Existing physical structures help civil engineering students understand structural analysis

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Abstract

Civil Engineering students taking structural analysis often struggle with the concept of load tracing and how to properly model structures using computer programs. Although load tracing examples in text books can help, they are often limited to one-bay examples and not a complete structure. Likewise, using computer programs to analyze structures are only as good as the model input by the user. In order to improve the understanding of civil engineering students in a structural analysis class, three existing structures on campus were used to better visualize load tracing and computer modeling. Survey results from the students indicate that using these existing structures helped them better understand the concept of load tracing and structural modeling.

Keywords

Civil engineering education, load tracing analysis, structural modeling

Introduction

Structural analysis is a required class in civil engineering education that requires engineering students to determine how structures are affected by external loads. Oftentimes, students are asked to understand abstract engineering concepts, such as load tracing and apply it to structural modeling. Load tracing is the ability to determine how external loads get distributed from the floor to the supporting beams and eventually to columns. Load tracing examples in text books are often limited to a single bay problem and not a complete structure. Additionally, civil engineers use computer modeling to analyze complex structures that are difficult or time consuming to analyze by hand. Structural modeling problems in textbooks are often too simplistic or too unrealistic for students to understand how to properly model a structure. Through evaluation of homework assignments and test problems, the author found that around half the class was having difficulty understanding the concept of load tracing and therefore having difficulty in structural modeling.

The perception that students learn engineering concepts through visualization techniques has been documented [1, 2]. Lack of effective visualization tools and time for instructors to learn new visualization technologies was noted as a barrier to engineering students learning abstract concepts [1]. In research conducted in civil engineering classrooms which utilized visualization software, researchers found increased collaboration among students [3] and improved student learning of abstract concepts [4]. Building on the idea that visualization could be used to improve students learning of abstract concepts and improve student collaboration, the author modified a structural analysis class in order to determine whether better visualization of abstract concepts could improve students learning of load tracing and computer modeling.

In order to address this perceived lack of understanding among students, the lab portion of a structural analysis class was modified to incorporate existing structures on campus as a visualization tool. The three structures used to enhance visualization were: an exterior walkway between two buildings, a tied arch pedestrian bridge and a suspended, switchback lobby stair in the engineering building. The structures were chosen because they were easily accessible by the students and had clear, exposed structural elements. This paper presents the survey results from students who were asked to evaluate how effective the use of these existing structures was in understanding these concepts.

Load Tracing

A lab was created in which students would visit a connector walkway between two engineering buildings on campus, see Figure 1 below. The connector represents an ideal load tracing visualization exercise because the entire structure is exposed. The walkway is constructed of a one-way spanning metal deck system. By looking at the underside of the walkway, the students could determine which direction the slab spans.

Figure 1: Exterior walkway between two campus buildings

The students were provided the external loads on the structure. Working in groups, they had to measure the length of structural elements and use the information to determine the load path of this existing structure. The students had to determine how much load and what type of load is carried by each of the floor members, and use that information to draw free body diagrams of each member.

After the lab assignment, students were given a survey to assess whether the lab successfully helped in better understanding the concept of load tracing. The students were asked to rate on a scale from 1 to 5 whether the lab (1) did not help at all understand load tracing to (5) the lab was very helpful in understanding load tracing and now they have full understanding. The survey questionnaire is shown below in Figure 2.

1	2	3	4	5
The lab did not help me at all understand load tracing	The lab helped a little, but I still struggle with load tracing	The lab was neither helpful, nor harmful to my understanding of load tracing	The lab helped my understanding of load tracing, but I still don't have a full grasp	The lab was very helpful in understanding load tracing and now I have a full understanding

Figure 2: Survey Questionnaire for Load Tracing

The results from the survey are shown in Figure 3. The survey results represent a compilation from two classes, one taught in the Fall of 2020 and the other in the Fall of 2021. Of twenty students surveyed, 94% of them rated the lab a 4 or a 5. Forty seven percent rated the lab a 4 indicating that the lab helped with their understanding, but that they still did not entirely grasp the concept, while another 47% rated the lab a 5 indicating that the lab gave them a full understanding of load tracing. Only 6% of the students indicated that the lab neither helped not hurt their understanding.

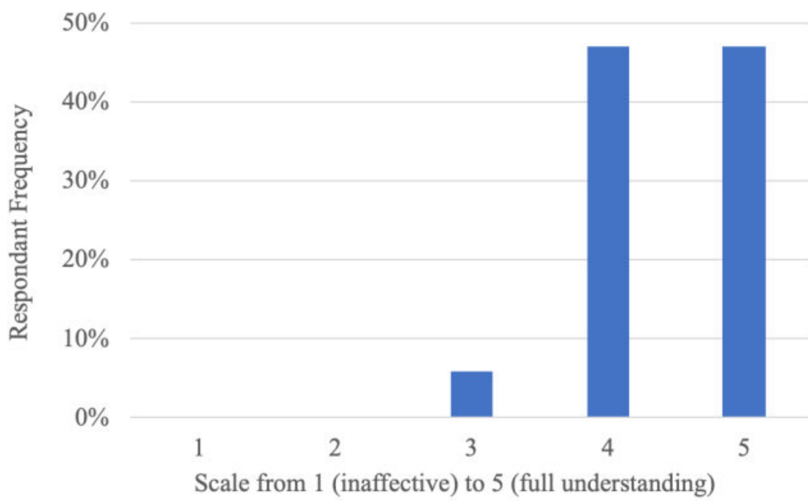

Figure 3: Results from Student Survey for Load Tracing Lab

Students were also asked to provide any additional feedback or comments regarding this lab. One student responded that although the lab helped in identifying one-way action, that another structure on campus showing two-way action would have been helpful.

