Chapter 6
Use of Simulation Through BIM-Enabled Virtual Projects to Enhance Learning and Soft Employability Skills in Architectural Technology Education

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Abstract Traditional teacher-led methods in higher education such as the customary use of lectures can result in passive learning behaviour being adopted by students. Academic theorists consider alternative approaches that encourage active learning more desirable. This chapter reports on the use of a simulated virtual project designed to introduce project-based learning into the classroom environment. Over a 2-day duration, several pairs of second year undergraduate Architectural Technology students developed competing designs across multiple predetermined work stages. Starting from an initial strategy briefing, students were able to rapidly progress through to a more developed design stage because of the use of BIM technology and processes. Data were collected from participants to measure perceptions of the various areas of learning and skills development that had occurred because of their participation in the virtual project. Findings indicate that students believe they had gained greater depth of subject understanding and developed a range of personal, interpersonal, self-management, and initiative and delivery skills. The conclusion is that further introduction of project-based learning via simulation using virtual projects could be of high value across a range of built environment programmes taught across the higher education sector.

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6.1 Introduction

> *"College is a place where a professor's lecture notes go straight to the students' lecture notes, without passing through the brains of either"* (attributed to Edwin Emery Slossan, circa 1910)

Traditional teacher-led classroom activity, including the prevailing lecture type delivery common to Universities continues to attract criticisms along the lines of the above. In a single academic year spent studying in a Higher Education Institution (HEI) that packages related classes into modules, a student taking six typical 20-credit modules, each employing a 1-h weekly lecture and a 1-h accompanying seminar delivery pattern would spend nearly 4 weeks in lectures alone. This time can largely be classified as *"passive learning"* in which the only activities engaged in are listening and note taking (Exley and Dennick 2009). Built environment education has conventionally been delivered through similar "chalk and talk" methods of teaching, which has not optimised student learning (Forsythe et al. 2013). Project-based learning (PBL) where active learning occurs through student endeavour focusing on problem-solving and the application of taught skills has been recognised as a valuable alternative in built environment education (Demian 2007). "Simulated projects", that replicate real-life problems within a safe environment, are suitable vehicles for PBL in built environment teaching and for enhancing learning and soft employability skills. Researchers in education have also recognised that the use of computer technologies can support project-based learning (Peterson et al. 2011). Recently, the introduction of Building Information Modelling (BIM) into built environment education has also enabled "virtual projects" to be used for facilitating learning through such project simulations. The aim of this research was to introduce a simulated virtual project within the second year of the Architectural Technology undergraduate degree programme in order to enhance learning about the AT discipline, BIM, and augment key softer employability skills that are desired by industry employers.

6.1.1 Project-Based Learning and the Use of Simulated Projects in Built Environment Education

Project-based learning anchors learning to the solving of predetermined problems that are generated within time-limited resource-constrained projects. This form of teaching activity is strongly linked with the more "open-ended" problem-based learning, which allows creativity and deeper understanding of concepts to be tested. Allison and Pan (2011) identified the difficulty in distinguishing between Project-based and Problem-based learning, and note the work of Graaff and Kolmos (2003) who argue that projects are always problem based in nature. To avoid confusion, PBL is hereafter used to refer to Project-based learning in this chapter. Demian (2007) notes the validity of PBL as an alternative to traditional built environment teaching methods and argues that PBL facilitates the development of interdisciplinary teamworking skills whilst also encouraging students to take ownership of the learning process. Other benefits include the opportunities to introduce additional impromptu situational learning activities into the project in order to further broaden the knowledge base and improve and enhance student communication and leadership skills. Such project simulations are recognised as a means of developing professional practice within professionally oriented courses, which help students develop useful real-world competencies and, importantly improve their employability skills (Sambell et al. 2012).

