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A Scavenger Hunt to Connect the As-Built World to Structural Engineering Theory

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A Scavenger Hunt to Connect the As-Built World to Structural Engineering Theory

Abstract

Many students enter the Civil Engineering field because of an interest in famous engineered structures. Although they may be familiar with these structures in name, they have difficulty connecting the concepts from their course work with the structural components from these fascinating structures. In order to help alleviate this problem, a new assignment based on a scavenger hunt was created for an introductory *Structural Analysis* course. The assignment was administered to encourage students to apply their knowledge to the world around them and observe the relevance of their education. Once students identify unique structures demonstrating specific features, they must try to use basic free body diagrams, loading concepts, and statics principles to estimate how a structure carries load and what types of loads may be applied.

In addition to analyzing the written and oral submissions, a survey was developed to determine gains made after participating in the assignment. Feedback was obtained from surveys administered before and after the activity. The surveys inquired about the following topics: examples of structures in the student's world, load types and magnitudes applied to structures, and application of their knowledge to these real world structures.

The initial survey responses confirm the perception of many professors and employers. The students struggled to connect real world structural examples with their knowledge base. Results from the initial and final surveys and the scavenger hunt assignment indicate that students make gains in knowledge with this activity. The students became more capable of using terminology to describe structural features such as fixed versus roller connections; applying environmental, dead, and live loads; computing structural determinacy; and describing structural function with free body diagrams. The responses show that it is possible to use a simple assignment based on real world structures within an established class to help students span the knowledge gap between the academic and as-built world. The implementation and collection of results is ongoing, but positive trends have been observed and the scavenger hunt assignment is being implemented at additional universities in *Statics* and *Structural Analysis* classes.

Introduction

Many students enter a Civil/Structural Engineering program with aspirations to design buildings and bridges because of what they see in the surrounding built world. However, in a Civil Engineering curriculum they are taught many theoretical concepts based on mathematics and may not connect the concepts with the structures that first inspired their studies. The students may graduate with a gap between knowing how to solve textbook style problems and knowing how to apply their education in an industry setting. This frustrates students and future employers. Civil Engineering curricula have been changed to deploy capstone style courses at the end of degree programs to help with this problem. However, the question remains: how can faculty implement other approaches that help students make the connection between the classroom and industry at an earlier stage of their education?

One simple and practical approach has been implemented at multiple universities to challenge the students using a unique hands-on homework assignment. The homework assignment is a scavenger hunt designed for students to apply basic mechanics and structural engineering concepts to describe the local surrounding as-built world. The students summarized their findings in a report and shared it with their classmates via an oral presentation.

Background

A scavenger hunt involves finding objects or information within a specified time frame. Often these items must be found within a specified location, and a theme may or may not be applied to the objects and information sought. One well documented purpose of a scavenger hunt may be to build team comradery[1]. In academics, team-building scavenger hunts can be useful to acquaint students to one another and encourage healthy communication through an enjoyable activity. Dyrud suggested that a scavenger hunt be used early in a course if the purpose is aimed at building teaming skills[1]. The process of participating in a scavenger hunt forces individuals to communicate their findings to others, encourages creativity, and provides an avenue for team work.

Scavenger hunts can also be used to teach students or to assess their abilities. Hollar, Dahm, and Harris documented a scavenger hunt to teach lab safety within a short 15-minute time period[2]. In this activity, students stayed within the classroom to identify staged lab hazards and demonstrate safety protocol. A discussion of lab safety took place following the activity. MacNamara and Svetz documented a scavenger hunt assignment to teach architecture students about structures and related technology[3]. This scavenger hunt did not require a long list of items, but each student group was asked to document the structural systems and technological elements, including mechanical units. Each student pair was assigned a building on campus to investigate, and students reported their findings using computer modeling. All findings were later showcased in a campus display. One purpose of the assignment was to build awareness of these elements to students studying architecture. Based on this study, nearly 80 percent of students reported the assignment improved their awareness of mechanical systems, and more than 75 percent of students reported the assignment improved their awareness of structural systems. Paul and Gould documented a scavenger hunt that takes place yearly as part of a week-long series of activities for engineering students at the University of Calgary[4]. This scavenger hunt is concentrated on a specific theme, unrelated to engineering, with clues that lead students to find a key hidden within the city of Calgary. Although the theme is unrelated to engineering, some clues are related to engineering knowledge and skills. Engineering related clues may require students to solve problems involving various engineering topics, such as circuitry or projectile motion. Paul and Gould reported that a new clue will be implemented in a future scavenger hunt, allowing students to learn about and operate a Computer Numeric Controlled (CNC) machine[4]. With the CNC clue, the authors expect students will improve abilities related to engineering, including spatial awareness and abstract thinking. This clue is considered a “maker project,” where students must create a physical object, and the authors believe this hands-on learning approach will benefit students.

