Pedagogy to Teach BIM in Construction Management Curriculum

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Abstract

Advancements in Information and Technology have increased the Building Information Model (BIM) applications in Architecture, Engineering, and Construction (AEC) domain. One of the Construction Management department's goals is to continue to improve the curriculum to reflect the global and national construction industry needs. The Construction Management department has included a BIM applications course in its undergraduate program's curriculum to accomplish this goal. The topics covered in the course include extracting the information for visualization, material quantification; value engineering; 4D modeling; clash detection and coordination; and site logistics. The research objective is to evaluate the effectiveness of the pedagogy adopted to teach the above topics in the BIM applications course in the Construction Management curriculum. The effectiveness of the adopted pedagogy is assessed through parameters such as a) usefulness of components covered in the class, b) helpfulness of the media of instructions, c) level of guidance provided by the instructor, d) ease of learning of the content, e) satisfaction and f) confidence levels of the students to complete the projects/assignments/exercises, the difficulty level of course components, and students' motivation to learn. Each activity is assessed by the instructor's expectation of students' achievements. The duration, usefulness, level of satisfaction of accomplishment, level of challenge, level of inspiration to complete, guidance provided by instructor, and confidence level are used pedagogy assessment parameters. The instructor has allocated the expected quantity of assessment parameters for each activity to complete. The average students' achievement of duration, usefulness, level of satisfaction of accomplishment, level of challenge, level of inspiration to complete, guidance provided by the instructor, and confidence level are within the instructor's expectation.

Keywords: BIM, Construction Management, Construction Education, Construction Management curriculum, Pedagogy

Introduction

Building Information Model (BIM) uses a three-dimensional (3D), digital model to represent the facility to be constructed and provides access to extract the information for various applications such as visualization, quantification, structural analysis, coordination, energy modeling, and facility management. Advancements in Information and Technology will enhance the BIM applications in AEC domains. One of the Construction Management department's goals at Kennesaw State University is to continue to improve the curriculum to reflect the current and evolving trends of information technology applications in the construction industry. The Construction Management department has included a BIM applications course in its undergraduate program's curriculum to accomplish this goal. One of the course objectives is to provide students hands-on learning experience on some BIM applications used in the construction industry. The BIM applications covered in the course include extracting the information for visualization, material quantification, value engineering, and coordination. Students are provided opportunities to explore these applications by performing ten activities in the course. The details of the ten activities are provided in Table 1.

Table 1: Activities related to BIM applications

Activity Number	Activity Name	Activity Details
1	Architectural Modeling	Students explore the different options to create and visually represent the data of a two-story residential building through 3D models.
2	Quantity Takeoff	Students explore to extract the quantities of different materials of a single-story educational building
3	Structural Modeling	Students explore different options to visually represent the rebar details of a reinforced concrete foundation and column.
4	Design Options	Students explore to extract data to perform value engineering between two different options of concrete formwork design.
5	Phasing	Students explore the different options to visually depict the data through 3D models and quantify the required materials for demolition and renovation of single-story commercial building
6	MEP Modeling	Students learn to create and visually represent plumbing and HVAC duct data of a two-story residential building through 3D models.
7	Creation New Families	Students learn to create and visually represent data of an architectural column.
8	4D Modeling	Students learn to visually represent the construction project schedule of the single-story residential building through the 3D model.
9	Clash Detection and Coordination	Students learn to coordinate between the architect, structural engineer, and mechanical engineer to create 3D models of a single-story small commercial building. They explore to visually represent the physical clashes between the components through 3D models. They also explore the usefulness of 3D models for coordination to resolve constructability problems.
10	Object Animation	Students learn to depict the challenges in a small residential construction site logistics plan through the 3D model.