6.1.2 Categorising and Defining Soft Employability Skills

"*Basic employability skills are transferable core proficiencies that represent essential functional and enabling knowledge skills and abilities required to succeed at all levels of employment in the 21st century workplace*" (Overtoom 2000, as cited in Rosenberg et al. 2012). In addition to harder "technical" transferable skills such as literacy and numeracy, softer employability skills are concerned with personal and social skills. From an appraisal of previous practice reports, Blades et al. (2012) were able to categorise 15 separate soft employability skills and attributes within four distinct areas: *personal skills; interpersonal skills; self-management-skills*; and *initiative and delivery skills.* Their categorisations of these employability skills are listed in Table 6.1.

In the present work, the research team was interested to observe how the use of PBL could help build career confidence and develop softer employability skills within Architectural Technology education. 14 of the 15 original skills identified by Blades et al. were used as constructs for the design of a research instrument, and the definitions of these 14 constructs used are reproduced in Table 6.2.

More detail on the design of the research instrument is provided further below, but first, as the use of a BIM-enabled virtual project was considered to be a suitable vehicle for purposes of PBL and the development of soft employability skills, it is worth briefly introducing BIM and commenting upon its current application in built environment education.

Table 6.1 Categorisation of soft employability skills and attributes (adapted from Blades et al. 2012)

Personal	Interpersonal	Self-management	Initiative and delivery
Confidence	Social/Interpersonal skills	Self-control	Planning
Self-esteem	Communication skills	Reliability	Problem-solving
Motivation	Teamwork	Positive attitude	Prioritising
Self-efficacy	Assertiveness	~~Presentation~~ (not used)	

Table 6.2 Definitions of soft employability skills and attributes (adapted from Blades et al. 2012)

Skill/attribute	Definition
Self-confidence	Belief in oneself or one's own abilities
Self-esteem	A positive or negative orientation towards oneself; an overall evaluation of one's worth or value
Motivation	Interest/engagement, effort and persistence/work ethic
Self-efficacy	Belief in one's ability to succeed in a particular situation
Social/interpersonal skills	Ability to interact appropriately with other people, without undue conflict or discomfort
Communication skills	Ability to convey information effectively so that it is received and understood; appropriate verbal/nonverbal communication with colleagues, managers, and customers/others
Teamwork	Ability to work cooperatively with others
Assertiveness	Ability to confidently express views or needs without either aggression/dominance/undue submissiveness towards others
Self-control	Ability to control own emotions and behaviour, particularly in difficult situations or under stress
Reliability	Attendance, time-keeping, consistent standards
Positive attitude	Keen to work, learn, accept feedback, and take responsibility
Planning	Ability to plan tasks and monitor progress
Problem-solving	Ability to identify problems and devise solutions
Prioritising	Ability to identify and focus on priority tasks

Table 6.3 Ranking of impact of VP on learning about industry and disciplinary-related aspects

Undertaking the virtual project helped me gain greater depth of understanding about…	Min.	Max.	Sum.	Mean
BIM	4	5	96	4.57
4D construction simulation	4	5	89	4.24
COBie and data drops	3	5	87	4.14
Design coordination through clash detection	2	5	87	4.14
Common Data Environments (CDEs)	2	5	86	4.10
5D cost modelling	3	5	85	4.05
General Architectural Technology concepts	3	5	85	4.05
5D quantity take-off processes	3	5	84	4.00
Design review in BIM	3	5	84	4.00
The use of massing models for the conceptual design stage	3	5	84	4.00
The project design briefing stage	3	5	83	3.95
The potential of BIM in facilities management	2	5	82	3.90
The NBS BIM Toolkit	3	5	82	3.90
Rendering and optimisation of visual production methods	3	5	82	3.90
Design authoring in BIM	3	5	81	3.86
Employers Information Requirements (EIR's)	2	5	80	3.81
Design coordination through model federation	2	5	80	3.81
BIM Execution Plans (BEP's)	3	5	79	3.76