The pedagogical benefits of a scavenger hunt assignment may be attributed to their connection to active and collaborative learning. Active learning is often referred to as learning through interaction in the classroom; however, if such interaction can take place solely among students, this type of learning could be fostered outside the confines of the classroom. Prince defines active learning as "any instructional method that engages students in the learning process," and the benefits of active learning may include improvements in knowledge retention, student interest, and thinking skills[5]. Knowing the benefits of active learning, it may be advantageous for instructors to design assignments to promote this type of learning beyond the classroom. If a scavenger hunt assignment requires students to interact and engage in the learning process outside the classroom, this activity could be considered a form of active learning. Scavenger hunts may also promote collaboration among students if the activity is performed in teams. Not only can collaborative learning activities prepare students for teamwork in the professional workplace[6], but it can also improve a student's attitude, academic performance, and retention in a field of study[5].

The scavenger hunt assignment described within this paper was aimed at providing a means for engineering students to connect what is learned in the classroom to the real world. This assignment was administered to students in *Structural Analysis* courses; however, this assignment could also be adapted to a general engineering mechanics course. In the assignment, students were guided to find specific structural connections and elements exhibited in the real world. Because students are exploring the local area to find structures and objects, their explorations consisted of independent site visits. Engineering professionals indicate the importance for engineers to gain experience through site visits, whether it be to understand the tolerances involved with construction[7] or to develop engineering judgment[8]. Just as professionals document the importance of site visits for young engineers, the authors also believe students benefit from site visits to better connect classroom or textbook problems to real-world scenarios. For example, a triangle and a circle in a free-body diagram often represent idealized pin and roller connections, respectively, but students need to recognize and understand how these connections function in real structures. Pictures and videos can help show select examples of structures to students in a classroom, but these limited views cannot take the place of seeing a structure first-hand. Scheduling a site visit or field trip during an academic term can be difficult to coordinate due to required curricular demands. Therefore, the scavenger hunt assignment was developed to provide students with an opportunity to evaluate real world connections and structural systems within an academic umbrella. In connection with pedagogical goals, the assignment was expected to improve student awareness of structural systems, their knowledge of structural systems, and their understanding of how classroom concepts are implemented by practicing engineers. Although the authors recognize that team building and communication skills could have been a potential benefit to the assignment based on the literature, these gains were not measured with data reported in this paper. Rather, the paper focuses on other pedagogical benefits related to conceptual understanding and awareness.

Scavenger Hunt Assignment

The scavenger hunt assignment was designed with the goal of getting students out of the classroom and into a real world setting to practice structural engineering principles. There were three critical phases of the assignment: 1) visit seven structures demonstrating seven different conditions, 2) analyze three of the selected structures using appropriate load types, free body diagrams, and structural determinacy, and 3) report the conclusions in written format to the professor and in oral format to the class. Appendix A contains an original copy of the assignment.

The scavenger hunt assignment was given near the halfway point in the semester and continued for approximately six weeks. During the first phase, students were given the project in class and instructed to begin thinking about structural examples in their lives. They were allowed to work with a partner or complete the assignment individually. The assignment required the submission of a final report approximately one month after it was assigned. The report required seven original pictures of structures that the group or student visited, including:

1. Bridge truss
2. Roof truss
3. Beam with a pin
4. Beam with a roller (or rocker)
5. Structure with a fixed connection
6. Flag pole
7. Cable or wire (used structurally)

Free body diagrams with appropriate loads correctly labeled were required on three of the seven structures.

During the second phase of the assignment, students were asked to take their structural examples and choose at least one to present to the class approximately two weeks after the assignment was submitted. No calculations were required, but the presentation was to include a description of the structure, the loads, and a discussion of whether the structure was statically determinate, indeterminate, or unstable. The presentations were limited to approximately three to five minutes in length so that every group could present within one class period. A PowerPoint presentation or equivalent was required to display and discuss the selected structures professionally.

The students were encouraged to be creative but also consider typical structures (i.e., bridges or buildings). One of the universities implementing the scavenger hunt is in a rural community and the other is in a dense urban area. It would be logical to assume that fewer typical structural examples are present in a rural community when compared to a dense urban community, but the students were challenged to think about all of the possible structures they interact with on a daily basis. Hints to walk around downtown locations and visit local trails were given to the students on the assignment. No limitations were placed on viewing external sources (i.e., internet or textbooks) for inspiration or guidance; however, the structures had to be something students personally documented regardless of whether the picture was obtained locally or from a trip.

