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Research Article

Teaching construction sciences with the integration of BIM to undergraduate architecture students

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Building information modeling (BIM);
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Student attitudes

Abstract This study aims to test two hypotheses: teaching building information modeling (BIM) in relation to construction science provides students with a remarkable understanding of the nature of construction science (Hypothesis 1), and if the student has positive attitude toward the use of the BIM program, then efficiency by which construction science is taught by its means is improved (Hypothesis 2). Results and process of a case study with a novel teaching methodology were discussed in terms of the benefits of the students. A questionnaire study was conducted on the student group with which the case study was performed to test each student's attitude. Results were evaluated statistically. When BIM is integrated with the teaching of basic construction courses within architecture degree programs, the students understood the building system principles simply and effectively. As a result of the statistical analysis, the students find the applied method effective. Moreover, their attitude toward BIM affects the process.

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1. Introduction

BIM is an important current development in the sphere of architecture and construction (Chen et al., 2019; Rogers et al., 2015). BIM represents a transition from 2D drawings to 3D drawings in architectural design because of its capacity to create object-based intelligent building models (Sabongi, 2009). In the BIM environment, components, such as walls, doors, and windows are used, instead of line, square, and circle geometries (Woo, 2006).

Indeed, the role of the educational process is crucial in making the transition to BIM (Boeykens et al., 2013). The number of BIM experts is likely to increase with the inclusion of BIM courses in architectural education, thereby enabling available BIM trained specialist personnel to be employed in various design and construction companies

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(Russell et al., 2014; Wu and Issa, 2014). However, although the use of the BIM environment is becoming popular, and its software is undergoing rapid advancement, its use in architectural education programs is being adopted slowly (Macdonald and Mills, 2011). Some universities began to include BIM in their educational programs because the software had become widely used in the construction industry. To be effective, the expansion of BIM technology in architectural education must, at least, keep pace with its adoption by the construction industry and must focus on current and future related problems (Becerik-Gerber et al., 2011).

In recent years, various methods have attempted to integrate BIM within the architecture curriculum. For example, Techel and Nassar (2007) proposed to teach BIM in sustainable design framework; Boeykens et al. (2013) proposed a BIM process for teaching multidisciplinary student teams that consisted of architecture and engineering students; and Guidera (2006), Vinsova et al. (2015), and Yan (2010) proposed a BIM course model to be carried out with the design studio. However, the teaching of BIM in architectural education is regarded skeptically by some because it is contrary to the principles of design thinking (Berwald, 2008; Deamer and Bernstein, 2011; Kocaturk and Kiviniemi, 2013). Teaching BIM to undergraduate architecture students, particularly at the first stage of the design process, does not seem appropriate. However, the teaching of BIM should a compulsory course because of its importance in the profession. Therefore, universities must find new education models by developing new methodologies that allow instructors to teach architecture along with BIM.

No teaching based on teaching BIM together with construction science is conducted in undergraduate architectural education. Teaching BIM in relation to construction science provides students with a better understanding of the nature of construction science (Hypothesis 1). With such method, the skepticism of BIM teaching in architectural education, which is explained in the background section, is avoided. Therefore, in this study, a novel teaching methodology is developed. Rather than integrating BIM within the architectural design studio, BIM teaching should be performed in a compulsory undergraduate course in which it should be integrated into construction science topics depending on the level of the students' knowledge. To test hypothesis 1, a questionnaire study was conducted in the student group with which the case study was performed. The results were evaluated statistically.

An improved instruction of the subject will not be limited to the course methodology. Students' interest in BIM programs can also trigger improved understanding and learning. Previous studies, such as that of Pektas and Erkip (2006)'s study on students' interest in computers, support this hypothesis. Therefore, the student's attitude toward BIM also is assumed to affect the learning process. The second hypothesis suggests that if the student has positive attitude toward the use of the BIM program, the efficiency by which construction science is taught by its means will be improved (Hypothesis 2). To test hypothesis 2, correlations among the questions were determined, and the results were evaluated statistically.

The objectives of this study are listed as follows.

- This study aims to create a novel teaching method that intends to teach BIM together with construction science.
- This study aims to test the hypothesis that teaching BIM in relation to construction science (the novel teaching methodology) provides students with improved understanding of the nature of construction science.
- This study aims to test the second hypothesis that if the student has positive attitude toward the use of the BIM program, then efficiency by which construction science is taught by its means is improved (Table 1).