These activities facilitated a virtual construction environment and allowed the students to extract the information for various BIM applications that included design and the construction process. The research objective is to evaluate the effectiveness of the pedagogy adopted to teach the above ten activities related to BIM applications in the course. It is assessed through parameters such as the usefulness of components covered in the course, helpfulness of the media of instructions, level of guidance provided by the instructor, ease of learning of the content, satisfaction, and confidence levels of the students to complete the activities, the difficulty level of course components, and students' motivation to learn. The following sections discuss the literature review related to the BIM in construction education and curriculum; methodology adopted for this study, including the framework developed for collecting the data; statistical data analysis and students' perceptions about the BIM applications course in the Construction Management curriculum.

Background

Three-dimensional computer models increase student understanding of visualization on complex blueprint material [1]. The survey response of students from the construction management program found that 3D visualization provides an opportunity to improve visual-spatial skills [1]. As a result of inadequate visual learning environments, construction engineering and management (CEM) instructors often face challenges communicating and transferring knowledge to students. Meadati et al. [2] present the results of a survey that discovered how BIM facilitates visual learners in teaching formwork concepts to CEM students. Irizarry et. al [3] explores the effectiveness of digital tools to overcome Civil Engineering (CE) and Construction Management (CM) students' visualization and learning challenges. From their study, Irizarry et. al [3], show that the use of building information modeling in Civil Engineering (CE) and Construction Management (CM) education applications has the potential to be more than a graphic representation tool, but a means to enhance student learning. Ahn & Kim [4] examines the degree of awareness and acceptance of BIM and BIM education among architecture students in Asia. A survey is conducted to measure recognition, interest, and experience with BIM and Industry Foundation Classes (IFC) among students participating in a design workshop in Busan [4]. Joannides et al. [5] evaluate the current implementation of BIM and identify trends in iBIM teaching in architecture and construction academic programs. Students to have a basic knowledge of BIM because BIM is as essential to industry [5].

Abdirad & Dossick [6] report on the trends of study on BIM curriculum design and synthesize implemented pedagogical strategies with detailed discussions on their implications and effectiveness across different tasks and contexts. From their recommendation [6], BIM educators and researchers can use it as a guide for designing or assessing their BIM curricula in future research. [7] present a curriculum design where students from five universities worked together to develop design and construction proposals. They [7] found that BIM Execution Planning for assigned teams, given that communication and coordination can be challenging across time zones and cultural differences. Working through technical challenges of exchanging BIM data, the students learned coordination skills in a global team environment that simulated real work experiences [7]. Ahmed et al. [8] study the most critical skills today's construction industry requires from graduating construction management students. Their finding identifies academic curriculums such as BIM application in construction management programs need to focus on to adequately prepare to graduate students entering today's modern and complex construction industry.

Implementing the BIM curriculum is challenging to students because of available teaching time, knowledge retention in students, and the program's flexibility to adapt to a fast-developing technology [9]. Ghosh et al. [9] discuss the advancement of the BIM curriculum, which focuses on the vertical integration of upper-division and lower-division students for a Site Logistics assignment to improve the BIM education continuum.

Adhikari et al. [10] investigate five significant aspects of students' perceptions toward a BIM application including, (1) the source of knowledge of BIM; (2) the perception of the BIM software applications with a level of competency; (3) the awareness level of BIM to get a job in the construction industry; (4) the perception of BIM-related jobs; the perception of the future of BIM in the construction industry; and (5) the importance of BIM education within the CM degree program and CM undergraduate capstone projects [10]. The result indicated that a) 90% of the respondents heard BIM and 71% of the respondents who knew BIM heard it at University, and b) most of the responded students had average and low levels of BIM familiarity and competency [10]. Suwal & Singh [11] focuses on students' perception towards the implementation of BIM courses. Their [11] findings suggest that online BIM learning platforms are highly rated by students as a positive learning experience, indicating the need for greater integration of such tools and approaches in AEC courses. Zhao et al. [12] apply a case study analysis of Virginia Tech's Department of Building Construction courses and the Integrated Construction Studio (ICS) to demonstrate how the BIM process helps students build their collaboration skills in 4Cs: Common goals, Communication, Coordination, and Cooperation. Their [12] findings from the case study suggest some outstanding observations for the educational integration of technology and collaboration in the industry. Clevenger et al. [13] developed three interactive, pilot Building Information Modeling that enabled educational modules designed to support and improve spatial understanding, interoperability, and communication within construction education and training. Three modules indicate that their use is beneficial to students and professionals and that more research is justified [13].