Implementation of structural analysis principles that had been previously covered in class were required to finish the assignment. For three of the seven documented structures, students were asked to complete a more in-depth analysis. Initially, they were asked to estimate the type of loads that the structure would support. The majority of students had approximately two lessons on load types earlier in the course. The students had a limited background on the magnitude of specific loads or advanced types of loading (i.e., wind, seismic, snow, rain, etc.); therefore, the goal of this question was for students to attempt to use engineering judgement and make reasonable, documented assumptions. Additionally, students were asked to take these loads and place them on a free body diagram (FBD) of the structure. Free body diagrams are a concept that was used on a weekly basis in the class and had been covered extensively in prerequisite courses. Finally, students were asked to consider if they could solve the resulting determinate, indeterminate, or unstable free body diagram. The determinacy of structures was extensively covered through multiple lessons earlier in the semester.

This scavenger hunt assignment was initially piloted in two *Structural Analysis* courses and a *Statics* course prior to data collection. Initial observations by the instructors indicated that the students were interested in the assignment, and the assignment appeared to make students more aware of statics concepts in traditional structures and everyday situations. With positive feedback in the pilot study, the effectiveness of the assignment learning outcomes was investigated, and the results are presented in this paper. Only results from *Structural Analysis* classes are presented in this paper. No student from the pilot study was enrolled in the classes studied in this paper; therefore, no one had completed the scavenger hunt in a previous course. The scavenger hunt project was added to the class without removing established content. The project did not necessitate removal of other content because of its applicability to the entire course and not an individual topic. Furthermore, because the duration of the project lasted approximately six weeks, students were capable of maintaining focus on new material while completing the project outside of class.

Data Collection and Student Surveys

The scavenger hunt assignment has been implemented at two different universities (denoted Univ 1 and Univ 2 for data comparison). One is a small public, undergraduate college in a rural area of the Mid-Atlantic region. The second university is a large, public university in a densely populated city on the West Coast. Two classes of *Structural Analysis* students at each university were asked to complete the assignment. The course objectives and material covered at both universities were the same.

The background of the students was similar at both schools; the students had completed *Statics* and *Mechanics of Materials* courses, but most students had not completed a dynamics, engineering materials, or previous structural engineering course. The students at the smaller university were primarily juniors and were part of a class with an average size of 13 (i.e., the total number of students enrolled in both sections of the course at University 1 was 25). The students at the larger university were mainly juniors, seniors, or graduate students that needed to gain a background in structural engineering before pursuing futures studies and were part of a class with an average size of 37 (i.e., the total number of students enrolled in both sections of the course at University 2 was 74). The undergraduate students at both universities were required to take the course as part of the Civil Engineering curriculum (regardless of interest or concentration area).

A survey was developed for use with this assignment and was given to the students at the end of the first week of classes and approximately one week before the end of the semester (after completion of the scavenger hunt assignment). The surveys were given to all students, but completion of the survey was optional. All responses were provided anonymously and participation in the survey was not graded. Five questions were asked in the survey:

1) Write down examples of structures in your community that demonstrate statics (structures) principles. Be explicit.
2) Write down examples of other objects you notice in your everyday life that demonstrate statics (structures) principles.
3) What kind of loads must the structures from 1) and 2) hold up?
4) Do engineers draw free body diagrams of these structures? Could you draw a free body diagram of the structures from part 1) and 2)?
5) Do you think the structures from part 1) and 2) are statically determinate or indeterminate?

The goal of the first two questions was to see if students could connect their world with structural engineering. The first question focused on traditional structures, many of which would be similar to those presented in class or in a textbook. The second question was intended to gauge how well students could expand their thought process and apply the structural engineering concepts to unique objects that were not the focus of their coursework. The remaining three questions required students to apply their acquired knowledge to structures in their world. The concepts are all fundamental to structural engineering and were covered during the first few weeks of the class. These concepts were also covered in prerequisite classes prior to the *Structural Analysis* course.

Results from the end of semester survey were compiled and compared to the initial survey results. Observations from the surveys were compared to the results obtained from the scavenger hunt assignment.

Results

Initial Survey

The initial survey was administered at the beginning of the semester. The students were introduced to the course learning objectives and were in the process of reviewing loads and structural determinacy prior to receiving the survey. The survey responses were based on this initial information and previous knowledge from other classes, internships, or life experiences. The responses for each question were categorized and analyzed to determine the class' baseline knowledge.