6.1.3 Building Information Modelling in Higher Education

Building Information Modelling (BIM) is a model-focused methodology to planning, creating, and preserving assets in the architectural engineering and construction (AEC) industry. Gledson (2016) describes BIM as the most "*prominent radical, transformative and disruptive innovation to hit construction industry*". In AEC education, Forsythe et al. (2013) note that BIM can be used to "*facilitate a more integrated and visual mode of teaching* [that] *provides a new basis for developing problem based learning – one that has the potential to allow students to aggregate their learning around a central project whilst enabling problems to be scaled at different levels of complexity*". Despite the importance of BIM to the AEC sector, HEIs have responded variously, and in some cases, relatively slowly to it. Woo (2006) argued there was no widespread strategy for teaching BIM in AEC curricula. Tasked by the Government BIM Task Group, a recent survey undertaking by the BIM Academic Forum (BAF) found there were clear distinctions between the higher and lower performing Higher Education Institutions (HEIs) in relation to UK HEI BIM readiness (Underwood et al. 2015). At the researchers home institution, Northumbria University, use of BIM and earlier 3D computer modelling precursors such as Virtual Reality (VR) have been embedded into the academic curriculum since 2003 (Horne and Thompson 2008). The current research team however, did not begin to use BIM for the purposes of simulating virtual projects for collaborative student group work to embed PBL until more recently, which presented the current research opportunity.

6.2 Research Method

A virtual project was used to facilitate project-based learning and ran over a 2-day duration in March 2016. The project opened with an initial discussion sessions that helped to contextualise and reinforce learning around several important BIM concepts detailed in PAS 1192-2 (BSI 2013). These included the importance of BIM Execution Plans (BEPs), and Common Data Environments (CDEs), the capture of Employers' Information Requirements (EIRs), and the use of Construction Operations Building Information Exchange (COBie) data drops. Pairs of students worked together with hardware and software provided by the tutors. The students were provided with a virtual site model and several partially completed architectural, structural, and services models. The VP was loosely structured around an existing UK industry process delivery model (RIBA 2013) and over the course of day 1, these small student groups worked to develop and enhance the existing designs in alignment with three COBie data drop stages (for details, see Love et al. 2014). During day 2, the students progressed to the aggregation of model files and producing BIM output in relation to 4D (time), 5D (cost) and facility and asset management data.

6.2.1 Research Instrument

A questionnaire survey was constructed to be able to gather sufficient data for analysis. The questionnaire consisted of 53 separate questions. An initial section included demographic questions to establish information about cohort composition and to be able to determine variances between individual groups. These questions focused on sex/gender, mode of study, and level of previous practical experience working within the Architectural Engineering Construction (AEC) industry.

Subsequent sections were included to measure the effectiveness of the virtual project on industry and discipline-specific learning; and measure the development of *Personal; Interpersonal; Self-management;* and *Initiative and delivery* skills. The constructs measured were identified from a review of literature. Use was made of an online web-based questionnaire to administer the survey and collect data from the cohort. From the 29 students who participated in the virtual projects, 21 students completed the questionnaire to the end meaning a response rate of 72.0 % was achieved. An additional four “abandoned” responses were also received although these were excluded from the analysis because of their incompleteness.

6.3 Results and Analysis

The majority of students were Male (71.4 %), and studying Full-Time (81.0 %). Two questions were included to determine relevant prior work experience although these were the only two questions not to receive full responses. Of the 19 students to complete Q6, a majority (88.2 %) confirmed that they did not undertake a placement year in the AEC industry. Similarly, Q7 was worded “*Have you had any work experience at all in the Architectural Engineering Construction (AEC) industry?”* The most frequent response from the 15 students that completed this question was *“Yes”* with 60.0 % of respondents selecting that option.

Questions 8–25 were designed to measure how undertaking the virtual project had helped the student gain a greater depth of understanding across a range of industry and disciplinary-related aspects. 5-point Likert scale questions were used and the available response options were listed as: *Strongly disagree* (1) *Disagree* (2) *Neutral* (3) *Agree* (4) *Strongly agree* (5). Table 6.1 shows the mean score and sum score of these aspects in descending order. This table highlights that the virtual project was most useful for gaining greater depth of understanding about the following aspects: *BIM; 4D construction simulation; COBie and data drops; Common Data Environments; 5D cost modelling concepts*; and *general Architectural Technology concepts*, all of which received a mean score of more than 4.00 out of 5.00.