Methodology

The ten activities referred to in Table 1 were taught over one semester in three credit hours BIM application course in this research. These ten activities were conducted through various teaching modes such as asynchronous online and synchronous online except activity 6, an asynchronous online format. The class met two times per week, and each class duration was 1.25 hours. After lecturing and introducing the required components, students were given time to work on the activities. The instructor allocated 2.5 hrs. of class time for students for each activity to complete except activity 1, which was assigned 5 hrs. of class time. After completion of each activity, students were asked to provide feedback about their perception of it. The feedback was collected using a questionnaire-based approach survey. The survey was developed to examine seven significant aspects of students' perceptions toward each activity. These include (A) Duration; (B) Usefulness; (C) Level of Satisfaction of your Accomplishment; (D) Level of Challenge; (E) Level of Inspiration to Complete; (F) Guidance provided by the Instructor and (G) confidence level. The survey consisted of multiple-choice questions. The survey questions were designed so that the respondents could complete the study within 5 minutes, provided they possessed all the answers. Most of the students involved in the study were junior-level undergraduate students from the CM department at Kennesaw State University. The most relevant questionnaire for each activity is shown below.

1) How long you took to finish the activity??
2) On a scale of 1 (lowest) – 5 (highest), please rate the usefulness of the activity
3) On a scale of 1 (lowest) – 5 (highest), please rate Ease of Learning commands to complete the activity
4) On a scale of 1 (lowest) – 5 (highest), please rate the Level of Satisfaction of your Accomplishment of the activity
5) On a scale of 1 (lowest) – 5 (highest), please rate the Level of Challenge of the activity
6) On a scale of 1 (lowest) – 5 (highest), please rate Level of Inspiration to Complete the activity
7) On a scale of 1 (lowest) – 5 (highest), please rate Guidance provided by the Instructor for the activity
8) On a scale of 1 (lowest) – 5 (highest), please rate your confidence level to complete a similar project related to the activity

Results Analysis and Discussion

A total of 32 students were enrolled in Building Information Modelling (BIM) application course. The response rate for ten activities is shown in Table 2.

Table 2: Response rate of each activities

Activity Number	Activity Name	Response Rate
1	Architectural Modeling	25 (78%)
2	Quantity Takeoff	26 (81%),
3	Structural Modeling	25 (78%)
4	Design Options	22 (69%),
5	Phasing	22 (69%),
6	MEP Modeling	18 (56%),
7	Creation New Families	21 (66%),
8	4D Modeling	21 (66%)
9	Clash Detection and Coordination	17 (53%),
10	Object Animation	15 (47%).

Before working on Activity-1, students were involved in completing practice exercises related to it. Since two weeks (4 sessions of 1.25 hours each) was spent on Activity- 1, the instructor expectation time for Activity-1 is calculated as 5 hours (4*1.25 = 5 hrs.). Since one week was spent on each activity for the remaining nine activities, instructor expectation time is calculated as 2*1.25 = 2.5 hrs. A comparison of instructor's expectation time and students' actual invested time is shown in Figure 1. Revit software is used on Activity-1, Activity-2, Activity-3, Activity-4, Activity-5, Activity-6, Activity-7, and Activity-9. Navisworks software was used for Activity-8, Activity-9, and Activity-10. As shown in Figure 1, it is observed that there is a decrease in the amount of time spent by students on software used with the semester's progress. The decrease in the amount of time spent by the student from Activity-1 to Activity-4, indicates the increase in their productivity and comfortability of using the Revit software. Similarly, the decrease in the amount of time spent by the student from Activity-7 to Activity-10 indicates the increase in their productivity and comfortability of using the Navisworks software. Activity- 6 was a little challenging for students as it involves mechanical and plumbing systems. Since the instructor provided less guidance to the students in Activity- 6 compared to other activities because it is involved with the asynchronous online format.