The initial survey responses for Questions 1 and 2 are organized by category and summarized in Table 1. The questions were open ended, and each student was allowed to answer with multiple responses; most students wrote one or two responses. As expected, the most common responses to Question 1 (give an example of structures in your community) were bridges or buildings (specific or generic). Question 2 asked for examples of other objects that exhibit structural (statics) principles. A much larger percentage (44 to 72%) of responses involved "other" structures not categorized by bridges or buildings, such as furniture, household goods, tools, signs, or cars. Students were more likely to give no response on Question 2 when asked to brainstorm examples of atypical structures, particularly at University 1.

Table 1 – Initial Survey Responses for Questions 1 and 2

Response Category	Question 1		Question 2	
	Univ 1	Univ 2	Univ 1	Univ 2
Generic "Bridges"	33%	18%	9%	6%
Generic "Buildings"	17%	24%	6%	12%
Detailed Bridge Response	11%	23%	3%	4%
Detailed Building Response	25%	9%	15%	6%
Other Response	11%	25%	44%	72%
No Response	3%	0%	24%	0%
Class Enrollment:	25	74	25	74

Question 3 asked what types of loads the student examples from Question 1 and 2 would support; responses to Question 3 are presented in Table 2. The percentage of correct responses was high (68 to 72%), but approximately 30% of students had no response or an incorrect response. Most of the students had been exposed to basic load types, including dead, live, and environmental (i.e., seismic, wind, snow, rain, etc.). Therefore, as expected, 40 to 50% of the responses mentioned one or more of these categories.

Table 2 – Initial Survey Responses for Question 3

Response Category	Question 3	
	Univ 1	Univ 2
Correct Answer	68%	72%
Incorrect Answer	0%	14%
No Response	32%	14%
Answer Includes: Live, Dead, and/or Environmental Loads	41%	50%
Class Enrollment:	25	74

Question 4 presented two different sub-questions (denoted 4A and 4B) about free body diagrams and the responses are given in Table 3. Question 4A asked "do engineers draw free body diagrams?" and had a "Yes" response 73 to 83% of the time. Only 2% of the students answered "No" while the remaining students were not sure or did not respond. This trend was expected because of the emphasis placed on drawing free body diagrams in prerequisite mechanics courses. Question 4B asked students if they could draw a free body diagram of their examples from Questions 1 and 2. Only 32 to 34% of students responded "Yes," but only 3 to 5% of students responded "No." The majority of students did not respond or were not sure. In general, students were able to identify the importance of free body diagrams, but they lacked confidence when asked to draw an accurate diagram.

A lack of student responses to Question 4B may also be related to the structure of Question 4. Question 4 was presented as a two part question rather than two separate questions. Students may have lost focus after answering the initial question or they may have incorrectly assumed that a "No", "Not Sure", or "No Response" answer for Question 4A meant that a response was not required for Question 4B. Furthermore, a lack of responses may also be attributed to the open ended nature of the questions. The response categories "Yes," "No," or "Not Sure/Maybe" were not provided to students, and the students were asked to develop answers independently.

Table 3 – Initial Survey Responses for Question 4

Response Category	Question 4A		Question 4B	
	Univ 1	Univ 2	Univ 1	Univ 2
Yes	73%	83%	32%	34%
No	0%	2%	5%	3%
Not Sure/Maybe	0%	11%	14%	2%
No Response	27%	5%	50%	61%
Class Enrollment:	25	74	25	74

The last question, Question 5, asked students if their example structures from Questions 1 and 2 were statically determinate or indeterminate. Results from Question 5 are presented in Table 4. The topics covered in Question 5 were taught at the beginning of this *Structural Analysis* course and were briefly introduced in prerequisite classes. Responses from Question 5 demonstrated that students did not have confidence identifying determinate versus indeterminate structures. Only 13 to 14% of students correctly identified all of their structures. The remaining percentage of students either drew incorrect diagrams, didn't know the answer, or offered no response.

University 1 had a large number of "No Response" answers to Question 5. This may be attributed to the dependence of Question 5 on Questions 1 and 2. Students that had trouble finding examples or who did not understand the terminology in the question could not answer Question 5. Furthermore, a lack of responses may also be attributed to the open ended nature of the questions. No guidance was given to the students when providing answers to the survey.