Questions 26–53 were designed to measure the impact of the virtual project across a range of key soft employability skills and comprised a series of 14-paired, “before and after” questions that focused on the development of *Personal,*

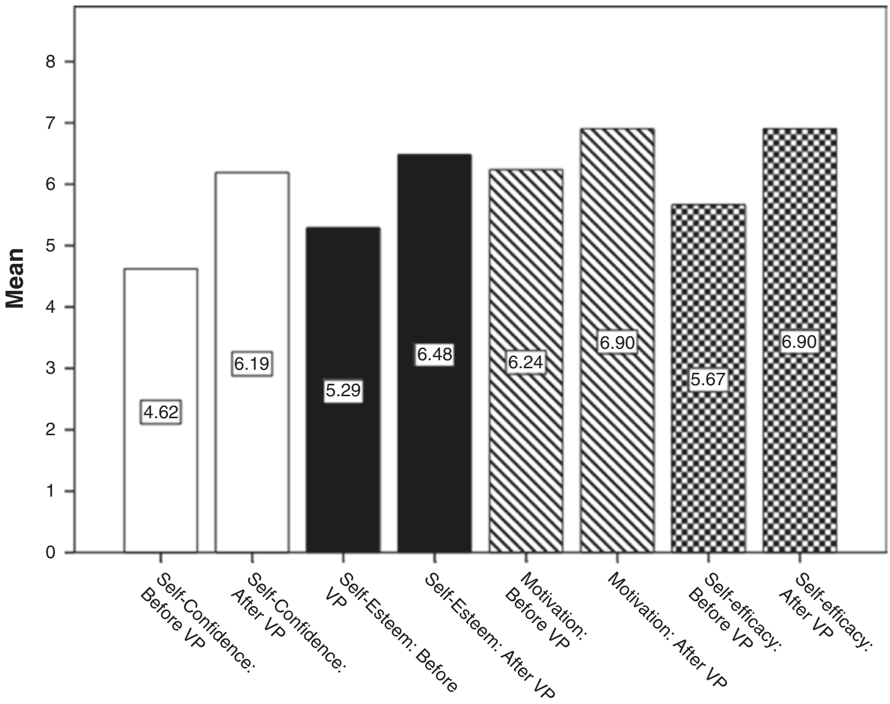

Fig. 6.1 Personal skills—mean scores before and after virtual project—all 21 responses

Interpersonal, Self-management; and *Initiative and delivery skills*. The students were first asked to reflect upon their ability before having undertaking the virtual project in relation to an employability skill and then score this skill on a scale from 0–10. One such example of this type of question is reproduced from Q38: "***Teamwork skills:*** *Please indicate on the sliding scale from 0-10, your ability to work cooperatively with others,* ***before*** *undertaking the virtual project*." After each "before" question, the students were then asked to self-reflect on the same skill after having undertaken the virtual project, and then score their subsequent ability in relation to this skill on the same 0–10 scale. One such example of this type of question is reproduced from Q39: *"**Teamwork skills:** Please indicate on the sliding scale from 0-10, your ability to work cooperatively with others,* ***after*** *having undertaking the virtual project"*.

The first group of questions focused on four separate *Personal skills*. These were: *Self-confidence; Self-esteem; Motivation;* and *Self-efficacy*. Figure 6.1 shows a rise across each measure with the joint largest mean scores of **6.90** being recorded in *Motivation* and *Self-efficacy* after having undertaken the virtual project. This group also records the greatest mean increase of all employability skills of **1.57** occurring in *Self-confidence* because of having undertaken the virtual project.

