 2013). The UK Government Construction Strategy Board (2011) required the U.K. AEC industry to achieve BIM Level 2 (i.e. three-dimensional environment with interdisciplinary data sharing) by 2016. The BIM Task Group (2011), funded by the UK government, was founded in 2011 aiming to strengthen the public sectors' capacity in BIM implementation towards collaborative BIM and to establish British Standards for BIM Level 2. More recently, the UK Government's Department for Business, Innovation and Skills (DBIS, 2016) has launched the Digital Built Britain programme focusing on the development of BIM Level 3. According toInnovate UK and Infrastructure and Projects Authority (2017), Level 3 of BIM has commenced its development and is expected to come to practice by mid-2020s.

Following the UK's BIM movement, a number of Australian government agencies (e.g., Transport for New South Wales, Transport and Infrastructure, and the Northern Territory Department of Infrastructure) have started moving towards using BIM (Consult Australia, 2016). The Report from Australia's Standing Committee on Infrastructure, Transport and

Cities (SCITC, 2016) recommended that the Australian government should form a smart infrastructure task force (modelled on the UK BIM Task Group) to promote the BIM policy nationwide, including the development of standards, training, and education on BIM. The Report further suggested that Australian government require BIM implementation at the LOD (i.e., Level of Detail) 500 on all infrastructure projects over $*50* million in funding provided by the government.

Somewhat similar to Australia, China's BIM movement was also guided by government from both federal and state levels. From the federal government side, China's BIM policy has moved forward fast in recent years, from announcing the digitalization visions in 2011 to proposing the BIM application across the entire project lifecycle in 2014 (Jin et al., 2015). In the state or provincial level, Shanghai Municipal People's Government (2014) announced the strategic objective of promoting BIM implementation in Shanghai, requiring that government-funded projects must adopt BIM starting from 2017.

Alongside the fast BIM movement in these three countries, challenges in implementing BIM have been studied in Australia (Aibinu and Venkatesh, 2014), China (Ding et al., 2015), and U.K. (Eadie et al., 2013). Commonly encountered challenges in BIM implementation included but not limited to cost of implementing BIM features within the existing practice, reluctance of moving from a 2D (i.e., two-dimensional) to a 3D working environment, lack of client demands, collaboration issues among project team members, and lack of industry standards or guidelines (He et al., 2012; Sackeyet al., 2014; Tang et al., 2015;Çıdık et al., 2017). Among these challenges, lack of sufficient education resources and university restrictions were identified by multiple studies (Trine, 2008; Gier, 2015; Puolitaival and Forsythe, 2016) as another key barrier in meeting the industry demand for BIM-capable employees.

2.2. BIM pedagogy and learning

BIM education and training was identified by Khosrowshahi and Arayici (2012) as one of the key strategies on UK's roadmap of BIM implementation. Institutional education is of key importance in BIM transition (Solnosky and Parfitt, 2015; Jäväjä and Salin, 2016). BIM-pedagogy-based studies have been adopted in multiple AEC disciplines, such as architecture (Mathews, 2013), construction engineering (Kim, 2011), and civil engineering (Ma et al., 2015). More recent BIM education-based studies (e.g., Zhang et al., 2018) have adopted team-based and project-based learning approach stressing the project delivery process. BIM has also been linked to other AEC subjects in pedagogical work, such as energy modeling (Lewis et al., 2015). Interdisciplinary BIM pedagogy (e.g., Solnosky et al., 2014) was further adopted aiming to expose students to multiple AEC disciplines in the BIM-based project teamwork.

Researchers (e.g., Gerber et al., 2013; Sacks and Pikas, 2013) suggested that BIM education should be improved to address the industry needs. Efforts (e.g., Solnosky et al., 2014; Wu et al., 2015; Lucas, 2017) have been made in addressing the gap between BIM education and industry requirements, such as inviting industry partners to evaluate student BIM work. The study of Wu and Issa (2014) revealed that a more proactive partnership would enhance the institutional education and help the industry partners recruit BIM talents. It was further suggested by Pikas et al. (2013) that BIM education should be practiced at the program level instead of an isolated course. Upon the completion of BIM pedagogical work, Zou et al. (2018) suggested that BIM learners' perceptions could be further compared to that of industry professionals in order to identify the gap.

3. Research Methodology

This study utilizes a multiple-case, single-unit of analysis (Gustafsson, 2017) case study method to investigate university students' perceptions of BIM practices among three cases which have been chosen using Simple Random Sampling (SRS) strategy (Berger and Zhang,

2005) in UK, Australia, and China. Although the main research instrument used for the single-unit analysis of this study is purely statistical – hence the choice of questionnaire survey as the main data collection means for this study, it is crucially important to note that the knowledge claim of this study does not follow that of a pure quantitative methodology. The case study method at the heart of this study, like experiments, bounds the findings of this study to be generalizable to theoretical propositions and not to the populations or universes the samples may seemingly represent. In this sense, the case study, does not represent a 'sample', and the investigators' goal is to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization) (Yin, 1989). The choice of questionnaire as a main instrument for the single unit of analysis of this study was made to meet multiple purposes. Firstly, it would have made it possible to conduct a pure statistical analysis between the cases which represented mainstream institutions in their country of origin. Furthermore, a statistical (pure and interpretative) analysis also made an internal comparison of perceptions of different aspects of this study within each of those selected cases internally. Last but not least, the other advantage of using questionnaire was that not only it could have used and did use the data collection methods as suggested by precedent studies (e.g., Eadie et al., 2013; Ding et al., 2015), but it will also provide a standardized tool for future studies on which identical or similar studies can be built that in return offers higher degree of validity and reliability of the current study. The validity and reliability of data collected through questionnaire survey were checked following the rules suggested by Heale and Twycross (2015). For example, (1) the same questionnaire was reviewed and agreed by BIM instructors from all the three institutions in this study to ensure that the same variables (e.g., students' motivations in BIM-related jobs) were measured; (2) theory evidence was applied by linking students' BIM perceptions to their learning behaviors;

and (3) homogeneity (i.e., internal consistency) of BIM categories in the questionnaire was analyzed using Cronbach's Alpha value (Cronbach, 1951).

Three institutions including Swinburne University of Technology (SUT) from Australia, Wenzhou University (WZU) from China, and University of Brighton (UoB) from UK were selected as three cases for the continental comparison of students' perceptions towards BIM-practice related questions. They were selected using simple random sampling method and the rationale behind selection of these three institutions was based on the fact that:

1. They all are representatives of mainstream universities in their country of origin. They do not represent the top-ranked or bottom of the league table universities.
2. They had all been actively implementing BIM undergraduate education in recent years (i.e. after 2012).
3. BIM educators from all these three institutions had been keen to carry out pedagogy research to evaluate their students' learning and perceptions of BIM practice and they all expressed strong interests in viewing their BIM education from a global perspective through institutional comparisons.

To make this study materialise and prior to its launch, BIM educators from all of the three institutions discussed, and confirmed that BIM pedagogy in their respective institutions represents the average level of BIM education in their home countries, in terms of the year BIM course was launched, and assessment of learning outcomes (e.g. teamwork and digital skills, as well as addressing the AEC industry needs in their countries).Fig.1 describes the research methods associated with the three pre-defined research objectives.

<Insert Fig.1 here>

As indicated in Fig.1, this study started with case studies method using multiple-cases comprising three institutions where a single-unit of analysis were utilised through a questionnaire survey as the data collection instrument within each institution. Since August

2017, researchers and educators from SUT, WZU, and UoB have communicated the teaching and learning experience of BIM and decided to conduct a comparative study by collecting their own students' perceptions of BIM. The shared questionnaire was initiated during August and September 2017 by BIM educators from the three institutions. BIM course instructors from these three institutions discussed and finalized the questionnaire in the end of September. Afterwards, the questionnaire was peer reviewed externally by BIM educators from other institutions and further modified during October 2017. Following the pilot study procedure described by Xu et al. (2018) when delivering questionnaires in different geographic regions, the initiated questionnairewas sent out to smaller groups of final year AEC students from the three institutions to ensure that: 1) these questions were clear and easily understood by students; and 2) the questionnaires were delivered by instructors in a consistent approach (e.g. students were provided with proper explanation of the research purpose). The formal questionnaire was then sent to AEC students in SUT, WZU, and UoB between November and December in 2017.

