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Application of BIM software in construction design education

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ABSTRACT: Building information modelling (BIM) software has become increasingly important in the international construction industry and is promoted as the technical innovation of the construction industry. Reported in this article is research to promote the use of BIM in teaching construction design majors at Chinese universities. Questionnaires, interviews, literature search and statistical analysis were used in this study. The questionnaire was given to teachers and students from the construction design majors in five universities. The results show that teaching with BIM software is more successful and effective than is the traditional way of teaching. Therefore, BIM should play a greater role in the teaching of construction design at universities.

INTRODUCTION

Building information modelling (BIM) first appeared in 1975 [1]. This type of modelling integrates relevant information throughout the life of projects in the construction industry, using parameterised models. Thus technical assistance is provided to the engineering teams [2]. With this, engineering designers can take measures to improve construction work efficiency, save construction costs and shorten the construction timeframe [3]. Building information modelling is increasingly used by construction designers around the world.

Currently popular BIM software includes ArchiCAD, MicroStation and Revit and is primarily produced by foreign companies [4], with Revit being the preferred system. Building information modelling software features such functions as visualisation, co-ordination, imitation, optimisation and drawing outputs [3].

The biggest difference between this software and traditional Computer-Aided Design (CAD) is that BIM is based on 3D modelling. Through Revit, models can be rapidly adjusted and standard options selected, as part of analysis and design. The system automatically supports flat, vertical, sectional and three-dimensional aspects [5].

Building information modelling has been used most successfully in construction projects in America, Japan and Hong Kong. Some Chinese enterprises have also used BIM for construction design, with great success [2].

Teaching in universities needs to keep up with the times and introduce BIM software in their classes [6]. To better understand the application of BIM software in teaching at Chinese universities [7], interviews, questionnaires and a literature search were used to investigate the teaching of construction design at five universities.

Efforts were made to acquire current BIM software for use in teaching in universities, thus promoting the connection between teaching in universities and practice in the real world.

The construction design major is challenging for students [7-9], not only in the specific required knowledge, but also in the requisite graphics and drawing skills [10]. This major requires relevant computer-based technical software [11][12].

In actual teaching, the sole use of the traditional 2D drawing method will not only present a challenge for the students' 3D thinking ability, but also create difficulties on actual projects [13].

The use of BIM has become compulsory for majors related to construction [14][15]. To sum-up, including the application of BIM software into the actual teaching will help promote excellence and best practice in construction design.

RESEARCH OBJECTS AND METHODS

Fifty teachers and 500 students from construction design majors at five universities were selected for this investigation. Questionnaires were used, which were distributed to all the 50 teachers and 500 students from the majors at the universities (10 teachers and 100 students at each university). All 550 copies were returned and were valid, resulting in an effectiveness rate of 100%.

Tables were drawn up based on the sampling, investigation and analysis of the data; statistical methods, such as mean $\bar{x}$ and variance s^2 were used to analyse and interpret the data. The result was quantitatively analysed to investigate the use of BIM software in the teaching of construction design.

INVESTIGATION OF BIM SOFTWARE-BASED TEACHING OF CONSTRUCTION DESIGN AT UNIVERSITIES

According to the investigation of the 50 teachers and 500 students of the construction design majors at five universities, the figures below indicate the use of BIM software in teaching construction design majors at the universities. The survey results are shown in Table 1 and are the teachers' responses.

Table 1: Use of BIM software in the teaching of a major in construction design at five universities.

University	Software applied	
	Yes	No
A	7	3
B	3	7
C	6	4
D	4	6
E	7	3

Statistics, i.e. mean and variance, were used to further process the data. Average *yes* responses to the use of BIM software in the five universities, x_1 = 5.4. Average of the *no* responses for the use of BIM software in the five universities: x_2 = 4.6. Therefore, the number of universities using BIM software in teaching is greater than those not using BIM software in teaching.

To further study the effect of using BIM software, 100 students using BIM and 100 students not using BIM were chosen from each university.

Table 2: Results of students using BIM software teaching versus those not using BIM.

	Using BIM software			Not using BIM software		
	Good	Moderate	Poor	Good	Moderate	Poor
University A	39	39	22	27	24	49
University B	40	35	25	38	38	24
University C	45	43	18	47	33	20
University D	42	45	13	31	39	30
University E	38	42	20	57	33	20

The data in Table 2 is too scattered to allow definite conclusions to be drawn. Hence, means and variances were worked out to enable conclusions to be drawn.

Table 3 is derived from Table 2 and shows the average number of students with *good*, *moderate* and *poor* performance for the two categories using and not using BIM software.

Table 3: Performance of students receiving BIM software teaching.