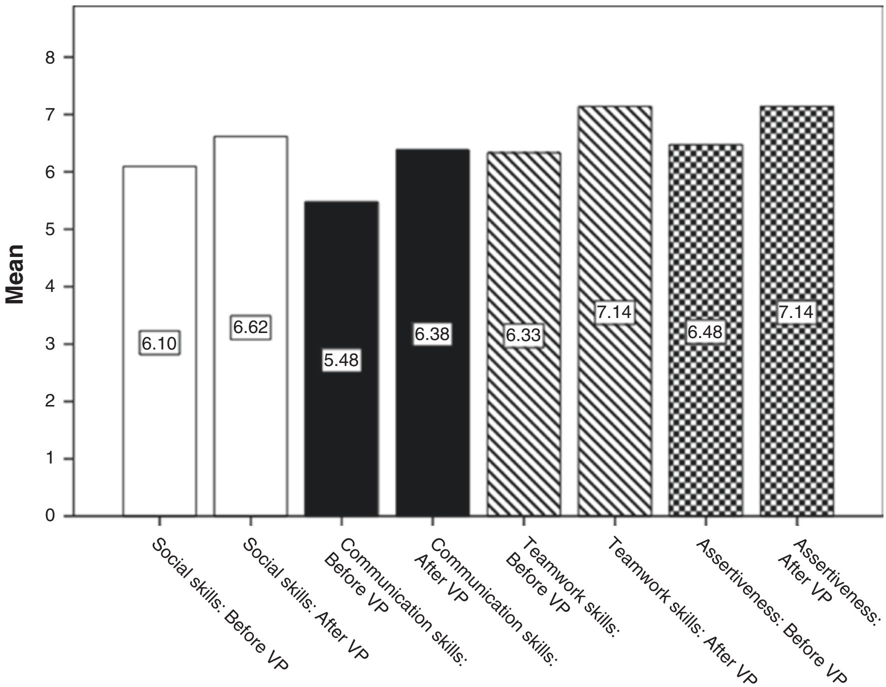

Fig. 6.2 Interpersonal skills—mean scores before and after virtual project—all 21 responses

The next group of questions focused on four separate *Interpersonal skills.* These were: *Social skills; Communication skills; Teamwork skills;* and *Assertiveness*. Figure 6.2 shows a rise across each measure with the joint largest mean scores of **7.14** being recorded in *Teamwork skills* and *Assertiveness* after having undertaken the virtual project. The greatest mean increase of **0.90** occurred in *Communication skills* because of having undertaken the virtual project.

The next group of questions focused on three separate *Self-management skills*. These were: *Self-control, Reliability,* and *Positive attitude*. Figure 6.3 shows a rise across each measure with the largest mean score of **7.24** of *Positive attitude* being recorded after having undertaken the virtual project. The greatest mean increase of **0.72** also occurred in *Positive attitude*.

The final group of questions focused on three separate *Initiative and delivery skills.* These were: *Planning, Problem-solving,* and *Prioritising*. Figure 6.4 shows a rise across each measure with the largest mean score of **7.57** being recorded in *Problem-solving skills* after having undertaken the virtual project. This was also the largest mean score across all employability skills recorded. The greatest mean increase of **0.90** also occurred in *Planning* because of having undertaken the virtual project.