2. Background

2.1. Advantages of using BIM in architecture undergraduate education

- BIM software has undergone continuous development, and its use is becoming increasingly widespread. In addition to the creation of a virtual model of the building that reflects its entire reality, BIM assists in generating information regarding its entire life cycle (Ding et al., 2015; Eastman et al., 2008; Mandhar and Mandhar, 2013). Kymmell (2008) expressed that BIM extended beyond virtual reality because its model represented the physical characteristics of actual situations. Thus, learning the properties of the BIM environment will be advantageous to undergraduate architecture students.
- For example, other than basic modeling, simulations, such as energy analysis in relation to sustainability, can be performed. By these analyses, less energy consuming buildings and those which use more renewable energy sources can be designed and constructed. Importantly, relationship with green building certifications can be established, and students can obtain basic information about sustainability in terms of the usage of these parameters in their own projects or in student competition projects.
- People in various professions, such as engineering, architecture, and contractual agreement, can possibly work together in the BIM environment, thereby minimizing errors and enabling professionals that work on the project to create a single communication language among them (Azhar, 2011; Hardin, 2009). Moreover, projects can be reviewed rapidly because of the coordination among various units. Therefore, time can be used efficiently. Consequently, because of their BIM experience, students will be knowledgeable and prepared for the working environment when they begin their professional career.
- Furthermore, in addition to 3D modeling, students must experience different parameters in the BIM environment, such as scheduling and cost projection. As a result of students learning about the applications of scheduling and cost projection in the BIM environment, they are able to create cost-efficient products, understand how much influence the choice of materials has on the final cost of a building, and make the correct decisions in the early phases of its design. Accordingly, savings can be made over the raw construction materials with less

Table 1 Flowchart of the steps followed in the study.

Problem statement
Teaching BIM in architectural programs is important. However, teaching BIM together with design studio is skeptical. Therefore, new methods should be developed.
Objective
This study aims to create and test the efficiency of a novel teaching method that intends to teach BIM together with construction science.
Hypothesis
Hypothesis 1: Teaching BIM in relation to construction science (the novel teaching methodology) provides students with improved understanding of the nature of construction science.
Define secondary factors
Hypothesis 2: If the student has positive attitude toward the use of BIM program, then teaching efficiency will be improved.
Test the hypothesis
Teaching methodology has been applied to a group of students, and a questionnaire has been conducted.
Evaluate the results
Results were evaluated statistically with one sample *t*-test and Pearson product moment correlation.

waste production, indicating that high-quality buildings can be produced at a low cost (Azhar et al., 2008; Glick and Guggemos, 2009).

- Strengthening the free-form modeling capacity in the BIM environment by means of features, such as Dynamo (Revit plug-in) is also possible. That is, students can experience non-Euclidean geometry forms in their projects within the BIM environment. The use of free-form modeling is becoming increasingly widespread with the creation of designs, which are removed from Euclidean geometry.

2.2. Present issues in teaching BIM in architectural education

- As noted by Deamer and Bernstein (2011), the use of BIM in architectural education must be approached with caution because of the lack of flexibility in the design (Kocaturk and Kiviniemi, 2013). Berwald (2008) concluded that BIM objects had to be shaped in a certain way. The creative process can be potentially hindered by the creative process.
- Cheng (2006) emphasized that rather than reinforcing the critical thinking ability of students in education, BIM overburdened them with excessive technical content (Holzer, 2015).
- Students can skip the design cognition stage in the architectural design sketch process because the BIM environment, in its current state, works with certain 3D objects. In contrast, during the sketch process, students can explore new relationships using digital or classical methods or models, and these relationships can guide them in redefining their ideas (Goel, 1995; Schon and Wiggins, 1992). Furthermore, when students carry out their designs using certain 3D objects in the BIM environment, they can circumvent phenomenological inferences in the design process and may not experience form-finding process developments, such as hermeneutics.
- If BIM is taught in courses that involve design studio, students will need a certain level of relevant knowledge (Kocaturk and Kiviniemi, 2013), and learning the use of BIM at a sufficient level is necessary so that the design process will not be restricted. Otherwise, students will learn BIM directly rather than learning about designing, which will direct the final design outcome.
- BIM programs are designed for standard building elements and are not suitable for creating non-standard elements in contemporary architecture (Mitchell, 2005; Stavric ve Marina, 2011). At present, BIM allows the modeling of structures easily, mostly in standard geometry. Students can easily model standard forms in the BIM environment and therefore leads them to use standard geometries in the architectural design studio. However, BIM is not specific to individual and unique design models, advance with the development of 3D printers, robots, and multi-axis CNC machines. The formation of structures with different shapes is a feature of modern architecture, which is consequently becoming more remote from easily produced Euclidean geometry.
- Although free-form options in the BIM environment increase continually, undergraduate architecture students find the use of these options (in their current forms) difficult. BIM needs a great deal of time and effort. Thus, students prefer not to occupy themselves too much on this topic because of the already demanding nature of an architecture degree program.