The questionnaire consisted of two major sections. The first section focused on collecting the background information of the students, including their age, AEC discipline (e.g. civil engineering or architectural technology etc.), and their prior learning experience of BIM. The second part of the questionnaire adopted five-point Likert-scale questions targeting students' perceptions of BIM's functions, BIM's usefulness to multiple AEC professions (e.g. structural design), desired BIM-related industry jobs (e.g., BIM coordinator), and challenges encountered in BIM practice.Likert scale, as suggested byVagias (2006), can be adopted to collect responses on the sample population's level of agreement, level of desirability, level of concern, or level of problem.Students were evaluated of their level of agreement on different BIM functions following their learning process, such as whether BIM was just another software tool like CAD. AEC professions were defined by IMSCAD (2013) that covered various players (e.g. construction management) who worked together to achieve project completion. Students were also asked to rank their level of agreement on BIM's applicability in multiple AEC professions. In the section related to BIM industry jobs, brief job descriptions were provided to students following the definitions provided by Joseph (2011). For example, BIM coordinators were defined as professionals who coordinated the multiple digital models from different disciplines (e.g. structural and mechanical models) involving clash-detection; BIM manager would develop BIM materials for marketing purpose, establish documented procedures and workflows, as well as adopting pro-active approaches in practicing new BIM software packages. In comparison, BIM director would work in the higher management position (e.g. executive) at the organization level and are responsible for visioning, planning, and strategizing BIM implementation. Students were asked to rank their level of desirability in the pre-defined BIM-related jobs. Finally, they were also guided to select a Likert-scale related to their level of concern in challenges encountered in BIM practice.

Statistical analyses were performed following the data collection of student responses from SUT, WZU, and UoB. Besides the basic statistical values (i.e., the mean value and the standard deviation for each Likert-scale item), main analysis methods included: 1) the relative importance index (*RII*) to rank students' perceptions towards items within each Likert-scale question; 2) the internal consistency analysis incorporating Cronbach's Alpha value, and analysis of variance (ANOVA) to studying the subgroup differences of students from SUT, WZU, and UoB. More detailed descriptions of these three methods are provided below:

- The *RII* has been widely applied in empirical studies in the field of construction engineering and management (CEM), such as Tam (2009)andEadie et al. (2013), and Xu et al. (2018). Its value ranges from *0* to *1*. A higher *RII* value means that the corresponding item was perceived by students with more significance or importance. It was calculated following Equation (1) proposed by Kometa et al. (1994) and Tam et al. (2000):

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

where w represents the Likert-scale score from *1* to *5*; A denotes the highest numerical score which was *5* in this study, and N meant the number of valid responses from students.

- Cronbach's Alpha value, initiated by Cronbach (1951), was adopted to measure the internal consistency among Likert-scale items within each question regarding students' perceptions of BIM practice. Ranging from *0* to *1*, the value between *0.70* and *0.95* would be considered acceptable with high internal consistency (Nunnally and Bernstein, 1994; Bland and Altman, 1997). A higher Cronbach's Alpha value means that a student who selected one numerical score in one item is more likely to assign a similar score to other items within the same question. For the overall student sample, an internal consistency analysis table was provided in each of the four sections corresponding to students' perceptions of BIM applicability, BIM usefulness, desired BIM-related jobs, and BIM-practice-related challenges respectively. An individual Cronbach's Alpha value and an item-total correlation coefficient were also computed corresponding to each item within every section. An individual Cronbach's Alpha value higher than the overall value would mean that the given Likert-scale item does not contribute to the internal consistency(Hanover College Psychology Department, 2018). In other words, it indicates that students tend to perceive differently of this given item than they would do to others.
- Within each section or Liket-scale question, ANOVA, as one of the parametric methods, was adopted to analyze the subgroup consistencies and differences for students from SUT,

WZU, and UoB. The parametric method was adopted in this study over non-parametric approach due to the facts (The Minitab Blog, 2015) that: (1) parametric tests perform well with skewed and non-normal distributions, especially for One-Way ANOVA in this study with each subgroupsample size over 15; and (2) parametric tests have more statistical power than non-parametric methods.Theadvantage of parametric over non-parametric methodsisalso stated by Sullivan and Artino (2013) in terms of the robustness.Parametric methods including ANOVA have been adopted in some earlier studies in the field of construction engineering and management (CEM), such as Aksorn and Hadikusumo (2008); Meliá et al. (2008); and Tam (2009). The robustness of parametric methods in being applied in questionnaire survey samples have been proved by Carifio and Perla (2008) and Norman (2010), including samples that were small-sized or skewed (e.g.,Pearson, 1931; Tam, 2009). Based on the null hypothesis that there were no significant differences of perceptions for students among SUT, WZU, and UoB using the level of significance at *5%*, the F value and its corresponding p value were computed for each item. A p value lower than *0.05* would reject the null hypothesis and suggest that students from these three institutions held different perceptions towards the given item. Following ANOVA, a post-hoc analysis was conducted to further confirm which pair of subgroups held significantly different perceptions. Based on 95% Confidence Internals, two types of post-hoc methods were adopted in this study, including Tukey Simultaneous and Fisher Individual.

Following the questionnaire survey accompanied with statistical analysis, a qualitative discussion was adopted to analyzepotential internal and external factors that could affect students' perceptions towards BIM practice, for example, the teaching and learning strategy of BIM (Wu and Issa, 2014), and local BIM climate (Xu et al., 2018), etc.

4. Results

4.1. Background of survey participants

At the end of December 2017, excluding those who had no prior learning experience of BIM, *117*, *35*, and *40* valid responses were received from SUT, WZU, and UoBrespectively.More information of the survey results (e.g., total number of questionnaire delivered at each institution) can be found in Table 1.

<Insert Table 1 here>

The number of total population within each institution referred to the total sample of students who could have BIM learning experience. The number of questionnaires distributed in each institution was counted as students who were willing to participate in the survey after being explained with the purpose of this study in the end of the BIM course. Following the anonymous site questionnaire survey procedure described by Chen and Jin (2013), as well as Han et al. (2018), potential survey participants could either decide to participate or decline the survey request. They could also withdraw the survey in the middle of filling the questionnaire. The returned questionnaire number was counted as those who completed and submitted the questionnaire. The valid questionnaire number was counted by excluding those incomplete questionnaires from the returned sample, as well as following the screening procedure described by Smits et al. (2017). For example, those who chose the same Likert-scale score for all items within one section would be considered invalid.

Based on the valid questionnaires returned, the background information (i.e. student age, AEC disciplines, learning experience of BIM) of student survey participants from these three universities are also summarized in Table 1.

4.2. Student perceptions towards BIM function

Students were asked of their opinions on BIM functions which reflected their understanding of BIM. Using the five-point Likert-scale format with *1* being “strongly disagree”, *3* indicating a neural attitude, and *5* meaning “strongly agree”, totally eight different functions listed in Table 2 were ranked according to their *RII* scores. Excluding those choosing*6* indicating that they were unsure of the answer, the statistical information including mean value, standard deviation, item-total correlation (ITC), and Cronbach’s Alpha value for the overall student sample are presented in Table 2.