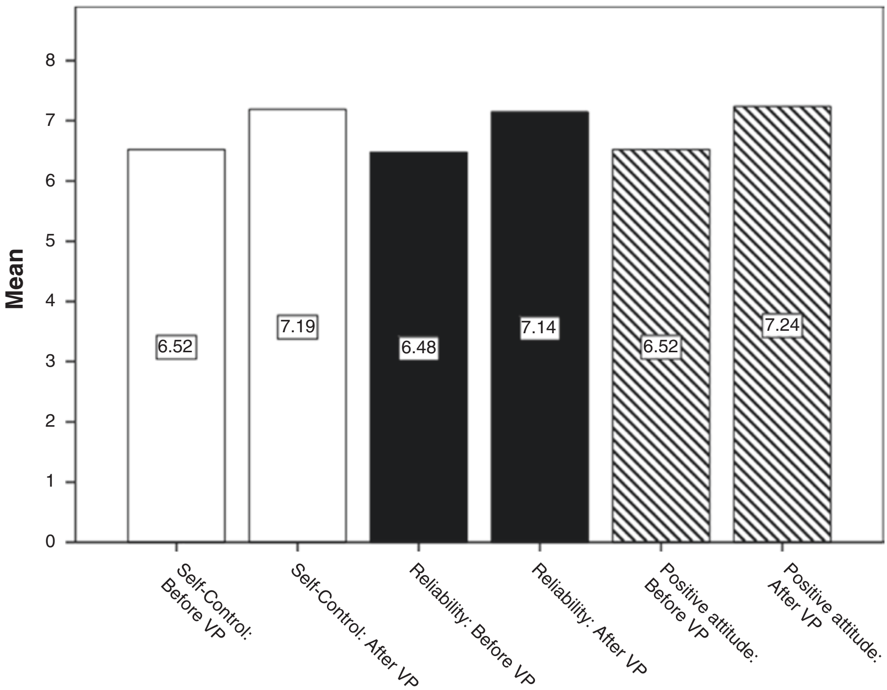

Fig. 6.3 Self-management skills—mean scores before and after virtual project—all 21 responses

To provide a recap: across the entire dataset of all students and in all four categories, the largest recorded mean scores all occurred after having undertaken the virtual project. These were *Problem-solving skills* (7.57); *Positive attitude* (7.24); *Self-control* (7.19); *Teamwork skills, Assertiveness,* and *Reliability* (all 7.14). The greatest increases (when comparing "before" and "after" mean scores) occurred in *Self-Confidence* (1.57) followed by *Self-Efficacy* (1.24), *Self-Esteem* (1.19) then *Communication skills* and *Planning* (both 0.90).

Examination of differences between groups of students with and without prior work experience in the AEC industry then occurred in relation to the key soft employability skills. For this analysis to occur, data could only be used from the subset of 15 students who responded to Q7 "*Have you had any work experience at all in the Architectural Engineering Construction (AEC) industry?"* Table 6.4 presents these filtered data in response to questions 26–53.

The five largest areas of variance between groups of students with and without prior relevant work experience ***before*** undertaking the virtual project occurred in the following categories: *Self-Esteem* (2.33); *Problem-solving* (2.11); *Planning* (2.06); *Self-Confidence* (2.00); and *Positive attitude* (1.94). Surprisingly in each of these categories, the mean self-perception of students without prior relevant

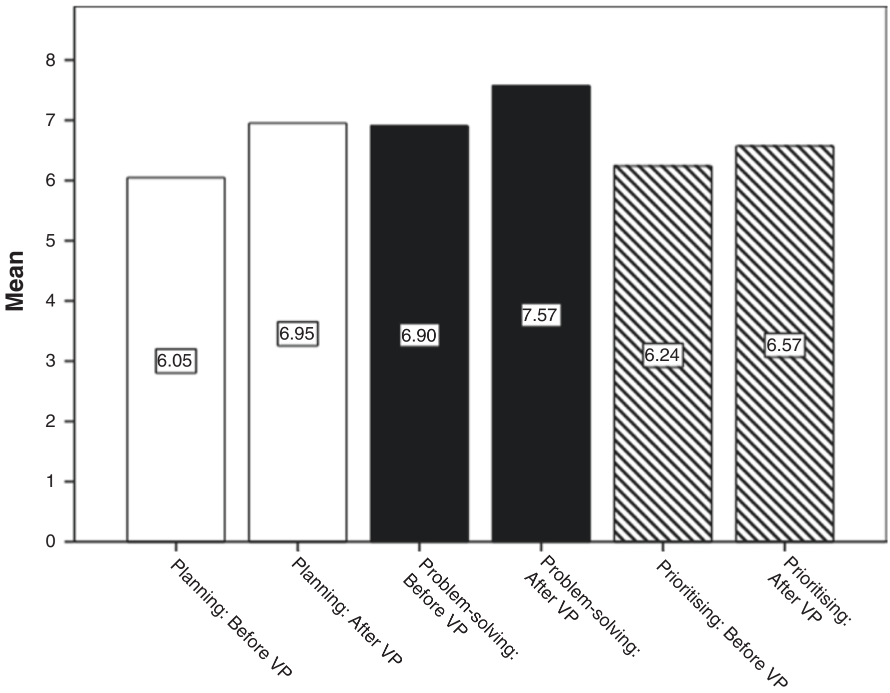

Fig. 6.4 Initiative and delivery skills—mean scores before and after virtual project—all 21 responses

work experience was higher in comparison with students who had relevant work experience.