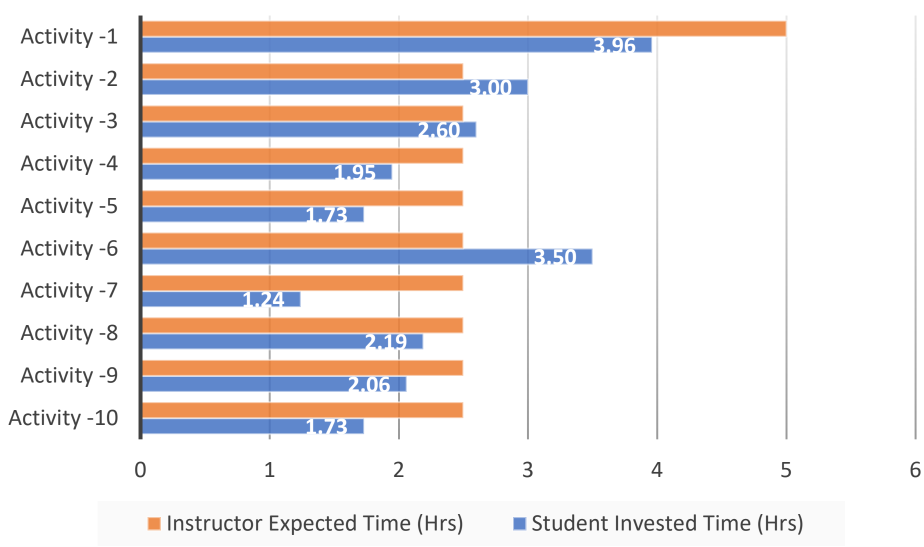

Figure 1: Comparison of instructor expectation time and students invested time

As compared to all activities, students took less time to complete Activity-7 and more time to complete Activity-1. Students were asked to rate on the 5-Likert scale (5 - very high to 1 - very low) their response on ease of learning and level of challenge of ten activities. It is essential to distinguish the relationship between ease of learning and level of challenge. Figure 2 shows a comparison between ease of learning and level of challenge of all ten activities. It indicates that ease of learning is inversely related to the level of challenge, which means when the ease of learning increases, the level of challenge decreases and vice versa. For example, Activity-6 has the lowest ease of learning and the highest level of challenge. As shown in Figure 2, ease of learning increased from Activity-6 to Activity-5 (from the left bar to right bar), while the level of challenge decreases.

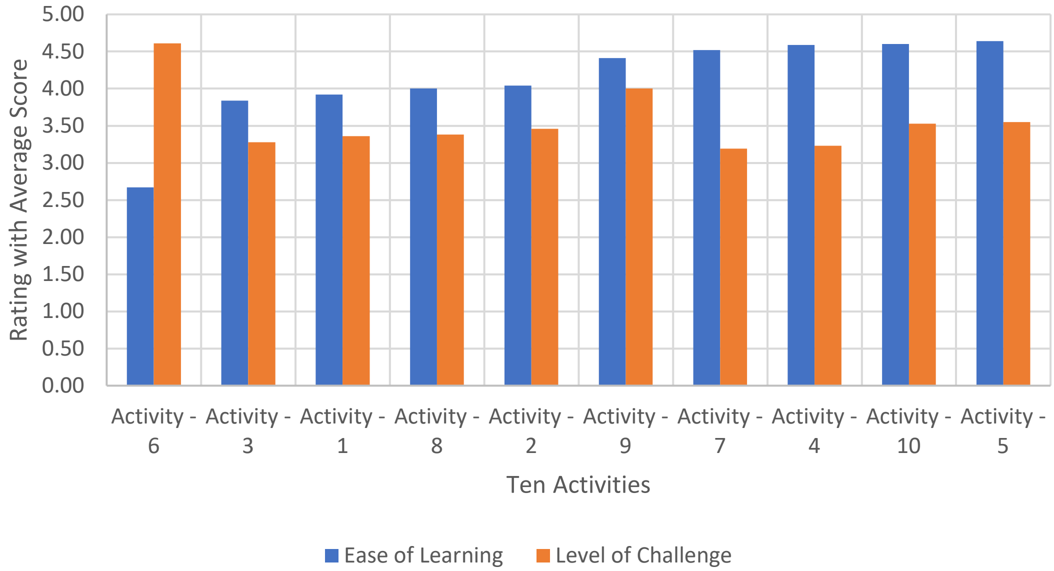

Figure 2: Comparison between ease of learning and level of challenge of all ten activities. (Rating among students: 5= very high, 1= very low)