Computer Modeling

Two labs were used to introduce students to computer modeling of structures. The first lab was chosen to provide students an opportunity to model a structure in two dimensions, while the second lab was chosen to provide students an opportunity to model a structure in three dimensions. The structures used for each lab were based on easily accessible, existing structures on campus.

Students were provided with a brief tutorial of a computer modeling program called Visual Analysis and were asked to learn the program for these two lab assignments. Visual Analysis is an easy-to-use computer modeling program, which students can download a student version for free.

Figure 4 below is an image of the pedestrian bridge on the Mercer University campus which connects on-campus student housing with the Mercer football stadium. For this lab, students worked in groups to determine the sizes and dimensions of all the major structural elements. They then used concepts learned from the load tracing lab to determine the loading on all the structural elements. Based on the information collected, the students used Visual Analysis to model the tied arch pedestrian bridge in 2D and were asked to determine the safest location to place a 500-lb Mercer Bear statue on the bridge.

Figure 4: Tied arch Pedestrian Bridge

For the second computer modeling lab, students were asked to produce a 3D computer model of the suspended switchback lobby stair in the main engineering building on campus. The lobby stair shown in Figure 5 below, was chosen due to its geometric complexity and three-dimensional aspect. Working in groups, students measured the sizes and dimensions of all the major structural elements, and determined the loading on these structural elements. Based on the sizes and measurements obtained from the site visit, the students modeled the stair in 3D and were asked to determine the safest location to place a 500-lb Mercer Bear statue on the stair.

Figure 5: Image of Suspended Lobby Stair

Upon completion of these two labs, students were asked to fill out a survey indicating whether the labs based on existing structures helped them better understand computer modeling of structures. The students were asked to rate on a scale from 1 to 5 whether the lab (1) did not help at all understand computer modeling to (5) the lab was very helpful in understanding computer modeling and now they have full understanding. The survey questionnaire is shown below in Figure 6.

1	2	3	4	5
The lab did not help me at all understand computer modeling of structures	The lab helped a little, but I still struggle with understanding computer modeling of structures	The lab was neither helpful, nor harmful to my understanding of computer modeling of structures	The lab helped my understanding of computer modeling of structures, but I still don't have a full grasp	The lab was very helpful in understanding computer modeling of structures and now I have a full understanding

Figure 6: Survey Questionnaire for Computer Modeling

The results from the survey are shown in Figure 7. The survey results represent a compilation from three classes, one taught in the Fall of 2019, one taught in the Fall of 2020 and the other in the Fall of 2021. Of twenty students surveyed, 100% of students rated the lab a 4 or a 5. Twenty five percent rated the lab a 4 indicating that the lab helped with their understanding, but that they still did not entirely grasp the concept, while 75% rated the lab a 5 indicating that the lab gave them a full understanding of computer modeling.

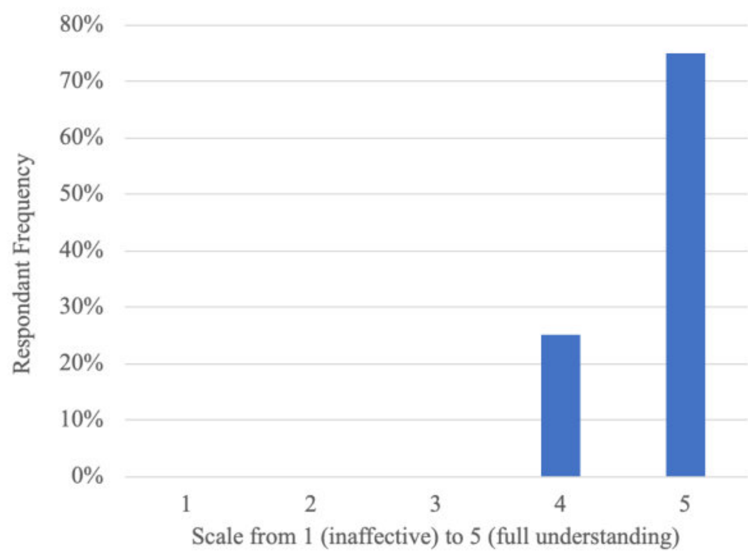

Figure 7: Results from Student Survey for Computer Modeling Lab

Students were also asked to provide any additional feedback or comments regarding this lab. One student responded that it was their favorite lab of all time and was very useful to their major. Another student commented that it was extremely helpful, but that they still did not feel like they had a full concept.

Summary and Conclusions

Results from student surveys indicate that using existing structures on campus as a visualization tool can be an effective way to help students understand the concepts of load tracing and computer modeling. A vast majority of students had a better understanding of load tracing when they were asked to perform load tracing as a lab exercise based on an existing walkway between two campus buildings. Additionally, all students indicated that they had a better understanding of computer modeling after being asked to model and analyze two existing structures on campus, a 2D tied arch bridge and a 3D suspended lobby stair.

Future work based on students comments from the survey will include finding a two-way structure on campus to provide a two-way load tracing example for the students.

References

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