3. Case study

3.1. Student profile

Undergraduate architecture students study construction science and materials 1, 2, and 3 as compulsory courses in consecutive terms at the university where this study was conducted. In these courses, students are taught about reinforced concrete, steel and timber building systems and components, and materials used in the construction and application properties of building products (developed with modern technologies) are discussed. They are also taught about walls, windows, doors, floors, stairs, structural elements, membrane systems, roofs, fine structural elements, and thin coatings. These construction courses are taught by means of traditional methods. After completing these three compulsory courses successfully, the students study a compulsorily construction project course in addition to an architectural design studio course, in which they draw upon their previous construction knowledge.

In the university, the context of the courses related to computer software varies. In connection with learning about computer programs, students are taught how to use Photoshop in their first year of "introduction to computer-aided design" compulsory course. In the second year, they

learn about CAD-based software: AutoCAD and a 3D modeling program: SketchUp in the "computer-aided design-1" compulsory course. In their third year, they learn about BIM based software: Revit program in the "computer-aided design-2" compulsory course (4 hours per week). Along with these compulsory courses, the architecture program comprises elective courses, namely, ArchiCAD, 3Dsmax, Maya, and Rhino.

In this work, the teaching process that uses the Revit program in "computer-aided design-2" compulsory course has been discussed. During this course, an experimental study was conducted.

3.2. Methodology

The integration of the students' BIM learning process into the construction courses rather than into design studio courses is appropriate (Fig. 1). Many BIM programs are available, and the program used in this study is Revit. However, the method used here can be performed using any other BIM programs.

In the first part of the course, the difference between BIM and CAD, the operation form of BIM software (Revit, ArchiCAD and Allplan), and its advantages are explained. Subsequently, the interface of the Revit program is introduced, and the creation of section and elevation are shown, wherein the course is continued using 3D modeling. The modeling of basic construction components, such as walls, curtain walls, doors, windows, foundations, structural columns, beams, floors, ceilings, roofs, stairs, openings, railings, and ramps are discussed. During the discussion of these modeling issues, the instructor also explains related construction science topics. If necessary, then the details of basic building components are given during the teaching of the Revit modeling process. For example, the following issues are mentioned: how to determine the layers of the walls? What do these layers (e.g., membrane, core, insulation) mean? In explaining these basic building components, some students reinforced their knowledge that were previously learned in the construction courses, whereas other students had no knowledge about construction and only became informed during this process.

In addition, classroom practices are carried out under the supervision of the instructor for each modeling subject.

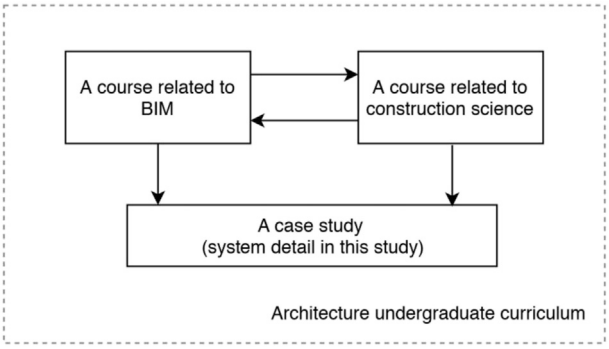

Figure 1 Teaching methodology for undergraduate architecture program.

In the later sections of the course, dimensioning, adding a component (e.g., furniture), preparation of sheets, site modeling, free-form modeling, preparation of schedule/quantities, creating system families, rendering, and preparation of animation are introduced. During the modeling studies, the applications of these subjects are also carried out under the supervision of the instructor. The students are given the same modeling studies during classroom practices, except for the last assignment (Table 2).

In the final stage of the course, the students are asked to make detailed drawing, with 1/20 or larger scale (e.g., 1/10 or 1/5) in the Revit environment. The students are asked to search for local detail drawing samples that they will draw in the Revit environment. For this study, students generally opt to use the details found from the websites of local insulation companies or detailed examples found in textbooks. They are free to select any type of detail. However, students are directed to choose other details if the detail does not have certain complexity. Therefore, the assignments will have the same level of complexity. While the drawings are being completed, a constant exchange of information between the instructor and the students occurs (Table 2).

Finally, the students are asked to upload their drawings to the cloud system, which is used in the course and enables the students to see the instructor's notes and other student's works that are uploaded to the system during the class. Thus, students can peer review one another's works, correct each other's mistakes, and make suggestions about their assignments. In particular, they compare their findings on the studies of system details and make comment regarding their characteristics. They may also combine their details and produce new versions (Table 2).