Table 4 – Initial Survey Responses for Question 5

Response Category	Question 5	
	Univ 1	Univ 2
Correct	14%	13%
Incorrect	0%	78%
Partially Correct	27%	6%
Don't Know	18%	0%
No Response	41%	3%
Class Enrollment:	25	74

Scavenger Hunt Assignment Results

The first part of the scavenger hunt assignment asked students to identify a unique real world structure from seven different categories. Table 5 lists the structure categories and the percent of students that correctly identified each structure type. One of the most surprising results was the lack of confidence identifying bridge or roof trusses. This topic is covered extensively in previous classes and was reviewed throughout the semester in *Structural Analysis*. However, it appears the students incorrectly think that any non-orthogonal member is a truss member. For example, as shown in Figure 1, numerous lateral braces for bridge beams may be labeled trusses. Because of rich bridge traditions near both universities, the bridge truss examples were primarily from a few structures in close proximity to campus. Many of the misinterpreted bridge truss examples were from two common bridges, a concrete arch as shown in Figure 1 and a steel girder bridge. The second difficult structural member for students to identify was a beam with a roller or rocker. Some students simply could not find an example or identified a pin connection. Two topics that are used routinely in structural analysis are pin and fixed connections. Almost 90% of the submissions correctly identified these connections. As expected, the easiest structure to identify was a flag pole. The cable/wire used structurally was also easily identified at University 2 due to the presence of a suspension bridge within a quarter mile of the Civil Engineering building and at University 1 due to numerous cable structures on campus.

Figure 1 – Incorrect Examples of Roof and Bridge Trusses

Table 5 – Structures Correctly Identified

Structure Category	Percent Correctly Identified Univ 1	Percent Correctly Identified Univ 2
Bridge Truss	73%	88%
Roof Truss	87%	79%
Beam with a pin	93%	88%
Beam with a roller (or rocker)	80%	88%
Structure with a fixed connection	93%	84%
Flag Pole	100%	91%
Cable or Wire (used structurally)	87%	91%
Class Enrollment:	25	74

The structure categories showed differing levels of creativity and variation among the responses. The students or groups with the highest percentage of correct responses tended to have some of the most diverse examples. The beam with a pin category had a variety of examples including an old truss bridge connection, a pin in a timber framing shelter, a crane support, a pocketknife, and an entrance gate. The examples for structures with a fixed connection included a concrete structural connection, a cantilevered light frame, a cantilevered observation platform, a soccer goal post, a sculpture, and a down spout anchored to the ground. The exception to this pattern was the flag pole category; the majority of responses for the flag pole category were found on campus. In the future the authors may broaden this category and label it cantilevered structures. Other unique responses demonstrated the students' ability to apply structural engineering concepts to atypical structures that were not studied in class. This included structures such as an elevation screw on a historical cannon, concrete corbels in the dormitories, high ropes course obstacles, a staircase, shoring on a construction site, cables on awnings, and a person doing a "plank" exercise.

The next part of the scavenger hunt assignment was to draw a free body diagram with correct loads on three of the seven selected structures. The students were given the freedom to pick the three structures and use any resource available to estimate the type and location of loads. Data in Table 6 indicated that the most popular structures selected for further analysis were the flag pole (i.e., cantilevered structure), the beam with a pin, the beam with a roller, and the structure with a fixed connection. The bridge truss, roof truss, and the cable or wire structures were typically not selected for further analysis. These results correspond with the students' familiarity analyzing pin, roller, and cantilevered structures throughout the *Structural Analysis* course.

Table 6 – Breakdown of Assignment Responses

Structure Category	Attempted		FBD Correct		Determinacy Correct		Loads Identified Correct	
	Univ 1	Univ 2	Univ 1	Univ 2	Univ 1	Univ 2	Univ 1	Univ 2
Bridge Truss	40%	14%	33%	50%	50%	63%	83%	50%
Roof Truss	27%	28%	25%	63%	75%	81%	75%	69%
Beam with a pin	53%	50%	25%	52%	75%	72%	75%	41%
Beam with a roller (or rocker)	33%	45%	60%	69%	80%	69%	60%	38%
Structure with a fixed connection	53%	34%	63%	60%	50%	85%	63%	50%
Flag Pole	60%	62%	44%	78%	67%	72%	67%	67%
Cable or Wire (used structurally)	33%	10%	80%	83%	60%	50%	100%	67%
Class Enrollment:	25	74	25	74	25	74	25	74
Response Avg:	43%	35%	47%	65%	65%	70%	75%	55%

Data supporting the breakdown of correct free body diagrams, the ability to identify structural determinacy, and selection of appropriate loads are also shown in Table 6. The free body diagrams for the cable or wire, beam with a roller or rocker, and the fixed connection were drawn correct over half of the time at both universities. The roof truss, bridge truss, and beam with a pin were drawn correctly half of the time at University 2 but closer to 25% at University 1. The flag pole examples at University 1 demonstrated a recurring common mistake: missing a support reaction. Another common mistake was incorrectly placing moment reactions on the diagram. The geometry and shapes of the structure were typically drawn correct on the free body diagram. Overall, the free body diagrams were drawn correctly approximately 47 to 60% of the time as indicated in Table 7.