<Insert Table 2 here>

The overall Cronbach’s Alpha value at *0.8245* suggests a fair internal consistency among students from these three universities, meaning that a student assigning a numerical score to one BIM function is likely to select a close score to the remaining items. According to Table 2, the two BIM functions (i.e. BIM as a management tool and as a digital platform) were ranked top based on their higher *RII* scores with lowest variations among students. These two functions were also the only two items with *RII* scores over *0.800*, or mean scores over *4.000*, indicating that students held the view between “strongly agree” and “agree” towards F5 and F6. In contrast, F1 (i.e. BIM as another software tool) was ranked lowest by students. Students also had the highest variations on F1. F1 was also the only BIM function that was perceived by students differently as they did to other functions, due to its significantly lower ITC with higher Cronbach’s Alpha value than the overall value. The overall sample was then divided into the three institutions and their internal consistency within their own institution were analyzed. Table 3 shows the comparison among them.

<Insert Table 3 here>

The overall Cronbach’s Alpha values for all the three sub-samples were relatively strong, indicating good internal consistencies within each of them. WZU students were found having significantly higher individual Cronbach’s Alpha values in F1 and F2 than their overall value, indicating that WZU students had highly differed perceptions of BIM as a software tool and as a 3D visualization tool. In investigate the subgroup differences, students from these three subgroups were compared of their perceptions using ANOVA. Table 4 displays the results of statistical comparison.

<Insert Table 4 here>

Table 4 reveals that there were significant differences of students' opinions on BIM functions. Although there was no significant difference regarding the overall perception of BIM functions among students from the three institutions, a few subgroup differences in individual items were found (i.e., F5, F6, and F8). It was suggested that SUT students had higher positive perception of BIM as management tool, digital platform, and environmental assessment tool compared to their peers from WZU and UoB. Fig.2 showcases the post-hoc analysis identifying SUT students' more confirmative perceptions towards F5 (i.e. BIM as a project management tool).

<Insert Fig.2 here>

4.3. Student perceptions towards BIM's usefulness in different AEC professions

Students were asked to rank the usefulness of BIM in various AEC professions listed in Table 5. Using the Likert-scale format, they were guided to choose a numerical score from *1* being "least useful" to *5* suggesting "most useful". Excluding those unsure of the answer, the overall sample analysis is summarized in Table 5.

<Insert Table 5 here>

The overall Cronbach's Alpha value at *0.9051* shows a fairly high internal consistency among items. Students generally held similar views on BIM's usefulness in multiple professions except architectural design, which was also one of the top-ranked items. The individual Cronbach's Alpha value higher than the overall value meant that students were likely to have different perceptions on BIM's usefulness in architectural design as they did to other professions. Three AEC professions (i.e. architectural design, structural design, and building services design) received the mean scores over *4.000,* indicating that students perceived BIM to be more useful in them. These three items were all related to project design stages. The overall student sample was then divided into three institutions and the subgroup analysis is summarized in Table 6 and Table 7.

<Insert Table 6 here>

It can be seen in Table 6 that all the three institutions had generally high internal consistency in their perceptions of these AEC professions however, exceptions can be found within these subgroups. Basically, UoB students had every item in Table 6 contributing to the internal consistency, meaning that UoB students who selected one numerical score to one item would be likely to assign a close score to all other items. WZU students had the largest variation of perceptions over these items. Specifically, they had more diverged opinions of BIM's usefulness in structural design, building services design, and building energy assessment. The architectural design was perceived by SUT students differently. Similar to the finding in Table 5, these three top-ranked items were viewed by students with more differences. Further subgroup analysis was conducted using ANOVA. Table 7 displays the outcomes of comparisons of students' perceptions towards each individual AEC profession as well as the overall view of these professions.

<Insert Table 7 here>

Similar to Table 4, significant differences were found in Table 7 regarding students' perceptions in most individual items and the overall perception. Students from SUT and UoB perceived BIM with significantly more usefulness in the overall and most individual AEC professions compared to WZU students. Fig.3 showcases the post-hoc analysis demonstrating that compared to peers from SUT and UoB, WZU students generally held significantly less confirmative views towards BIM's overall usefulness in all these listed AEC professions. The same factors that affected WZU students' less positive perceptions on BIM's applicability might also be applied in BIM's usefulness (i.e., local BIM practice and teaching delivery of BIM).

<Insert Fig.3 here>

4.4. Students' desired BIM-related AEC jobs

Following the studies of Wu and Issa (2014), and Uhm et al. (2017), this study asked for students' motivations in multiple BIM-related AEC industry jobs listed in Table 8 and Table 9. Students were asked to select a five-point Likert-scale score to show their interests in these BIM-related jobs. Based on the numerical score options with *1* meaning "least desired", *2* being "not very interested", *3* indicating neutral, *4* denoting "interested", *5* inferring "most desired", the statistical analysis for the overall sample is provided in Table 8.

<Insert Table 8 here>

High internal consistency was found in the overall sample according to Table 8, with all BIM-related jobs contributing to the internal inter-correlation. No jobs received mean scores over *4.000* which indicated higher level of motivation of students. However, two BIM-related jobs (BIM software developer and BIM facility manager) received mean scores below *3.000*. The BIM jobs ranked top by students included BIM project manager, BIM engineer, and BIM leader/director. It was indicated that students generally were more interested in management or engineering related jobs. By further dividing the overall sample into three subgroups according to their institutions, internal consistency analysis was re-performed and is shown in Table 9.

<Insert Table 9 here>

Though all three subgroups had high overall Cronbach's Alpha values, the internal consistencies for WZU and UoB students were even higher compared to that of SUT. Each subgroup has one item with its individual Cronbach's Alpha value higher than its overall value. Similar to the findings shown in Table 8, students from SUT and WZU were more interested in jobs related to manager, leader, or director. UoB students had less interests in being a BIM quantity surveyor. Further, subgroup analysis in Table 10 enables the cross-institutional comparison of student motivations in BIM-related industry jobs.

<Insert Table 10 here>

Similar to Table 4 and Table 7, significant differences among subgroups were found in majority of these individual items in Table 10. However, differing from Table 4 and Table 7 where WZU students showed less positive perceptions in BIM applicability and usefulness, the overall mean values showed that SUT and WZU students had significantly more motivation in obtaining a BIM-related AEC job compared to their peers from UoB. The reason of UoB students' less interests in BIM jobs remain to be discussed.

4.5. Student perceptions on challenges in BIM practice and implementation

The last section of the questionnaire targeted student opinions of challenges encountered in BIM practice. These challenges listed in Table 11 were adapted from Jin et al. (2017a). Students were asked to rank the level of challenges, from *1* being "least challenging" to *5* indicating "most challenging". Excluding those who selected *6* inferring that they were unsure of the given challenges, the overall sample analysis is provided in Table 11.

<Insert Table 11 here>

Relative weaker internal consistency was found in challenge-related items, compared to that in other sections. Respondents tended to have a more varied opinions on the challenge related to the high cost of BIM software, which was the top-ranked difficulty together with lack of governmental legislation/incentive. Overall, all challenges in Table 11 received the mean scores between *3.000* and *4.000*, indicating that students generally held the perception between neutral and "challenging". The lack of client demand, which was identified by Aibinu and Venkatesh (2014) as one of these main barriers in Australia's AEC market, was ranked bottom by the overall student sample. Table 12 summarized the subgroups' internal consistencies.

<Insert Table 12 here>

It is found in Table 12 that SUT students had much lower internal consistency compared to that in WZU and UoB. The overall lower internal consistency was caused by the sample from SUT, where students had different opinions on high cost of BIM software as well as upgrading of existing hardware. UoB students also held different views on upgrading existing hardware as they did to other potential challenges. The more diverged views of SUT students on challenges could be explained by the higher diversity of the SUT student sample in terms of their age range, AEC disciplinary background, and learning experience. The subgroup comparison for students among the three institutions is continued in Table 13.

<Insert Table 13 here>

Unlike three previous sections where significant differences were identified among the three subgroups, students from SUT, WZU, and UoB were found with fewer differences regarding their opinions on challenges encountered in BIM implementation. Though in most cases, they were found with consistent opinions on these challenges listed in Table 13, SUT students were more concerned on the government legislation and incentive policy on promoting BIM usage. Post-hoc analysis further suggested that SUT students perceived higher degrees of challenges in the items related to hardware upgrading and evaluation of the BIM value.Overall, SUT students also held more conservative views on BIM-implementation-related challenges.