3.3. Course Outcomes

At 1/20 or greater scale detail drawings, the students produced different products. For example, one student found terrace roof details for an insulation company from the company's website. Initially, as a system detail, the student marked a part of the roof of the building, which he modeled in Revit. Then, from the terrace roof detail, the student began to draw system detail as "terrace roof not to

Table 2 Progress of the course.

BIM and its advantages are explained.
Interface of Revit program is introduced.
Modeling of basic construction components in relation to construction science are discussed in detail.
Features, such as dimensioning, preparing of sheets, and rendering are introduced.
Students are asked to make detailed drawing, and discussions in relation to construction science are continued.
Students are asked to upload their drawings to the cloud system.
Students can peer review one another's works, and discussions in relation to construction science are continued.

be walked on" for the part that was marked in the Revit model. The details were added to the drawn system detail with the support of 2D drawing in Revit (Fig. 2). During this process, the student learned to read the details, understood different detail options (in this example, two types of terrace roof examples: cannot walk on them and one type of terrace roof example: can walk on it), obtained knowledge about the layers of the details (e.g., membrane, insulation), and learned to draw in Revit. Thus, the student represented the interaction among these parameters simultaneously.

Another student found a detail from an insulation company's website and attempted to represent this detail in his own Revit model. He aimed to use the wall detail that contains bricks of the example detail that he found (Fig. 3). During the modeling process in Revit, the Revit library was used to bring identifiable components, such as bricks, to the detailed drawing. During his modeling of the brick wall in Revit, the student brought the brick from the Revit library to his drawing and experienced the use of the Revit library for the production of the detail. In addition, during the drawing of this detail modeling, the student envisaged how the details of different wall types (e.g., those made using brick coating, conventional brick, or gas concrete) were developed. In this type of mixed walls, he learned the insulation that can be used in different places.

Students who modeled the classic pitched roof detail learned many further details from the arrangement of tiles to the pediment during the modeling process. For example, in the example shown in Fig. 4, the student attempted to model a roof detail based on the example of the detail he had found. In this detail, aside from his experience in basic modeling, such as creation of roof, column, and beam, he also began to examine the relation of the roof to these systems. When he was drawing an inclined beam, which he incorporated in Revit, he began to adjust the "properties" settings (e.g., "start level offset" and "end level offset") of the beam. Thus, he began to discover some specific features in the "properties" section. In addition, while creating the details of the roof, the student learned the possible ordering of building elements, such as finishing elements (e.g., tiles), coating materials (e.g., plywood, sheathing), membranes (e.g., vapor retarder), and rafters. After this process, he started to process the detail in 2D by creating the "callout detail" using various necessary additional lines, such as highlighting the membrane layer with a dotted line. Thus, a new line style was created in terms of shape and thickness in Revit for a 2D line used in the callout detailing process. In addition, in the detailing process (for example, for the replacement of the bricks to the wall), he used the Revit library. Here, the student examines the library and inevitably finds some unfamiliar building elements. Therefore, he can have a general knowledge about them. Some students also started to do a "family" creation for some specific components while creating a detail drawing. Thus, at each stage, the student becomes more involved with the Revit program. At the detail modeling stage, the student begins to perceive building and drawing as a single entity. In addition, with many different views provided by Revit (e.g., sections, elevations, plans, and perspectives), the student can easily ensure the control of his/her modeling and drawings alternately.

3.4. Questionnaire

At the end of the 2019 spring semester, a questionnaire was conducted with 32 students who took this course to test the hypotheses as framed from the students' perspective. The questionnaire was given to the students online in the last lesson of the semester, which avoided bias by preventing them from communicating with one another beforehand. An appropriate amount of time was allowed for the questionnaire to be completed by the students who were informed in advance that their identity will be kept anonymous. The questionnaire used in the study was provided in the Appendix (Table A1).