Table 7 – Total Assignment Responses Answered Correctly

Identified	Free Body Diagram		Determinacy		Applied Loads	
	Univ 1	**Univ 2**	**Univ 1**	**Univ 2**	**Univ 1**	**Univ 2**
Correctly	47%	60%	64%	59%	73%	43%
Incorrectly	53%	40%	36%	41%	27%	57%
Class Enrollment:	25	74	25	74	25	74

The ability to identify structural determinacy was performed correctly at least half of the time for every category of structure at both universities. Data in Table 6 indicated that the beam with a pin, beam with a roller, flag pole, and the roof truss were performed correctly most frequently at both universities. The cable or wire and bridge truss were performed correctly between 50 and 63% of the time. The other structures had mixed responses between 50 and 85% correct. Data in Table 7 indicated that, out of all the structures, determinacy was identified correctly approximately 60% of the time. It should be noted that in the case when the free body diagram was drawn incorrectly, the determinacy calculation was determined based on the drawing not the real structure.

The responses for "estimate the typical loads" the structure might experience varied significantly. Some students interpreted this as only a categorical question (i.e., live, dead, self-weight, environmental, etc.), some gave precise objects that would load a structure (i.e., people, cars, etc.), and others simply listed numerical values (i.e., 5 lb/ft, 100 kips, etc.). Many had a combination of these responses. Data in Table 6 indicate the percentage of correctly identified loads for all structural categories. A correct answer was determined using the following criteria: either a load with a reasonable magnitude and correct units, at least two categorical examples, or at least two examples of loads on the structure. On average between both universities, at least 50% of the responses had a correct answer, while some structures like roof trusses, flag poles, and cables or wires were correct more frequently. It should be noted that the vast majority of responses were categorical or categorical and numerical. Data in Table 7 indicated that the applied loads were correct 43 to 73% of the time.

Final Survey

The final survey was administered near the end of the semester. The scavenger hunt and presentations had been completed prior to administering the survey. The same five questions were posed in both the initial and final survey. The students did not know the survey was going to be given a second time and many did not realize they had already taken the survey earlier in the semester.

The responses for Questions 1 and 2 for the final survey are organized by category and shown in Table 8. The final survey responses for Question 1 (give examples of structures in your community) were more diverse and complete when compared to the initial survey responses. Nearly every student responded to the question and 36 to 40% of the responses were something other than a bridge or building. In the original survey only 11 to 25% of the answers were "other responses." Additionally, generic answers like "Bridges" and "Buildings" were less prevalent. A visual comparison of initial and final survey data for Question 1 is presented in Figure 2.

Table 8 – Final Survey Responses for Questions 1 and 2

Response Category	Question 1		Question 2	
	Univ 1	Univ 2	Univ 1	Univ 2
Generic "Bridges"	24%	26%	5%	6%
Generic "Buildings"	13%	23%	2%	5%
Detailed Bridge Response	12%	4%	4%	0%
Detailed Building Response	15%	5%	9%	3%
Other Response	36%	40%	79%	85%
No Response	0%	1%	2%	0%
Class Enrollment:	25	74	25	74