5. Discussion of findings

Two of the BIM functions (i.e. as a project management tool and as a digital platform for interdisciplinary collaboration) were perceived most positive by the overall student sample. This was consistent with findings from industry-based surveys (e.g.Eadie et al., 2013) that collaboration was a key issue in successful BIM practice. BIM as an interdisciplinary digital platform had also been emphasized in the institutional education (e.g. Jin et al., 2017c). The survey question reflecting students' perceptions of BIM functions indicated that students from the three selected institutions had gained certain understanding of BIM, especially compared to some AEC industry professionals, who might still consider BIM mainly as a visualization tool (Zhang et al., 2018). Nevertheless, subgroup differences should be noticed among students from these different institutions. For example, compared to students from SUT and UoB, WZU students agreed more on the view that BIM was a software tool similar to CAD and as a 3D visualization tool. SUT students held more positive views of BIM as a project management tool, digital platform, as well as an environmental assessment tool. These differences among subgroups could be due to both external and internal factors. External factors include the local BIM climate defined by Xu et al. (2018) related to the local BIM industry culture. Internal factors include students' teaching and learning experience, which is not only related to students' time of learning, but also how the BIM course was delivered and assessed. For example, in SUT, the BIM education had focused on not only 3D visualisation and engineering drawings, but also management-based BIM and environmental sustainability. In comparison, WZU's BIM education had highlighted more on training students with BIM software skills. WZU's BIM pedagogical method could reflect the local industry culture, as BIM had been largely applied as a 3D visualization skill (Jin et al., 2015) and there was a large need of BIM technicians. These different pedagogical delivery and assessment methods could result in students' differed perceptions towards BIM, as reflected in the questionnaire survey results summarized in Tables 2, 3, and 4. Furthermore, the continental comparison of BIM education indicate the pedagogical and practical needs between technical and managerial skills in BIM. Both technical skill and management capability are needed in BIM practice, and the educational focus between techniques and management could be emphasized accordingly in institutional education.

Students seemed to perceive that BIM offers more usefulness when applied in early design stages involving architectural, structural, and building services design. In contrast, AEC professions perceived less use at later project stages (e.g. facility management and quantity surveying). Facility management or quantity surveying related BIM jobs also received the least interests from students. As found by Zou et al. (2018), students generally perceived more usefulness and showed more interest in BIM at the early stages of a project. This could be due to the fact that BIM has been more widely applied in AEC design-related practice. The application of BIM in follow-up project work such as facility management remain relatively rare (Carreira et al., 2018) and needs more academic research.

Compared to those from SUT, Australia and UoB,UK, students from WZU, China consistently held significantly less positive views on BIM's usefulness in various AEC professions. Factors causing the significant differences in WZU students remain to be explored, although it could be due to the local BIM climate in China as defined by Xu et al. (2017) where WZU is located, and how the BIM teaching was designed, delivered, and assessed. Some other internal factors that caused WZU student's different perceptions could be further investigated. For example, in this case study, WZU students all came from the same discipline (i.e., CE), with little age variation, and similar learning experience of BIM. These internal factors could lead to WZU students' more consistent views on BIM practice with smaller variation of opinions. Compared to their peers from WZU, SUT and UoB students came from different AEC disciplines with larger variations of age, and possibly with a larger variation of practical experience. As a result, students from SUT and UoB could have larger variations of their opinions compared to their WZU counterparts (e.g., Table 10 and

Table 13). Further studies are needed to investigate these internal or personal factors affecting individual students' perceptions, such as AEC discipline, age, and prior industry experience.

When it came to students' motivation in obtaining BIM-related industry jobs, WZU and SUT students had similar levels of motivation, significantly higher than the motivation of UoB students. It was inferred that students' perceptions of BIM's applicability and usefulness might not necessarily lead to their motivation in findings a relevant BIM job. The current case studies can lead to further research on the comparison among BIM pedagogical activities crossing institutions, and how the pedagogical approach would affect students' perceptions.

Finally, when asked about their opinions on the challenges encountered in BIM implementation, fewer subgroup differences were found among students across the three institutions, except for the concern on governmental legislation and incentive policy to promote BIM practice. SUT students expressed their concern over the perceived the challenges in Australia's BIM policy movement. According to multiple Australian industry and governmental reports (e.g., Consult Australia, 2016; Gelic et al., 2016; SCITC, 2016), although Australian governmental authorities have been intensifying the BIM usage and research, the adoption of BIM has not been mandated so therefore needs to undergo further development (Gelic et al., 2016). SCITC (2016) recommended the Australian government follow the strategy of UK's BIM Task Group (2011) to implement BIM policy nationwide. In comparison, internationally, multiple countries including U.K. and China have mandated the use of BIM (Consult Australia, 2016). Therefore, it is inferred that Australia might have a longer way to undergo before reaching mandatory BIM adoption. Correspondingly, Students at SUT Australia also perceived more challenges in the legislation and policy. It has also been previously identified by Zou et al. (2018) that students held some similar perceptions to AEC professionals towards BIM implementation. The differing views among SUT students towards these challenges (i.e., BIM software costs and hardware upgrading) could be due to the higher diversity of SUT student sample in terms of their age groups, BIM learning experience, and AEC disciplinary background.

Based on this comparative study, a framework is initiated in Fig.4to illustrate students' BIM learning and practical process.

<Insert Fig.4here>

As can be seen in Fig.4, there is a starting phase corresponding to BIM learning when students started their college BIM courses. In the middle of their BIM learning (e.g., the end of one BIM course), students could have developed their perceptions towards BIM practice. It should be noticed that their perceptions, as shown in Fig.4, are affected by multiple factors, including both internal factors such as students' own disciplines and prior industry experience (Zou et al., 2018), as well as external factors (e.g., the teaching delivery of BIM courses). The perceptions would drive their continuous learning and practice by adopting BIM in their academic or professional work. It should be noticed that the learning process does not necessarily end but continues after students become industry practitioners who would then be involved in the local industry culture and industry guidelines. It is also noticed that there is a starting phase of BIM learning, but not necessarily a last phase due to the loop described in Fig.4. Industry practitioners with BIM experience, could also return to university to redevelop their BIM learning skills and perceptions. According to Fig.4, multiple factors affect the learning process consisting of learning, post-learning perceptions, and behaviors to transform a learner to an industry practitioner. These influencing factors, as indicated in this study, include but are not limited to: students' disciplines (e.g., construction management); learning resource affected by the pedagogical delivery and assessment method determined by BIM educators; industry guideline and policy influenced by governmental authorities; local industry culture formed by project owners, AEC employers, and industry practitioners. The interconnections among these multiple roles (i.e., authority, employer, educator, owner, and learner/practitioner) can be seen in Fig.4. More demographic factors can be studied in the future for their impacts on BIM learning, such as age, gender, and prior industry experience.

6. Conclusions

This study aimed to address the issue of limited research that had been conducted to investigate the individual perceptions of AEC students towards BIM practice and the lack of cross-institutional comparison of students' perceptions following their BIM learning. The questionnaire-survey approach was adopted to gaugestudents' perceptions from three different case study universities located in Australia, China, and UK. The statistical evaluation was carried out to study the overall sample and subgroup differences in terms of students' perceptions towards BIM functions, BIM's usefulness in different AEC professions, their motivation in multiple BIM-related jobs, and their opinions on challenges encountered in BIM practice. However, as the main underlying method used for this research remains to be case study method, the generalisation of the findings does not use the statistical discourse at its core. By contrast the discourse for making the generalisation of the findings of this study lays its foundation on analytical discourse.