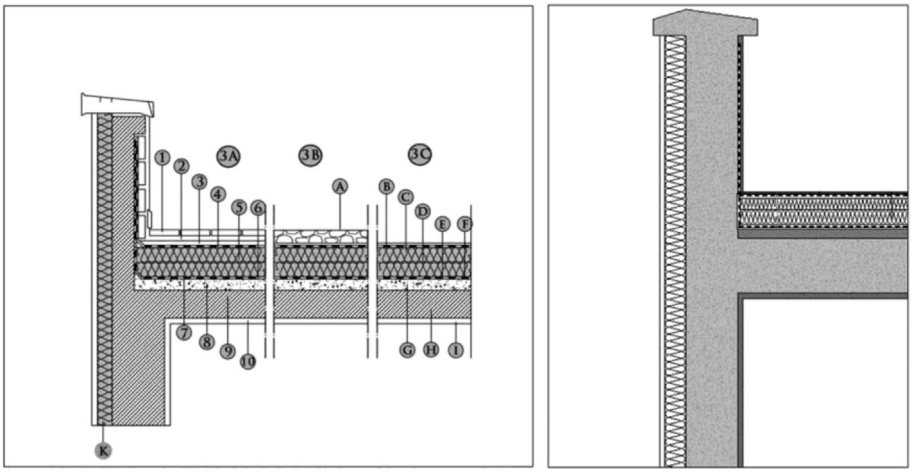

Figure 2 Terrace roof detail found by the student (belonging to KnaufInsulation company) and the type of 3D terrace roof detail, modeled by the student in Revit environment. 3A-Detail of a terrace roof (can be walked on). 3B- Detail of a terrace roof (cannot be walked on). 3C- Detail of a terrace roof (cannot be walked on).

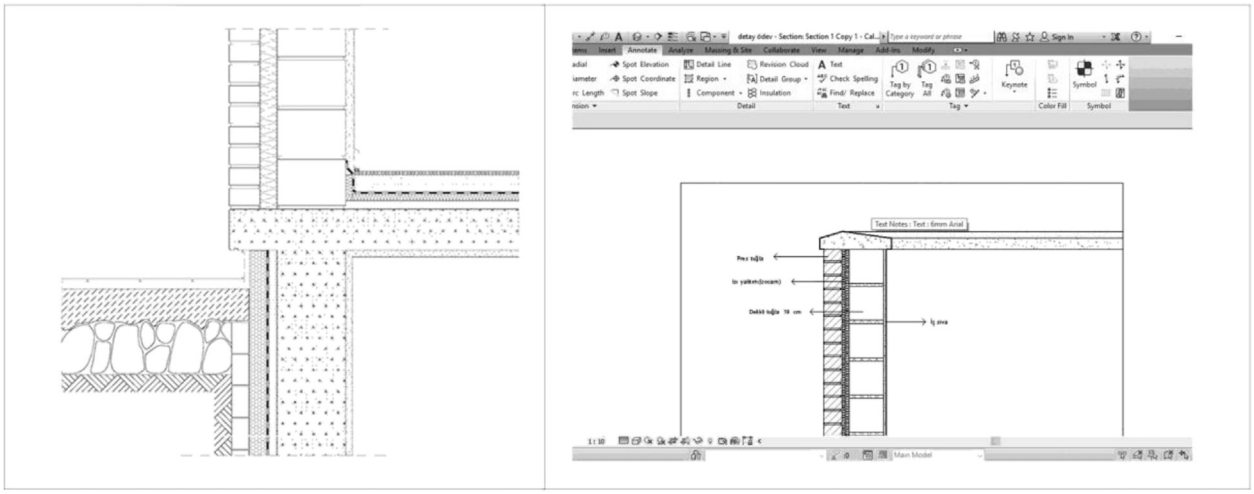

Figure 3 Brick wall detail (belonging to Izocam insulation company) found by the student, and the brick wall detail modeled by the student in the Revit environment.

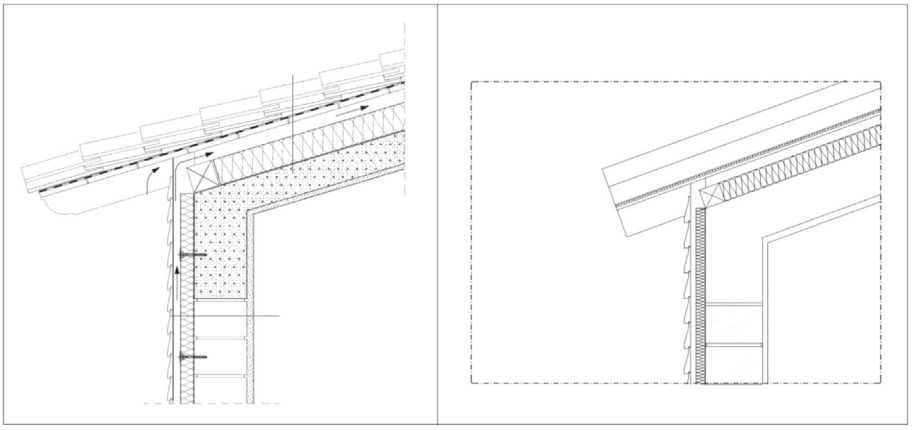

Figure 4 Roof detail (from Izocam company) found by the student and a roof detail modeled by the student in the Revit environment.