To investigate the students' usefulness of activities, the students were asked to rate all activities with a 5 - Likert scale (5 is very high to 1 is very low). For example, figure 3 shows that Activity- 6 is less usefulness and Activity- 9 is more usefulness. Activity- 9 was clash detection/project coordination among the architecture, structural, and HVAC models. Since the responded students are from the Construction Management department, they felt that project coordination would benefit their degree program in the BIM application course.

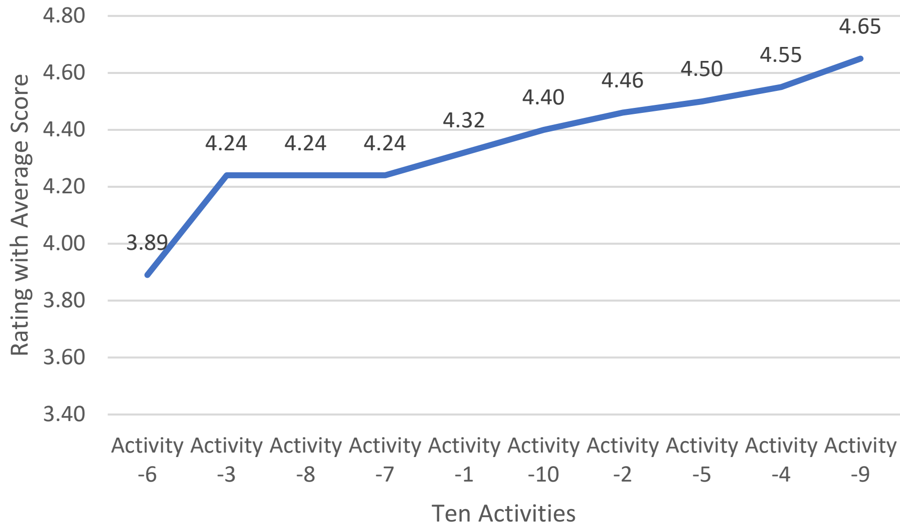

Figure 3: Usefulness of all ten activities.

Students' perceptions of their accomplishment of different activities with respect to their learning progress during the entire semester were investigated through their satisfaction and confidence levels. The students were asked to rate their satisfaction and confidence levels of accomplishing all activities with a 5 - Likert scale (5 is very high to 1 is very low). Figure 4 shows that satisfaction and confidence level are slightly on an upward slope with respect to their progress during the semester except for Activity-6.