The overall analysis revealed that students generally held more positive views on BIM functions as a project management tool and as an interdisciplinary digital platform rather than as a 3D visualization tool. Students generally perceived more usefulness of BIM in early project stages or design-related work, but less at later stages of project work such as on facilities management. Facilities management related jobs were also ranked by students as one of the least desired BIM jobs. Students' perceptions on BIM function, usefulness, and their motivations in BIM-related jobs showed to some degree their discernment on the latest industry practice as well as their understanding of BIM. Cross-institutional comparisons of student perceptions and motivations in BIM revealed that students from WZU China held significantly less positive view on BIM usefulness. However, those from UoB U.K. showed significantly less motivation in obtaining a BIM-related industry job. Students from SUT Australia held more varied views among these challenges, and they were more concerned about government legislation or incentive policies. This could be linked to the BIM policy movement in Australia, which might be behind the U.K. and China. Compared to peers from two other institutions, SUT students also perceived higher degrees of challenges in hardware upgrading and sufficient evaluation of BIM value.

The qualitative discussion following the questionnaire survey and statistical analysis led to a framework describing the loop from an individual's start of BIMlearning into an industry practitioner. Multiple stakeholders (e.g., employer) and influence factors to individuals' perceptions of BIM were discussed within the context of the BIM learning loop.Based on the findings from the comparative study including the proposed framework, the following suggestions are provided for both BIM educators and industry practitioners: 1) students' perceptions on BIM practice are affected by both external and internal factors, such as demographic factors (e.g., gender), professional experience, learning experience of BIM, pedagogical delivery of BIM, students' discipline (e.g., architectural technology), and the social, cultural, and economic background of their country of study or work (e.g., Australia, China, and U.K. in this case study). It is recommended that future research address these factors' impacts on BIM learners' perceptions and behaviors; 2) Corresponding to industry practice, both managerial and technical skills of BIM should be emphasized in BIM education. A comprehensive education program or curriculum covering different aspects of BIM would be needed for students from various disciplines; 3) with proper education, college graduates could develop consistent perceptions as industry practitioners do. Therefore, institutional education plays an important role in preparing students for their future career. Overall, both educator and employers should be aware of these aforementioned individual factors that may affect the perceptions of BIM learners and practitioners. A closer connection between educators and employers would be helpful in establishing a stronger joint vision of BIM education areas such as BIM in life cycle assessment.

By proposing the framework that described multiple influencing factors to BIM learning and that linked multiple professional roles in BIM learning and practice, this BIM comparative study contributes to the body of knowledge in managerial BIM in terms that: 1) the continental comparison provides insights for peer BIM educators based on students' perceptions following their learning activities. Educators could thenreflect and react towards their own BIM pedagogical workaccordingly based on students' feedback; 2) it allows the further comparison between BIM learners and industry practitioners by addressing the connection between industry needs and education visions, such as the needs between technical and managerial BIM skills; 3) it contributes to the body of knowledge in BIM pedagogy and education by extending managerial BIM research from previously limited to industry practitioners to learners and college graduates, by proposing multiple factors (e.g. student demographic factors) affecting learners' perceptions of BIM.

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Table 1. Comparison of student background among SUT, WZU, and UoB

Description		SUT (Australia)	WZU (China)	UoB (U.K.)
Summary of survey results	Total student population for BIM survey	428	38	98
	Total questionnaire distributed	387	38	76
	Total questionnaire returned	257	36	44
	Return rate	66%	95%	58%
	Valid questionnaire number for this study	117	35	40
Student age (years)	Minimum	19	21	19
	Maximum	41	23	38
	Median	22	22	20.5
	Mean	22.9	22.0	21.8
	Standard deviation	3.5	0.8	4.1
Disciplines		Around 66% of students came from CE (excluding CEM*), 25% enrolled in CEM, and 9% from other disciplines (e.g., building services engineering).	All from CE	CE (45%), Building Surveying (25%), Architectural Technology (20%), and CEM (9%)
Learning experience of BIM		Minimum learning experience of BIM at 1 month, maximum learning and practical experience at 84 months, median, mean, and standard deviation at 12, 19, and 13.7 months respectively	One semester in Fall 2017	One semester in Fall 2017

*: CEM stands for construction engineering and management.

Table 2. Overall sample analysis of BIM functions (Overall Cronbach's Alpha = *0.8245*)

BIM Function	**Mean**	**Std***	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
F1: BIM can be used as another computer software tool like CAD	3.459	1.471	0.692	8	**0.394**	**0.8290**
F2: BIM can be used as a 3D modelling tool for visualization	3.908	1.228	0.782	3	0.535	0.8058
F3: BIM can be used as an energy assessment tool	3.792	1.305	0.758	6	0.665	0.7871
F4: BIM can be used as a quantity surveying tool	3.603	1.296	0.721	7	0.598	0.7969
F5: BIM can be used as a management tool in project design, construction, and asset management.	4.127	1.152	0.825	1	0.547	0.8045
F6: BIM is can be used as a digital platform for interdisciplinary collaboration.	4.078	1.140	0.816	2	0.591	0.7992
F7: BIM can be used as a data exchange platform.	3.876	1.251	0.775	5	0.475	0.8137
F8: BIM can be used as an environmental impact assessment tool for managing building performance throughout its life cycle.	3.886	1.248	0.777	4	0.604	0.7963

*: Std stands for standard deviation. The same rule applies to all other tables.

Table 3. Comparison of internal consistency among SUT, WZU, and UoB regarding the question of BIM functions

BIM functions	SUT (Australia) Overall CA=0.8311		WZU (China) Overall CA=0.8503		UoB (U.K.) Overall CA=0.8051	
	ITC	**CA**	**ITC**	**CA**	**ITC**	**CA**
F1	0.477	0.824	**-0.021**	**0.8975**	0.423	0.8045
F2	0.611	0.804	**0.101**	**0.8734**	0.493	0.7877
F3	0.629	0.801	0.879	0.7953	0.720	0.7506
F4	0.596	0.806	0.700	0.8177	0.542	0.7798
F5	0.477	0.821	0.815	0.8055	0.701	0.7561
F6	0.616	0.805	0.719	0.8171	0.422	0.7964
F7	0.447	0.826	0.801	0.8032	0.461	0.7919
F8	0.631	0.802	0.736	0.8127	0.448	0.7939

*: 1. The definitions from F1 to F8 are provided in Table 2. The same rule applies to Table 4. 2. ITC stands for Item-total Correlation, and CA means Cronbach's Alpha.

Table 4. ANOVA results for subgroup analysis of students from the three different universities to the question of BIM functions

BIM Function	**SUT (Australia)**		**WZU (China)**		**UoB (U.K.)**		**Statistical comparison**		**Post-hoc analysis results**
	Mean	Std	Mean	Std	Mean	Std	*F* value	*p* value	
F1	3.308	1.551	3.943	0.725	3.524	1.565	2.65	0.073	WZU Students held somewhat more confirmatory views compared to SZU peers.
F2	3.855	1.308	4.171	0.514	3.905	1.322	0.93	0.396	No significant subgroup differences
F3	3.880	1.409	3.719	0.888	3.663	1.258	0.50	0.605	No significant subgroup differences
F4	3.701	1.410	3.455	1.003	3.402	1.168	1.03	0.358	No significant subgroup differences
F5	4.336	1.179	3.656	0.745	3.890	1.148	**5.85**	**0.003 ***	SUT students held more confirmative views than two other subgroups
F6	4.282	1.224	3.600	0.770	3.841	0.925	**5.76**	**0.004 ***	SUT students held more confirmative views than two other subgroups
F7	3.923	1.421	3.563	0.878	3.902	0.944	1.07	0.344	No significant subgroup differences
F8	4.051	1.286	3.744	1.272	3.485	0.870	**3.12**	**0.047 ***	SUT Students held somewhat more confirmatory views compared to WZU peers.
Overall	3.916	0.916	3.735	0.569	3.749	0.780	1.01	0.368	No significant subgroup differences

*: A *p* value lower than *0.05* indicates significant differences among respondents from the three different institutions