The five largest areas of variance between groups of students with and without prior relevant work experience ***after*** undertaking the virtual project occurred in the following categories: *Motivation; Self-Efficacy; Self-Esteem; Planning;* and *Communication Skills* (all 1.44). Again, in each of these categories, the mean self-perception of students without prior relevant work experience was higher in comparison with students who had relevant work experience.

The five largest growth areas in skills development for students with prior work experience occurred in the following categories: *Self-Esteem* (1.89); *Self-Confidence* (1.67); *Self-Efficacy* (1.56); *Planning* (1.44); *and Problem-solving* (1.22).

The five largest growth areas in skills development for students without prior work experience occurred in the following categories: *Self-Efficacy* (1.50), *Self-Confidence; Self-Esteem; Motivation* and *Teamwork skills* (all 1.00).

In this subset of students, remaining consistent with the analysis of data across the entire data set, the largest mean score overall was again recorded in the category of an increase in *Problem-solving skills* after having undertaken the virtual project (7.87). Other categories where notable increases were recorded include

Table 6.4 Employability skills—differences between students with and without prior work experience in the AEC industry (subset of 15 responses)

	Yes		No		Variance	Total	
Any prior work experience in the AEC industry?	Mean	N	Mean	N	in groups	Mean	N
Self-confidence: Before virtual project	4.00	9	6.00	6	*2.00*	4.80	15
Self-confidence: After virtual project	5.67	9	7.00	6	*1.33*	6.20	15
Impact of VP	*1.67*		*1.00*		*-0.67*	*1.40*	
Self-esteem: Before virtual project	4.00	9	6.33	6	*2.33*	4.93	15
Self-esteem: After virtual project	5.89	9	7.33	6	*1.44*	6.47	15
Impact of VP	*1.89*		*1.00*		*-0.89*	*1.53*	
Motivation: Before virtual project	5.33	9	6.67	6	*1.33*	5.87	15
Motivation: After virtual project	6.22	9	7.67	6	*1.44*	6.80	15
Impact of VP	*0.89*		*1.00*		*0.11*	*0.93*	
Self-efficacy: Before virtual project	4.67	9	6.17	6	*1.50*	5.27	15
Self-efficacy: After virtual project	6.22	9	7.67	6	*1.44*	6.80	15
Impact of VP	*1.56*		*1.50*		*-0.06*	*1.53*	
Social/interpersonal skills: Before virtual project	5.67	9	6.50	6	*0.83*	6.00	15
Social/interpersonal skills: After virtual project	6.33	9	7.00	6	*0.67*	6.60	15
Impact of VP	*0.67*		*0.50*		*-0.17*	*0.60*	
Communication skills: Before virtual project	4.33	9	6.17	6	*1.83*	5.07	15
Communication skills: After virtual project	5.44	9	6.83	6	*1.39*	6.00	15
Impact of VP	*1.11*		*0.67*		*-0.44*	*0.93*	
Teamwork skills: Before virtual project	6.00	9	6.67	6	*0.67*	6.27	15
Teamwork skills: After virtual project	6.78	9	7.67	6	*0.89*	7.13	15
Impact of VP	*0.78*		*1.00*		*0.22*	*0.87*	
Assertiveness: Before virtual project	5.22	9	6.83	6	*1.61*	5.87	15
Assertiveness: After virtual project	6.33	9	7.50	6	*1.17*	6.80	15
Impact of VP	*1.11*		*0.67*		*-0.44*	*0.93*	

(continued)

Table 6.4 (continued)