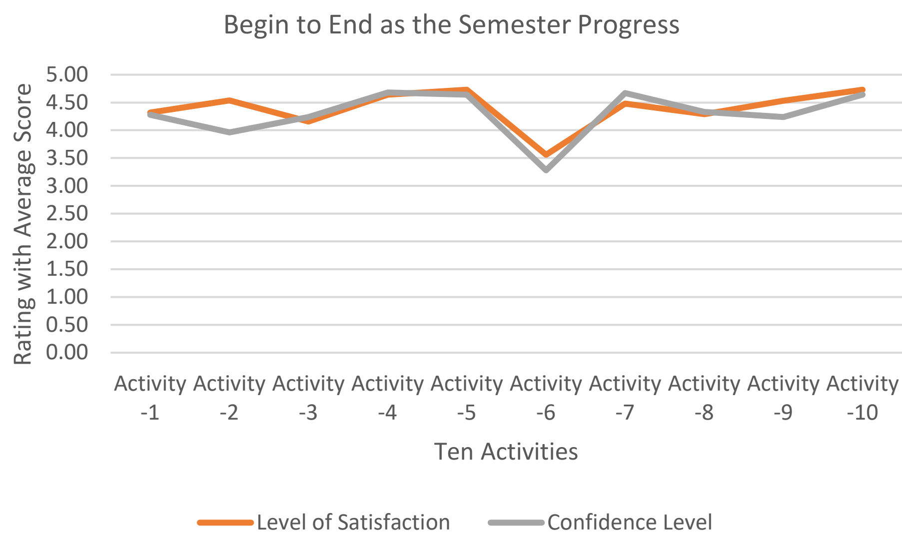

Figure 4: Satisfaction and confidence level of all activities as semester progress.

The impact of the instructor's guidance on student's completion of activities was measured through time spent by the student and their level of inspiration. The students were asked to rate their level of inspiration and guidance from instructor for all activities with a 5 - Likert scale (5 is very high to 1 is very low). As shown in Figure 5, the student's level of inspiration to complete and the guidance provided by instructor is higher on Activity-7. Time spent by students to achieve it is less on Activity-7 is low. For Activity-1, since the guidance provided by the instructor was high, level of inspiration to complete it was also higher. It is essential to distinguish the relationship between the level of inspiration to complete and the guidance provided by the instructor. As guidance provided by the instructor is increased, it increased the level of inspiration to complete, ease of learning, level of satisfaction, and confidence level.

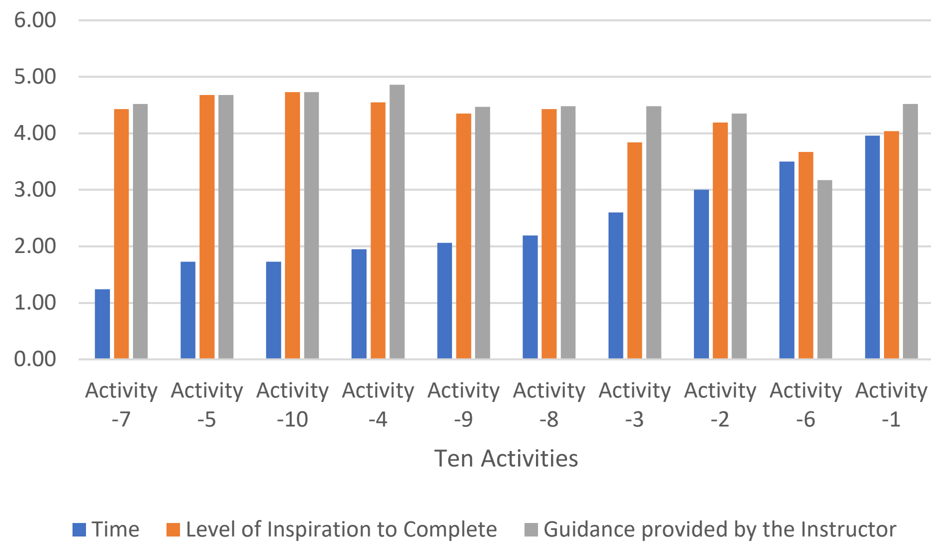

Figure 5: Related to time (hrs.), level of inspiration (5-Likert), and guidance (5-Likert) of ten activities

At the end of the semester, a survey was conducted to evaluate the satisfaction level of the students to complete all ten activities. The students were asked to rate the level of satisfaction with 5 - Likert scale (5 - extremely satisfied - 1 is somewhat dissatisfied). Out of 32 students, 22 students only responded to the survey. Figure 6 shows the students' level of satisfaction with each activity. Students were extremely satisfied with Architectural Families, 100%, Structural Families, 95%, Design Options, 95%, Four-Dimensional Modeling, 95%, Phasing, 95%, Creation of New BIM Families, 95%. Students were satisfied with Quantity Takeoff, 82%, Dynamic Simulation, 86%, and less satisfied with Clash Detection/ Coordination, 73%. The overall average of all activities indicated that students are extremely satisfied with all the activities of the BIM applications course.