Table 5. Overall sample analysis in the question of BIM's usefulness in different AEC professions (overall Cronbach's Alpha = *0.9051*)

AEC profession	**Mean**	**Std**	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
Architectural design	4.278	0.840	0.856	2	**0.4533**	**0.9085**
Structural design	4.306	0.895	0.861	1	0.5699	0.9019
Building services design	4.069	0.973	0.814	3	0.6733	0.8951
Construction project management	3.903	1.092	0.781	4	0.7824	0.8866
Cost estimate/Bills of quantities	3.875	1.170	0.775	5	0.6961	0.8934
Quality control/quality assurance	3.667	1.177	0.733	8	0.7892	0.8857
Quantity surveying	3.708	1.090	0.742	7	0.7447	0.8895
Facility management	3.417	1.232	0.683	9	0.7629	0.8880
Building energy assessment	3.819	1.095	0.764	6	0.6265	0.8984

Table 6. Comparison of internal consistency among SUT, WZU, and UoB regarding the question of BIM's usefulness in different AEC professions

AEC profession	**SUT (Australia) Overall CA=0.8937**		**WZU (China) Overall CA=0.8676**		**UoB (U.K.) Overall CA=0.9189**	
	ITC	**CA**	**ITC**	**CA**	**ITC**	**CA**
Architectural design	**0.3543**	**0.9011**	0.5463	0.8583	0.6465	0.9138
Structural design	0.5559	0.8891	**0.2603**	**0.8810**	0.7426	0.9090
Building services design	0.7144	0.8780	**0.4011**	**0.8704**	0.7552	0.9070
Construction project management	0.7372	0.8760	0.8290	0.8305	0.7333	0.9082
Cost estimate/Bills of quantities	0.6544	0.8821	0.7066	0.8426	0.5866	0.9173
Quality control/quality assurance	0.7464	0.8740	0.8028	0.8327	0.8194	0.9020
Quantity surveying	0.6879	0.8794	0.8288	0.8320	0.6493	0.9147
Facility management	0.7657	0.8727	0.7858	0.8338	0.8136	0.9027
Building energy assessment	0.6672	0.8810	**0.2354**	**0.8829**	0.6938	0.9108

*: ITC stands for Item-total Correlation, and CA means Cronbach's Alpha.

Table 7. ANOVA results for students from SUT, WZU, and UoB responding to the question of BIM usefulness in different AEC professions

AEC profession	**SUT (Australia)**		**WZU (China)**		**UoB (U.K.)**		**Statistical comparison**		**Post-hoc analysis results**
	Mean	Std	Mean	Std		Std	*F* value	*p* value	
Architectural design	4.336	0.812	4.029	0.785	4.561	0.743	**4.28**	**0.015 ***	WZU students held significantly lessconfirmative views than peers from two other institutions.
Structural design	4.455	0.864	3.576	1.173	4.500	0.679	**13.52**	**0.000 ***	Same as above
Building services design	4.160	0.951	3.781	0.906	4.079	0.969	1.94	0.147	No significant differences
Construction project management	4.211	1.010	2.871	1.118	3.902	0.860	**21.77**	**0.000 ***	WZU students held significantly lessconfirmative views than peers from two other institutions.
Cost estimate/Bills of quantities	4.152	1.133	2.966	1.117	3.895	0.924	**13.52**	**0.000 ***	Same as above
Quality control/quality assurance	3.848	1.292	2.933	1.112	3.474	1.033	**6.96**	**0.001 ***	WZU students held significantly lessconfirmative views than peers from SUT.
Quantity surveying	3.856	1.136	2.793	1.013	3.737	1.032	**10.86**	**0.000 ***	WZU students held significantly lessconfirmative views than peers from two other institutions.
Facility management	3.480	1.283	2.833	1.206	3.588	0.892	**3.98**	**0.021 ***	Same as above
Building energy assessment	3.881	1.235	3.387	0.882	3.875	0.871	2.46	0.088	WZU students held somewhat lessconfirmative views than peers from SUT.
Overall	4.043	0.766	3.266	0.702	3.992	0.659	**15.51**	**0.000 ***	WZU students held significantly lessconfirmative views than peers from two other institutions.

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

Table 8. Overall sample analysis in the question of desired BIM-related AEC jobs (Overall Cronbach's Alpha = *0.9045*)

BIM-related job titles	**Mean**	**Std***	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
BIM manager	3.521	1.159	0.704	4	0.6180	0.8973
BIM engineer	3.799	1.094	0.760	2	0.5905	0.8988
BIM coordinator	3.201	1.144	0.640	6	0.7949	0.8878
BIM technician	3.042	1.256	0.608	8	0.7693	0.8886
BIM modeler/operator/draughtsman	3.313	1.220	0.663	5	0.6404	0.8962
BIM quantity surveyor	3.076	1.212	0.615	7	0.6127	0.8977
BIM project manager	3.806	1.136	0.761	1	0.5375	0.9015
BIM leader/director	3.632	1.133	0.726	3	0.6184	0.8973
BIM software developer	2.646	1.287	0.529	11	0.6043	0.8985
BIM consultant	3.042	1.251	0.608	8	0.6423	0.8961
BIM facility manager	2.840	1.120	0.568	10	0.6671	0.8948

Table 9. Comparison of internal consistency among SUT, WZU, and UoB regarding students' motivation in different BIM-related industry jobs

BIM-related job titles	**SUT (Australia) Overall CA=0.8535**		**WZU (China) Overall CA=0.9537**		**UoB (U.K.) Overall CA=0.9454**	
	ITC	**CA**	**ITC**	**CA**	**ITC**	**CA**
BIM manager	0.4505	0.8477	0.7405	0.9513	0.8164	0.9380
BIM engineer	0.3508	0.8535	0.8662	0.9463	0.7520	0.9407
BIM coordinator	0.7179	0.8269	0.8721	0.9464	0.9132	0.9355
BIM technician	0.7479	0.8230	0.8434	0.9472	0.8836	0.9355
BIM modeler/operator/draughtsman	0.5123	0.8437	0.8395	0.9474	0.8097	0.9383
BIM quantity surveyor	0.6505	0.8318	0.8294	0.9482	**0.4118**	**0.9530**
BIM project manager	**0.2715**	**0.8583**	0.7726	0.9500	0.8139	0.9381
BIM leader/director	0.5002	0.8442	**0.5952**	**0.9557**	0.7607	0.9404
BIM software developer	0.5928	0.8369	0.7575	0.9514	0.6942	0.9428
BIM consultant	0.5194	0.8433	0.8122	0.9486	0.8029	0.9386
BIM facility manager	0.5832	0.8379	0.8010	0.9491	0.7400	0.9411

*: ITC stands for Item-total Correlation, and CA means Cronbach's Alpha.