In this study, Pektas and Erkip (2006)'s study was used as reference in preparing the questions in the survey. In a similar way, Pektas and Erkip (2006) studied the students' attitude toward computer usage in design. This questionnaire consisted of 10 questions altogether, which were placed in two categories: "Student's attitude toward learning construction science using Revit" and "Student's attitude toward Revit". Some questions in the survey were worded negatively to test the validity. In addition, questions about gender, year of study, and age of the student are included. However, these data were not included in the statistical analysis because all of the students are 3rd year undergraduate architecture students aged 18–24. Also, gender was not included in the statistical analysis because it is not related to the hypothesis (Tables 3 and 4).

A five-point Likert scale was used for the questionnaire responses. The following options were given: Strongly disagree = 1, Disagree = 2, Undecided = 3, Agree = 4, and Strongly agree = 5. Therefore, the ordinal scale was used to measure the responses. The SPSS statistical software package program was used to evaluate the results of the survey statistically.

3.5. Findings

At the end of this survey, all the students answered the questions completely. The evaluation of the answers shows that the majority of the class has interest in using Revit. For example, to the question "I enjoy working with Revit," 37.5% of the students answered Agree, and 34.4% of the students answered "Strongly agree". Moreover, in the question "I would like to learn more about Revit," 31.3% of the students answered "Agree," and 53.1% of the students answered "Strongly agree." To the question "Revit is exciting," 46.9% of the students answered "Agree," and 25%

Table 3 Details of survey parameters.

Survey parameters	Case study information
Department where the course was given	Department of Architecture
Time of study	2019 Spring
Duration of the course	14 weeks
Time of the course	4 h per week
Type of the course	Compulsory course
Number of students	32 (18 females and 14 males)
Age of students	18–24
Level	Undergraduate
Year of study	3rd year

Table 4 Two categories of the questionnaire.

Category	Question
Student's attitude toward Revit	1. I do not find Revit interesting 2.I enjoy working with Revit 3.I would like to learn more about Revit 4.Revit is exciting 5.I only use Revit when necessary
Student's attitude toward learning construction science with Revit	6. Revit did not help me to learn construction science 7. Revit helped me to learn construction science 8. Revit helped me to understand more about the nature of building components, such as floor, columns, beams, and stairs 9. I think BIM (like Revit) programs are more efficient to use than CAD programs in the construction industry 10. Revit did not help me to understand the system details of a building

of the students answered "Strongly agree" (Table 5).The responses to the questions in the category of "Student's attitude toward learning construction science with Revit" shows that many students think that Revit helps in learning construction science. For example, to the question "Revit helped me to learn construction science," 40.6% of the students answered "Agree," and 18.8% of the students answered "Strongly agree." To the question "Revit helped me to understand more about the nature of the building components such as floor, columns, beams, stairs," 40.6% of the students answered "Agree," and 21.9% of the students answered "Strongly Agree". To the question "I think BIM (like Revit) programs are more efficient to use than CAD programs in the construction industry", 50% of the students answered "Agree," and 21.9% of the students answered "Strongly agree" (Table 5).

Before calculating Alpha, the negatively worded sentences were reversed, so as not to affect the scale direction. Then, the reliability test was performed, and Cronbach's Alpha value was found 0.915 (number of items: 10). This finding shows that the statistical data are internally consistent.

In addition to the above data, one sample *t*-test was applied to each variable to test hypothesis 1. The mean value of Likert scale, 3, was used as test value to compare the mean of the sample. A low *p*-value (<0.05) indicates a high significance between sample mean and test value. A high significance in each variable (Table 6) is shown. According to the percentage of students' answers to the questionnaire and one sample *t*-test, hypothesis 1 is correct. Thus, teaching BIM in relation to construction science will provide the student with a better understanding of the nature of construction science.

Pearson product moment correlations were made between variables in the categories "Student's attitude toward learning construction science with Revit" and "Student's attitude toward Revit" categories to test hypothesis 2. A significant correlation was found between most of the variables in the two categories ($^{*}p < 0.05$, $^{**}p < 0.01$). These, the variables in these 2 categories seem to be mutually dependent (Table 7). These results prove the hypothesis 2. Thus, the student, who is interested in Revit, is better involved in the construction

Table 5 Percentage of the students' answers to the questions of the questionnaire.

No		Strongly disagree %	Disagree %	Undecided %	Agree %	Strongly agree %
1	I do not find Revit interesting	65.6	–	15.6	6.3	3.1
2	I enjoy working with Revit	6.3	3.1	18.8	37.5	34.4
3	I would like to learn more about Revit	3.1	–	12.5	31.3	53.1
4	Revit is exciting	9.4	3.1	15.6	46.9	25.0
5	I only use Revit when necessary	53.1	28.1	9.4	3.1	6.3
6	Revit did not help me to learn construction science	31.3	31.3	31.3	–	6.3
7	Revit helped me to learn construction science	6.3	–	34.4	40.6	18.8
8	Revit helped me to understand more about the nature of building components such as floor, columns, beams, and stairs	3.1	6.3	28.1	40.6	21.9
9	I think BIM (like Revit) programs are more efficient to use than CAD programs in the construction industry	6.3	–	21.9	50.0	21.9
10	Revit did not help me to understand the system details of a building	21.9	34.4	34.4	3.1	6.3

Table 6 One sample *t*-test of variables (Test Value: 3, Confidence Interval Percentage: 95%).