Teaching mode	Result - average number	%
Receiving BIM software teaching	Good performance (x_1)	40.8
	Moderate performance (x_2)	40.8
	Poor performance (x_3)	19.6
Receiving traditional construction design teaching	Good performance (x_4)	40.0
	Moderate performance (x_5)	33.4
	Poor performance (x_6)	28.6

The *good* performance for both teaching modes yields $\bar{x}_1$ = 40.8 and $\bar{x}_4$ = 40. As the results are very similar, it is hard to draw conclusions about the teaching effectiveness. Next, variance was used to analyse the differences. In Table 4, x_1 and x_2 refer to the *good* values for using BIM software and not using BIM software respectively in Table 2.

Table 4: Quadratic sum of all students of good performance from the five universities.

University	x_1	x_2	$\sum R$	$(\sum R)^2$
A	39	27	66	4356
B	40	38	78	6084
C	45	47	92	8464
D	42	31	73	5329
E	38	57	95	9025

The average of students of good performance using BIM software teaching is μ_1, while that of those not using BIM is μ_2. The null hypothesis H_0 is $\mu_1 = \mu_2$.

Table 5: Statistical F-test of the null hypothesis.

Quadratic		Freedom		Variance	
Quadratic sum	309.4	Freedom among groups	1	Variance among groups	4.6
Overall quadratic sum	4.6	Freedom among sections	4	Variance among sections	76.1
Quadratic sum of blocks	304.2	Error freedom	4	Error variance	0.15
Quadratic sum of errors	0.6	Overall freedom	9	F	30.4

As per $df_b = 1$, $df_e = 4$ and $\alpha = 0.01$, check Table 5 to learn that $F_{(1,4)0.01} = 21.2$, while the test statistic value of F really calculated $F = 30.7 > F_{(1,4)0.01} = 21.2$, i.e. $P(F > 21.2) < 0.01$.

The sample statistics show that the alternative hypothesis should be accepted, i.e. the averages of the two sums are unequal. Hence, there is a gap between students of good performance using BIM software teaching and those not using BIM software.

Further analysis now follows. Variance of students of good performance who received BIM software teaching:

$$s_1^2 = [(39\text{-}40.8)^2 + (40\text{-}40.8)^2 + (45\text{-}40.8)^2 + (42\text{-}40.8)^2 + (38\text{-}40.8)^2]/5 = 6.16$$

Variance of students of good performance who received non-BIM software teaching:

$$s_2^2 = [(27\text{-}40)^2 + (38\text{-}40)^2 + (47\text{-}40)^2 + (31\text{-}40)^2 + (57\text{-}40)^2]/5 = 118.4$$

$s_1^2 = 6.16$, is far smaller than $s_2^2 = 118.4$. Thus, students who received BIM software teaching are more likely to perform well.

Now consider students of moderate performance. For students of moderate performance who received BIM software teaching, $\bar{x}_2 = 40.8$, which is larger than students of moderate performance who received non-BIM teaching with $\bar{x}_5 = 33.4$. Among such students of moderate performance, those who received BIM software teaching have better results than those who do not.

Finally, consider students of poor performance. Students of poor performance who received BIM software teaching have $\bar{x}_3 = 19.6$, while for students of poor performance who did not receive BIM teaching, $\bar{x}_6 = 28.6$ ($\bar{x}_3 < \bar{x}_6$). Those who received BIM software teaching have far better performance than those who do not.

To further investigate the effect of BIM in improving students' ability, a random sample was taken of students of good performance, who received BIM software teaching.

Table 6: Students of good performance, who received BIM software teaching.

University	Aids visualisation	Simulation	Other	Total
A	17	16	6	39
B	18	18	4	40
C	19	21	5	45
D	16	17	9	42
E	17	15	6	38
Total	87	87	30	204

The above table (Table 6) shows the biggest influences of BIM software as measured by the opinions of students of good performance and who received BIM software teaching. According to the data in the table, the total sum for aids visualisation is 87 with an average 17.4, while the total sum for simulation is 87 with an average also of 17.4. Thus, one can see aiding visualisation and simulation have the biggest influence upon students. Besides:

Variance of students of good performance, who received BIM software teaching and believe visualisation is important:

$$s_1^2 = \left[(17-17.4)^2 + (18-17.4)^2 + (19-17.4)^2 + (16-17.4)^2 + (17-17.4)^2 \right] / 5 = 1.04$$

Variance of students of good performance, who received BIM software teaching and believe simulation is important:

$$s_2^2 = \left[(16-17.4)^2 + (18-17.4)^2 + (21-17.4)^2 + (17-17.4)^2 + (15-17.4)^2 \right] / 5 = 4.24$$

Variance of students of good performance, who received BIM software teaching and believe visualisation is important is $s_1^2 = 1.04$, while variance of students of good performance, who received BIM software teaching and believe simulation is important is $s_2^2 = 4.24$, $s_1^2 < s_2^2$; thus, it can be seen that visualisation of the BIM software has the bigger influence upon the students.