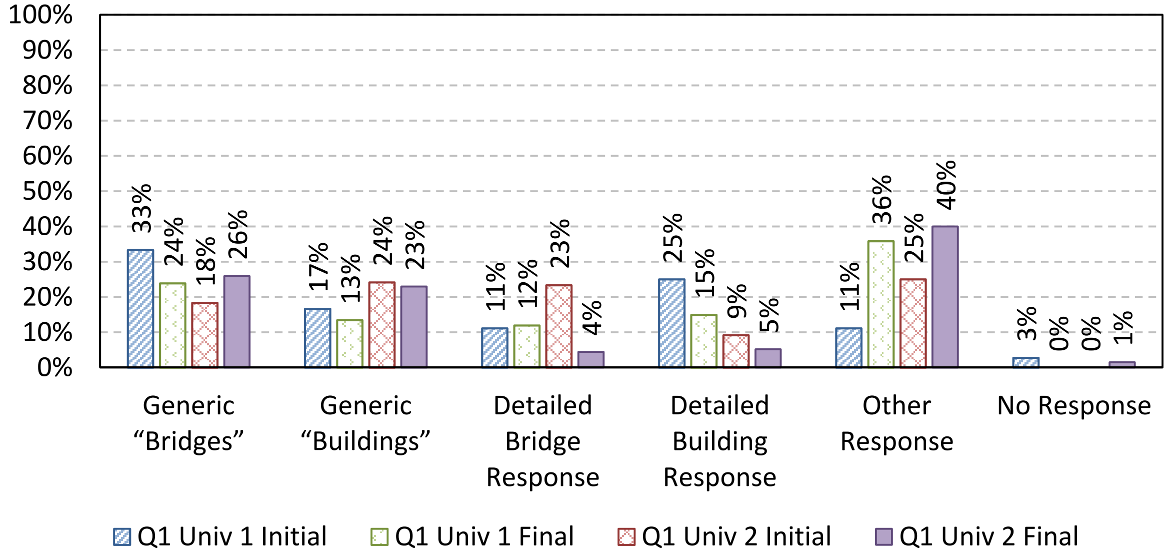

Figure 2 – Comparison of the Initial and Final Survey Responses for Question 1

Question 2 asked for examples of other objects that exhibit structural (statics) principles. Approximately 80% of responses involved the "Other Responses" category, and less than 20% of the answers involved the traditional "Bridges" or "Buildings" categories. Compared to the initial survey results, students were much more aware of atypical structures and less than 2% of the surveys had no response. The "Other Response" answers submitted in the final survey varied greatly and were creative. Responses included: fences and cell phone towers, spider webs, dams/levees, viaducts, retaining walls, gazebos/pergolas/trellises, and flag poles. Most of these responses corresponded with structures that students selected to present in their scavenger hunt assignment and presentation. A visual comparison of the initial and final survey data for Question 2 is presented in Figure 3.

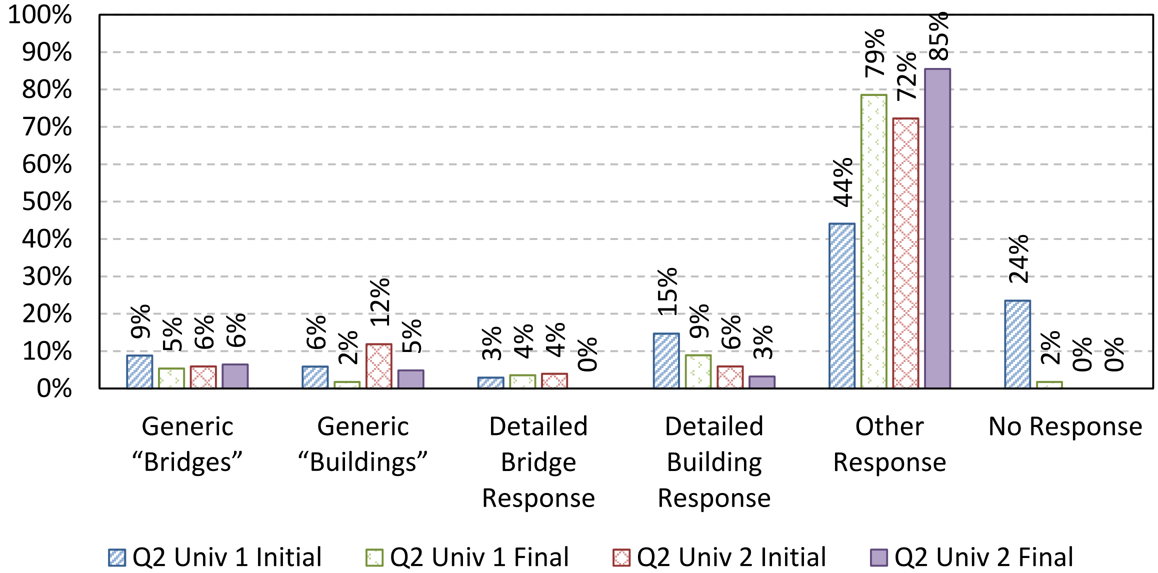

Figure 3 - Comparison of the Initial and Final Survey Responses for Question 2

The responses from Question 3 (what kind of loads must the structures from Questions 1 and 2 hold up) are summarized in Table 9 and demonstrated that the students have gained skills related to identifying loads carried by typical structures. While most students are not capable of identifying every load for a structure, approximately 90% of students responded with at least one correct load that their examples would support. In the initial survey, 68 to 72% of students identified at least one correct load. In the responses, 85% of the students used basic load categories (i.e., dead, live, and environmental loads) to describe the types of loads on their structures as compared to 40% in the initial survey for University 1. At University 2, the percentage of responses that included environmental load types were not significantly different. The lack of significant differences in the initial and final survey results at University 2 may be associated with a lack of specifically identifying load types in addition to load magnitudes during example problems discussed in class. A visual comparison of the initial and final survey data for Question 3 is presented in Figure 4.