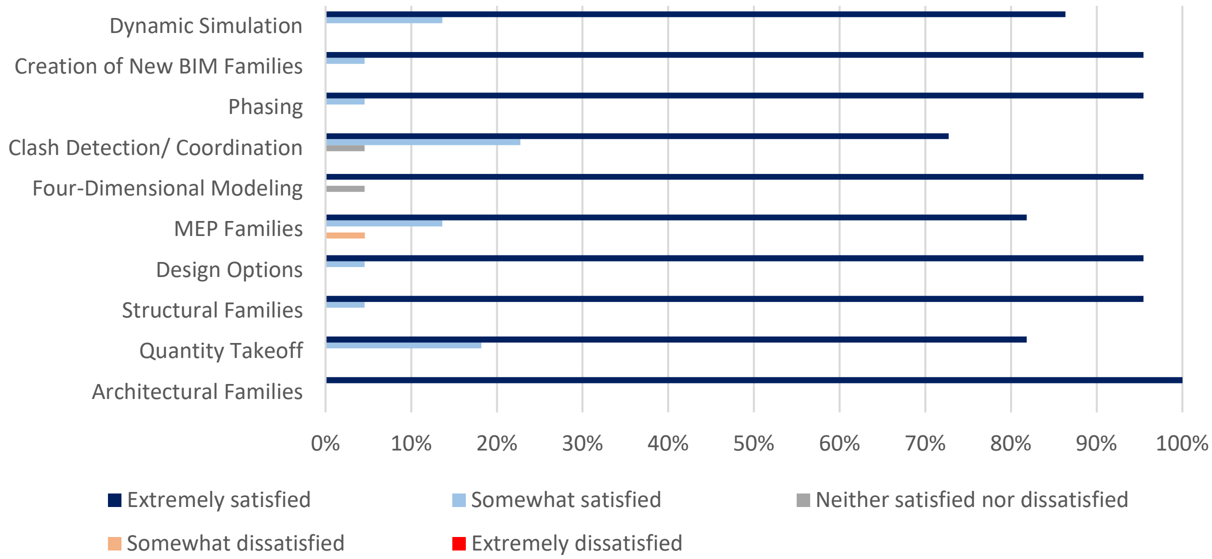

Figure 6: Level of satisfaction about each assignment of BIM Applications

Conclusion

The research analyzed the students' perception of the BIM applications course in its undergraduate program's curriculum. The research objective was to evaluate the effectiveness of the pedagogy adopted to teach ten activities related to BIM applications in the course. Each activity was assessed by the instructor's expectations with students' achievements. The duration, usefulness, level of satisfaction of accomplishment, level of challenge, level of inspiration to complete, guidance provided by instructor, and confidence level were used pedagogy assessment parameters. At duration, the instructor was allocated 2.5 hrs. of expected time for each activity to complete except activity 1, which is allocated of 5 hrs. of class time. The average student achievement on duration was 2.4 hrs., which was within the expectation of instructor. At usefulness, level of satisfaction of accomplishment, level of inspiration to complete, guidance provided, the instructor was allocated 4 on the Likert scale (1-5). The average student achievement as usefulness was 4.35, level of satisfaction of accomplishment was 4.38, level of inspiration to complete was 4.29, guidance provided was 4.43, which was within the instructor's expectation. The instructor was allocated 3.5 on the Likert scale (1-5) because of the asynchronous online and synchronous online teaching format. The average student achievement of a level of challenge was 3.56, within the instructor's expectation.

From this study, ease of learning is opposite relation to the level of challenge. As the ease of learning is increased, the level of challenge decreases. Satisfaction and confidence level are slightly increasing slope relation to activities of BIM course as semester progress. These are the instructor's expectations as semester progress because all ten activities are independent of each other and unique application of BIM. For example, clash detection/project coordination activity is of higher usefulness while HVAC 3D modeling is less helpful. The average of all ten activities with a significant satisfaction level is found as 90%. Overall, the research from the student perspective would address perceptions of the BIM applications course, especially construction management students' opinions related to BIM implementation, and help implement into the curriculum from student feedback.

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