No	Question	Mean	Std. Deviation	Std. Error Mean	*t*	df	Sig. (2-tailed) (*p*)
1	I do not find Revit interesting *(Negatively worded sentence)*	1.72	1.143	.202	−6.344	31	**.000**
2	I enjoy working with Revit	3.91	1.118	.198	4.587	31	**.000**
3	I would like to learn more about Revit	4.31	.931	.165	7.974	31	**.000**
4	Revit is exciting	3.75	1.164	.206	3.645	31	**.001**
5	I only use Revit when necessary *(Negatively worded sentence)*	1.81	1.148	.203	−5.850	31	**.000**
6	Revit did not help me to learn construction science *(Negatively worded sentence)*	2.19	1.091	.193	−4.214	31	**.000**
7	Revit helped me to learn construction science	3.66	1.004	.177	3.699	31	**.001**
8	Revit helped me to understand more about the nature of building components such as floor, columns, beams, and stairs	3.72	.991	.175	4.101	31	**.000**
9	I think BIM (like Revit) programs are more efficient to use than CAD programs in the construction industry	3.81	.998	.176	4.605	31	**.000**
10	Revit did not help me to understand the system details of a building *(Negatively worded sentence)*	2.38	1.070	.189	−3.304	31	**.002**

science, and therefore has a better understanding of it. In this case, if the student has a positive attitude toward using the BIM program, the efficiency, by which construction science is taught by its means, will be improved.

Cohen (1988) has evaluated the strength of relationship between variables in the Pearson Correlation as: small: 0.10 to 0.29, medium: 0.30 to 0.49, and large: 0.50 to 1.00. For example, a moderate positive correlation of the "Revit helped me to learn construction science" variable with the

Table 7 Results of Pearson product moment correlations between "Student's attitude toward learning construction science with Revit" and "Student's attitude toward Revit" categories.

		1. Revit does not interest me	2. I enjoy working with Revit	3. I would like to learn more about Revit	4. Revit is exciting	5. I use Revit only when I must do so
6. Revit did not help me to learn construction science	Pearson Correlation	**.536**[a]	**−.409**[b]	**−.377**[b]	**−.597**[a]	.338
	Sig. (2-tailed) *(p)*	**.002**	**.020**	**.033**	**.000**	.058
7. Revit helped me to learn construction science	Pearson Correlation	**−.593**[a]	**.459**[a]	**.464**[a]	**.642**[a]	**−.534**[a]
	Sig. (2-tailed) *(p)*	**.000**	**.008**	**.007**	**.000**	**.002**
8. Revit helped me to understand more about the nature of building components, such as floor, columns, beams, and stairs	Pearson Correlation	**−.642**[a]	**.587**[a]	**.553**[a]	**.692**[a]	**−.586**[a]
	Sig. (2-tailed) *(p)*	**.000**	**.000**	**.001**	**.000**	**.000**
9. I think BIM (like Revit) programs are more efficient to use than CAD programs in the construction industry	Pearson Correlation	−.274	.215	.343	**.375**[b]	−.144
	Sig. (2-tailed) *(p)*	.129	.237	.055	**.035**	.431
10. Revit did not help me to understand the system details of a building	Pearson Correlation	**.617**[a]	**−.590**[a]	**−.542**[a]	**−.751**[a]	**.505**[a]
	Sig. (2-tailed) *(p)*	**.000**	**.000**	**.001**	**.000**	**.003**

[a] Correlation is significant at the 0.01 level (2-tailed) (**$p < 0.01$).
[b] Correlation is significant at the 0.05 level (2-tailed) (*$p < 0.05$).

"I enjoy working with Revit" and "I would like to learn more about Revit" variables exists. A large positive correlation exists between the "Revit helped me to learn construction science" variable and the "Revit is exciting" variable. Furthermore, the correlation of the "Revit helped me to understand more about the nature of building components such as floor, columns, beams and stairs" variable with "I enjoy working with Revit", "I would like to learn more about Revit" and "Revit is exciting" variables is substantially positive.