INSPIRATION FOR CONSTRUCTION DESIGN TEACHING

BIM software as used in university teaching constitutes an irreversible trend: the BIM software is an inspiration for construction design teaching within universities. With construction design teaching a key task based on modern teaching ideas, the application of BIM software to the construction design teaching should improve and develop students' basic knowledge and expertise.

Reinforce the development of students' basic skills: as BIM software is a complex professional product, solid expertise is required for its use. As another drawing tool following CAD, BIM requires higher skills than CAD. So, the users are supposed to have better ability and be a good master of all skills needed for design.

This includes some expressive skills used in construction design, such as photography, model making and drawing. Also, the users need to have abstract design ability. Since BIM software has higher requirements for operational skills, teachers should pay attention to improving students' basic skills and enhancing their hands-on operation of the software.

Increase the learning difficulty and lift the knowledge beyond the basics: BIM software is complicated knowledge and so it is inadequate to merely have the basics. During the use of this software in teaching, the teacher should increase the knowledge level of the students to a higher level.

As a new *star* in the construction industry, BIM software is highly appreciated by construction designers for its unique technical capabilities. It plays a big role in improving the efficiency of projects, enhancing the quality of construction and shortening the duration of construction. The use of BIM software in university teaching is a breakthrough for modern teaching and has promising prospects for the future. Although the teaching of construction design at Chinese universities has not totally caught up with overseas practice, within a few years, BIM is expected to play a big role in the teaching of construction design at Chinese universities.

CONCLUSIONS

Building information modelling software uses a digital representation of a construction project, including the processes and resources for all stages of the project life circle. The BIM software is the hi-tech frontier in the construction industry and connects with counterparts elsewhere in the world. Recently, BIM software has been rapidly adopted in the teaching of construction design at universities.

The use of questionnaires, literature search and interviews were used to determine the status of the use of BIM software in a construction design major at universities in China. The research revealed that BIM software is playing a big role in university classes.

Through this study, constructive proposals are made for the integration of BIM with teaching, and prospects for the future application of such software are explored. Although not all universities are using BIM in their teaching, in the near future, it can be predicted, BIM software will be widely used in university teaching of construction design, to nurture practical talent for the construction industry and to link class teaching to international practice and modern design technology.

REFERENCES

1. Chien, K-F., Wu, Z-H. and Huang, S-C., Identifying and assessing critical risk factors for BIM projects: empirical study. *Automation in Construction*, 45, 1-15 (2014).

2. Farr, E.R.P, Piroozfar, P.A.E. and Robinson, D., BIM as a generic configurator for facilitation of customisation in the AEC industry. *Automation in Construction*, 45, 119-125 (2014).
3. Wong, J.K-W. and Kuan, K-L., Implementing *BEAM Plus* for BIM-based sustainability analysis. *Automation in Construction*, 44, **8**, 163-175 (2014).
4. Fridrich, J. and Kubečka, K., BIM - The process of modern civil engineering in higher education. *Procedia - Social and Behavioral Sciences*, 141, 763-767 (2014).
5. He, G., BIM and BIM related software. *Civil Engng. Infor. Technol.*, 17, **2**, 16-18 (2010).
6. Ragusa, G. and Lee, C.T., The impact of focused degree projects in chemical engineering education on students' research performance, retention, and efficacy. *Educ. for Chemical Engineers*, 7, **3**, e69-e77 (2012).
7. Zhan, Q. and Liu, G., Education knowledge management - new perspective on Educational Technology Research Institute. *Modern Educational Technol.*, 13, **2**, 36-40 (2002).
8. Chiu, C-Y. and Russell, A.D., Design of a construction management data visualization environment: a bottom-up approach. *Automation in Construction*, 35, 353-373 (2013).
9. Stelios, D.G., Supersaturated designs: a review of their construction and analysis. *J. of Statistical Planning and Inference*, 144, **1**, 92-109 (2014).
10. Douglas, R.S, Colleen, M.S. and Tran, V.T., A new look at an old construction: constructing (simple) 3-designs from resolvable 2-designs. *Discrete Mathematics*, 325, **6**, 23-31 (2014).
11. Simanaviciene, R., Liaudanskiene, R. and Ustinovichius, L., Assessing reliability of design, construction, and safety related decisions. *Automation in Construction*, 39, **4**, 47-58 (2014).
12. Emami, A.M.A., Construction design zoning of the territory of Iran and climatic modeling of civil buildings space. *J. of King Saud University - Science*, 23, **4**, 355-369(2011).
13. Abulnour, A.H., The post-disaster temporary dwelling: fundamentals of provision, design and construction. *HBRC J.*, 10, **1**, 10-24 (2014).
14. Uzunoglu, S.S. and Quriesh, A., A method of adapting construction education in architectural design education. *Procedia - Social and Behavioral Sciences*, 51, 546-552 (2012).
15. Häfner, P., Häfner, V. and Ovtcharova, J., Teaching methodology for virtual reality practical course in engineering education. *Procedia Computer Science*, 25, 251-260 (2013).