	Yes		No		Variance	Total	
Any prior work experience in the AEC industry?	Mean	N	Mean	N	in groups	Mean	N
Self-control: Before virtual project	6.00	9	7.33	6	*1.33*	6.53	15
Self-control: After virtual project	7.00	9	8.00	6	*1.00*	7.40	15
Impact of VP	*1.00*		*0.67*		*-0.33*	*0.87*	
Reliability: Before virtual project	5.67	9	7.33	6	*1.67*	6.33	15
Reliability: After virtual project	6.67	9	7.83	6	*1.17*	7.13	15
Impact of VP	*1.00*		*0.50*		*-0.50*	*0.80*	
Positive attitude: Before virtual project	5.56	9	7.50	6	*1.94*	6.33	15
Positive attitude: After virtual project	6.67	9	8.00	6	*1.33*	7.20	15
Impact of VP	*1.11*		*0.50*		*-0.61*	*0.87*	
Planning: Before virtual project	4.78	9	6.83	6	*2.06*	5.60	15
Planning: After virtual project	6.22	9	7.67	6	*1.44*	6.80	15
Impact of VP	*1.44*		*0.83*		*-0.61*	*1.20*	
Problem-solving: Before virtual project	6.22	9	8.33	6	*2.11*	7.07	15
Problem-solving: After virtual project	7.44	9	8.50	6	*1.06*	7.87	15
Impact of VP	*1.22*		*0.17*		*-1.06*	*0.80*	
Prioritising: Before virtual project	5.56	9	7.00	6	*1.44*	6.13	15
Prioritising: After virtual project	6.33	9	7.33	6	*1.00*	6.73	15
Impact of VP	*0.78*		*0.33*		*-0.44*	*0.60*	

Self-control (7.40); *Positive attitude* (7.20); *Teamwork skills*; and *Reliability* (both 7.13) all of which were measures of skills having developed after having undertaken the virtual project.

Across this subset of students the joint greatest mean increase of all employability skills was recorded in the *Personal skills* and *Interpersonal skills* categories of *Self-Esteem* and *Self-Efficacy* (both 1.53), followed by *Self-Confidence* (1.40); and *Motivation, Communication skills,* and *Assertiveness* (all 0.93).

6.4 Conclusion

Having undertaken the virtual project, students perceived that they had gained greater depth of conceptual understanding, subject-specific knowledge and improved their employability skills. Analysis of the data reveals that actual gains had been recorded across all of the aspects. The virtual project was most useful for gaining greater depth of understanding about the following aspects: *BIM; 4D construction simulation; COBie and data drops; Common Data Environments; 5D cost modelling concepts*; and *general Architectural Technology concepts*, all of which received a mean score of more than **4.00** out of **5.00**. There was positive correlation between self-perception of their existing skill level before the virtual project and the gains they had made because of having undertaken the virtual project. The largest mean score recorded was in *Problem-solving skills* after having undertaken the virtual project. This was consistent even when filtering the subset of students who responded to a question enquiring about prior relevant work experience. Other categories that remained consistently high across all students even when filtering for differences in prior relevant work experience included the categories of *Positive attitude*; *Self-control*; *Teamwork skills* and *Reliability.* Similarly, the largest mean increases of all employability skills because of undertaking the virtual project were recorded in *Personal skills* categories of *Self-Confidence; Self-Esteem;* and *Self-Efficacy.*

6.4.1 Limitations, Consequences, and Opportunities for Future Research

One possible limitation in the research method used relates to the timing of when the students were presented with the survey questionnaire. In the present research, students answered both the "before" and "after" questions at the same time, on completion of the virtual project. It is clear that administering the "before" and "after" questions at those respective project stages may have produced different results. Having observed such student learning and skills development as a result of undertaking the virtual project however, the implications of this research are clear.

There is high educational value in providers of built environment education further absorbing and embedding Building Information Modelling into their curriculum for the purposes of introducing simulated virtual projects as vehicles to facilitate project-based learning. A similar virtual project is planned for the next academic year for purposes of research replication. In the next VP, quantitative data will be augmented with qualitative interview data for purposes of triangulation.

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