However, as a result of this analysis, the conclusion was reached that the variable: "I think BIM (like Revit) programs are more efficient to use than CAD programs in the construction industry" is not related to all of the variables within the "Student's attitude toward Revit" category. From this result and one sample *t*-test result of this variable, a conclusion may be drawn that while the students are generally aware of the importance of BIM in the construction industry, their attitude toward Revit vary.

4. Conclusion

- The statistical results coincide with the inferences made by the author mentioned in Course Outcomes. During the course, students learned construction science simultaneously with BIM in their studies. The same result is obtained from the statistical analysis based on the questionnaire answered by the students.
- When modeling with BIM is taught, the construction science is also taught inevitably. For example, the students see the mutual relationships between columns and beams, as well as the replacement of columns and beams in relation to the grid in BIM. In addition, the BIM environment provides insight into the student about how the system works. For example, the replacement of different types of stairs between the floors can be clearly seen in the views of plan, section, and perspective. BIM also gives students a convenient preview of complex systems, such as pitched roofs, so that they can easily understand how these systems work overall. Moreover, they can experience different systems with a selection of concrete or steel system options.
- With this teaching methodology, the gap between two types of courses can be closed, and the student's simultaneous learning of construction knowledge and BIM program can increase their productivity.
- Students also began to realize that they could have the opportunity to enter into the professional architectural environment more quickly than they would otherwise, because they learned about the BIM environment during their undergraduate study, and they are aware that this program is being increasingly used across the world. As they study the BIM program course and during their internships in the relevant offices, students inevitably begin to try and make use of BIM in the architectural environment. Thus, they observe that some architectural offices want to adopt BIM because of the particular advantages of working in the BIM environment, whereas other offices need to use the BIM technology because of requirements imposed by the authorities.
- The students seem surprised when they encounter the parametric features of BIM. Because they study the Revit course after learning CAD. In the CAD environment, they take a much longer time to draw something than in BIM environment, where, in fact, they draw it too quickly. For example, the walls should be trimmed before drawing the door, and the door should be drawn within the trimmed area of the walls because the AutoCAD program works with the logic of drawing on paper. However, for the placement of the door on the wall, trimming the wall in the BIM environment, which does the trimming automatically and correctly locates the door on the wall.
- Students began to create their own Revit library with the detail drawings, which were given to them as homework exercises. Every student was able to share their details instantly with their classmates because an internet-based cloud environment is used in the course. Thus, each student had the drawing details of their classmates to enrich their libraries. The creation of a library by a group is important because different construction techniques and different materials are used in different parts of the world, and different standards are created. For example, the roof and window details of a rainy area cannot be same as those for a very sunny region. Therefore, the library should contain different details according to each region, and the accumulation of these libraries can increase the diversity of the details worldwide. An increase in diversity can be made with the use of construction details related to the region. Increasing the scope of these libraries using different methods is possible.

5. Limitations and future work

- The number was limited to 32 because this study was conducted with a group of students who took the course. However, accurate results can be achieved if this type of questionnaire is conducted with more students.
- The sample data can consist of more students with different professional backgrounds or test years for more reliable results.
- The results of Pearson correlation do not reveal the benefits of teaching methodology. In addition, performing other tests is useful to prove hypothesis 2 because the results of Pearson correlation may not provide strong evidence about this issue.
- In relation to the methodology, various experiments may be conducted to measure/compare the efficiency of students on different platforms, such as Revit, ArchiCAD, AutoCAD, Google SketchUp.

Declaration of Competing Interest

There are no conflicts of interest to declare.

Appendix

Table A1 Questionnaire used in the study

How old are you?	18—24 ☐	25—30 ☐	31—40 ☐	41—50 ☐	51+ ☐
What is your gender?	Male ☐	Female ☐			
What is your year of study?	1st year ☐	2 nd year ☐	3rd year ☐	4th year ☐	5th year ☐
	Strongly Disagree (1)	Disagree (2)	Undecided (3)	Agree (4)	Strongly agree (5)
1. I do not find Revit interesting.	☐	☐	☐	☐	☐
2. I enjoy working with Revit.	☐	☐	☐	☐	☐
3. I would like to learn more about Revit.	☐	☐	☐	☐	☐
4. Revit is exciting.	☐	☐	☐	☐	☐
5. I only use Revit when necessary.	☐	☐	☐	☐	☐
6. Revit did not help me to learn construction science.	☐	☐	☐	☐	☐
7. Revit helped me to learn construction science.	☐	☐	☐	☐	☐
8. Revit helped me to understand more about the nature of building components, such as floors, columns, beams, and stairs.	☐	☐	☐	☐	☐
9. I think BIM (e.g., Revit) programs are more efficient to use than CAD programs in the construction industry.	☐	☐	☐	☐	☐
10. Revit did not help me to understand the system details of a building.	☐	☐	☐	☐	☐

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