Table 10. ANOVA results for subgroup analysis of students divided by institutions responding to the question of desired BIM-related AEC jobs

BIM-related job titles	**SUT (Australia)**		**WZU (China)**		**UoB (U.K.)**		**Statistical comparison**		**Post-hoc analysis**
	Mean	Std	Mean	Std	Mean	Std	*F* value	*p* value	
BIM manager	3.818	1.128	3.394	0.747	2.586	1.268	**14.57**	**0.000** *	UoB students had significantly less motivations compared to peers from twoother institutions.
BIM engineer	4.061	0.895	3.545	1.063	3.313	1.401	**7.52**	**0.001** *	SUT students had more motivations than peers from two other institutions.
BIM coordinator	3.388	1.240	3.375	0.907	2.567	1.104	**6.09**	**0.003** *	UoB students had significantly less motivations compared to peers from twoother institutions.
BIM technician	3.000	1.331	3.500	1.047	2.710	1.189	**3.28**	**0.040** *	UoB students had significantly less motivations compared to peers from WZU.
BIM modeler / operator / draughtsman	3.304	1.332	3.375	0.976	2.933	1.311	1.18	0.309	No significant differences
BIM quantity surveyor	3.140	1.290	3.406	0.837	2.625	1.212	**3.62**	**0.029** *	UoB students had significantly less motivations compared to peers from twoother institutions.
BIM project manager	4.227	0.930	3.469	0.842	3.118	1.365	**17.61**	**0.000** *	SUT students had more motivations than peers from two other institutions.
BIM leader/ director	3.863	1.017	3.594	0.911	3.125	1.385	**5.65**	**0.004** *	UoB students had significantly less motivations compared to peers from SUT.
BIM software developer	2.396	1.326	3.250	1.164	2.500	1.270	**5.40**	**0.005** *	WZU students had more motivations than peers from two other institutions.
BIM consultant	2.990	1.403	3.281	1.085	2.727	1.180	1.47	0.234	No significant differences
BIM facility manager	2.806	1.191	3.219	0.832	2.273	1.098	**5.99**	**0.003** *	UoB students had significantly less motivations compared to peers from twoother institutions.
Overall	3.345	0.804	3.404	0.779	2.830	1.052	**5.25**	**0.006** *	Same as above

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

Table 11. Overall sample analysis in the question of challenges encountered in BIM implementation (Overall Cronbach's Alpha = *0.7904*)

Challenges	**Mean**	**Std***	***RII***	**Ranking**	**Item-total Correlation**	**Cronbach's Alpha**
Insufficient BIM education resource or training	3.204	0.994	0.641	5	0.5425	0.7599
High cost of BIM software tools	3.307	1.068	0.661	1	**0.3584**	**0.7907**
Upgrading of existing hardware	3.277	0.929	0.655	4	0.3478	0.7891
Attitudes of AEC companies towards BIM adoption	3.175	0.984	0.635	7	0.5371	0.7608
Lack of client demand for using BIM	3.029	0.947	0.606	8	0.5563	0.7582
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	3.182	0.949	0.636	6	0.5574	0.7580
Lack of legislation or incentives from government or authority	3.307	1.054	0.661	1	0.5529	0.7579
Lack of industry standards in BIM applications	3.292	0.986	0.658	3	0.5344	0.7613

Table 12. Comparison of internal consistency among SUT, WZU, and UoB regarding students' perceptions of challenges encountered in BIM implementation

Challenges	**SUT (Australia) Overall CA=0.7266**		**WZU (China) Overall CA=0.8876**		**UoB (U.K.) Overall CA=0.8376**	
	ITC	**CA**	**ITC**	**CA**	**ITC**	**CA**
Insufficient BIM education resource or training	0.5619	0.6690	0.5449	0.8845	0.5693	0.8183
High cost of BIM software tools	**0.2200**	**0.7413**	0.7420	0.8652	0.5003	0.8273
Upgrading of existing hardware	**0.2137**	**0.7345**	0.5975	0.8799	**0.4018**	**0.8424**
Attitudes of AEC companies towards BIM adoption	0.4244	0.6980	0.6600	0.8735	0.7392	0.7939
Lack of client demand for using BIM	0.4688	0.6899	0.6519	0.8743	0.7119	0.7980
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	0.4762	0.6871	0.6944	0.8707	0.7317	0.8054
Lack of legislation or incentives from government or authority	0.5030	0.6804	0.7384	0.8658	0.4857	0.8285
Lack of industry standards in BIM applications	0.4960	0.6827	0.6609	0.8735	0.4769	0.8292

*: ITC stands for Item-total Correlation, and CA means Cronbach's Alpha.

Table 13. ANOVA results for subgroup analysis of students among SUT, WZU, and UoB responding to the question of challenges encountered in BIM practice

Challenges	**SUT (Australia)**		**WZU (China)**		**UoB (U.K.)**		**Statistical comparison**		**Post-hoc analysis**
	Mean	Std	Mean	Std	Mean	Std	*F* value	*p* value	
Insufficient BIM education resource or training	3.240	1.066	3.406	0.946	2.912	0.933	2.09	0.126	No significant differences
High cost of BIM software tools	3.411	1.149	3.094	1.027	3.294	1.031	1.04	0.356	No significant differences
Upgrading of existing hardware	3.385	1.055	2.969	0.861	3.171	1.071	2.19	0.115	SUT students perceived a higher degree of challenge compared to their WZU peers
Attitudes of AEC companies towards BIM adoption	3.313	1.113	2.969	0.822	3.031	0.933	1.83	0.164	No significant differences
Lack of client demand for using BIM	3.113	0.934	2.806	0.792	2.971	0.904	1.44	0.241	No significant differences
Lack of sufficient time to evaluating the ratio of BIM inputs and outputs	3.319	1.063	3.167	0.747	2.839	0.688	3.02	0.052	SUT students perceived a higher degree of challenge compared to their UoB peers
Lack of legislation or incentives from government or authority	3.495	1.139	3.103	0.817	3.033	0.850	**3.10**	**0.048 ***	Same as above
Lack of industry standards in BIM applications	3.387	1.152	3.241	0.786	2.938	0.801	2.29	0.105	Same as above
Overall	3.329	0.632	3.079	0.620	3.082	0.700	3.06	0.050	No significant differences

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

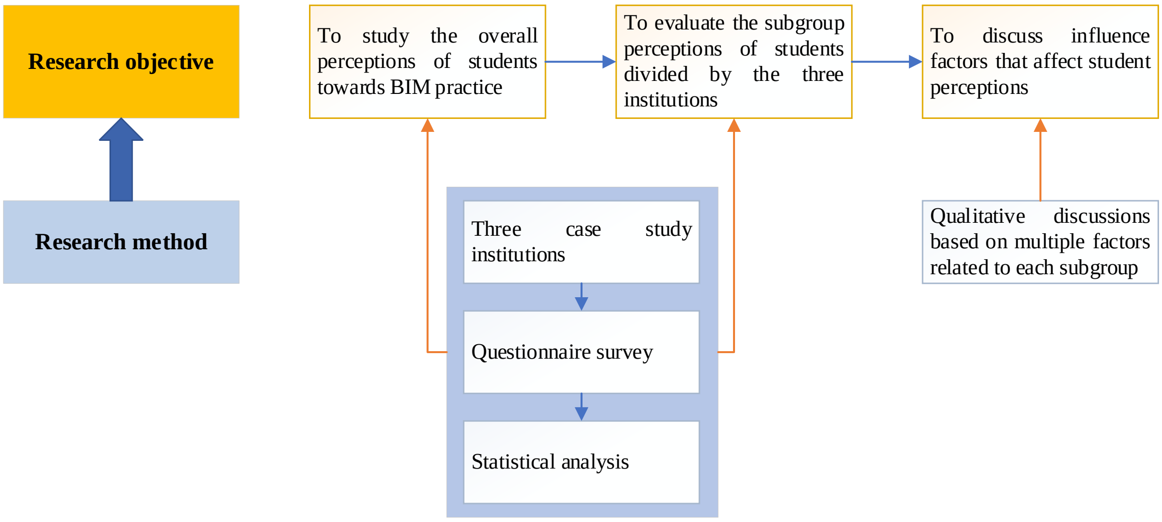

Fig.1. Description of research methods to achieve research objectives

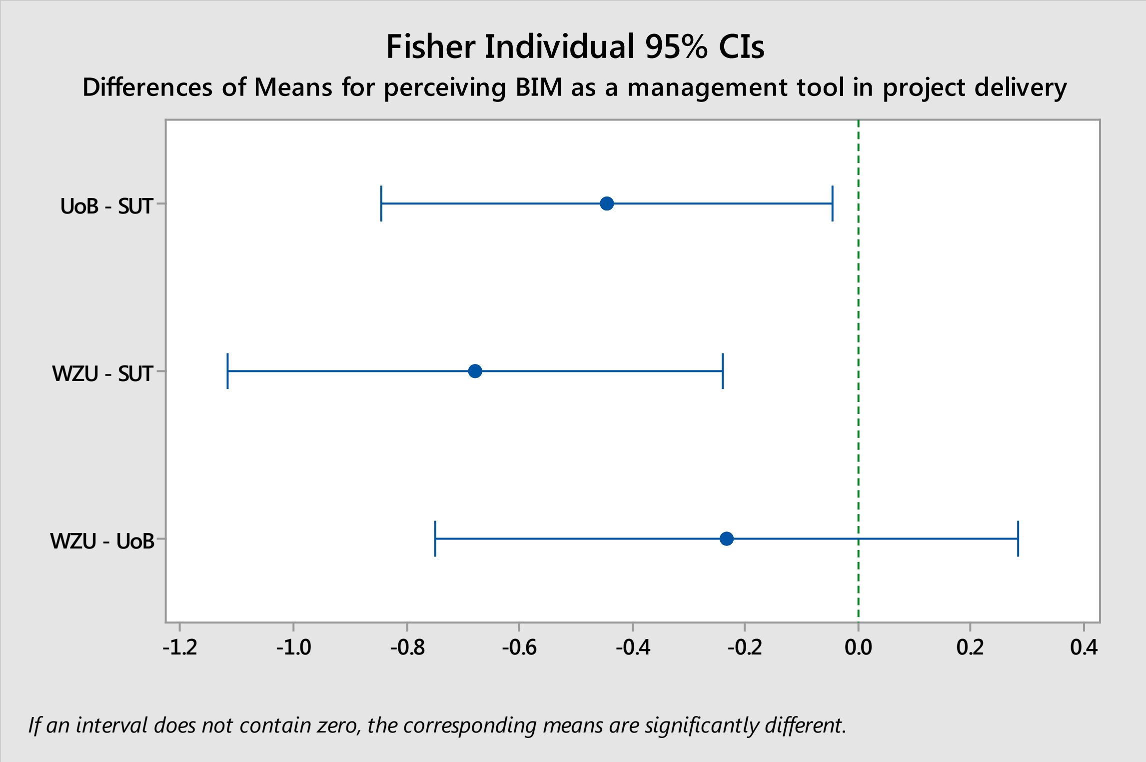

Fig.2. Post-hoc analysis of subgroup differences towards perceiving BIM as a management tool in project management

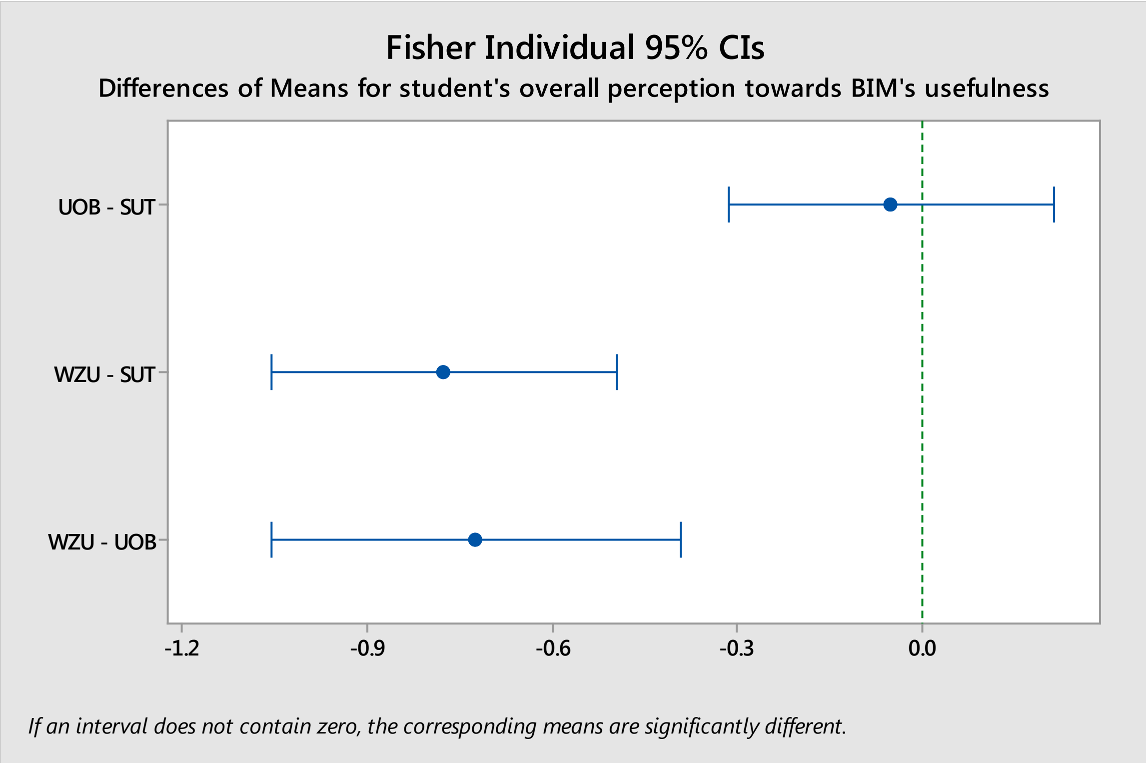

Fig.3. Post-hoc analysis of subgroup differences towards perceiving BIM's overall usefulness in different AEC dicsiplines

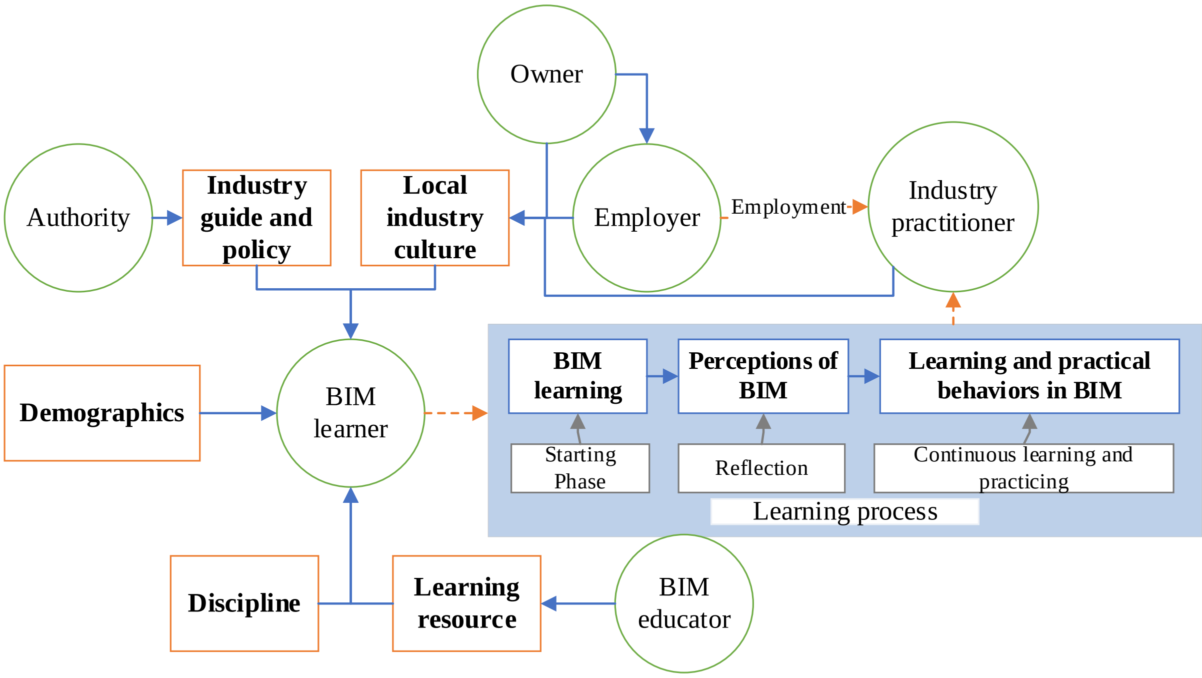

Fig.4. Framework describing the BIM learning process