Table 9 – Final Survey Responses for Question 3

Response Category	Question 3	
	Univ 1	**Univ 2**
Correct Answer	100%	89%
Incorrect Answer	0%	4%
No Response	0%	7%
Answer Includes: Live, Dead, and/or Environmental Loads	85%	44%
Class Enrollment:	25	74

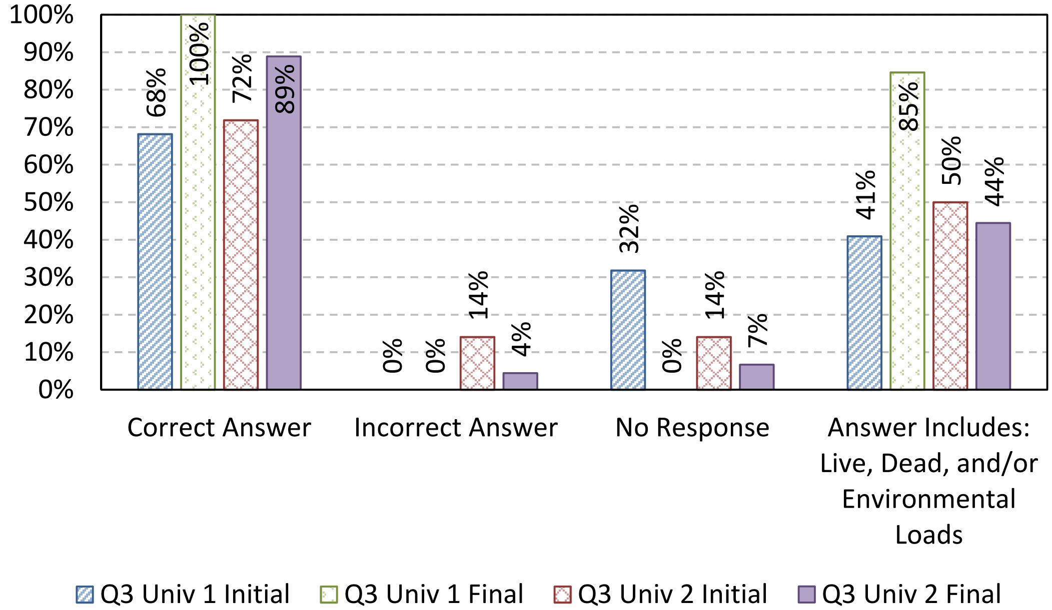

Figure 4 - Comparison of the Initial and Final Survey Responses for Question 3

Question 4 presented two different sub-questions (denoted 4A and 4B) about free body diagrams and the responses are presented in Table 10. Question 4A asked “do engineers draw free body diagrams?” and had a “Yes” response 91 to 100% of the time while the remaining students did not respond. The initial survey had a “Yes” response of 73 to 83% of the time. Question 4B asked students if they could draw a free body diagram of their examples from Questions 1 and 2. Many students responded with “Yes”, but 38 to 56% of students did not respond. No students responded with a “No” or a “Maybe.” In the initial survey, 32 to 34% of students responded with a “Yes” and the remainder said “No,” “Not Sure/Maybe,” or didn’t respond. The overall confidence of the class in understanding free body diagrams and understanding how to draw an accurate free body diagram increased. A visual comparison of the initial and final survey data for Questions 4A and 4B are presented in Figure 5 and Figure 6, respectively. As mentioned in the discussion of the initial survey results, a lack of student responses to Question 4B may be related to the structure of Question 4.

Table 10 – Final Survey Responses for Question 4

Response Category	Question 4A Univ 1	Question 4A Univ 2	Question 4B Univ 1	Question 4B Univ 2
Yes	100%	91%	62%	44%
No	0%	0%	0%	0%
Not Sure/Maybe	0%	0%	0%	0%
No Response	0%	9%	38%	56%
Class Enrollment:	25	74	25	74

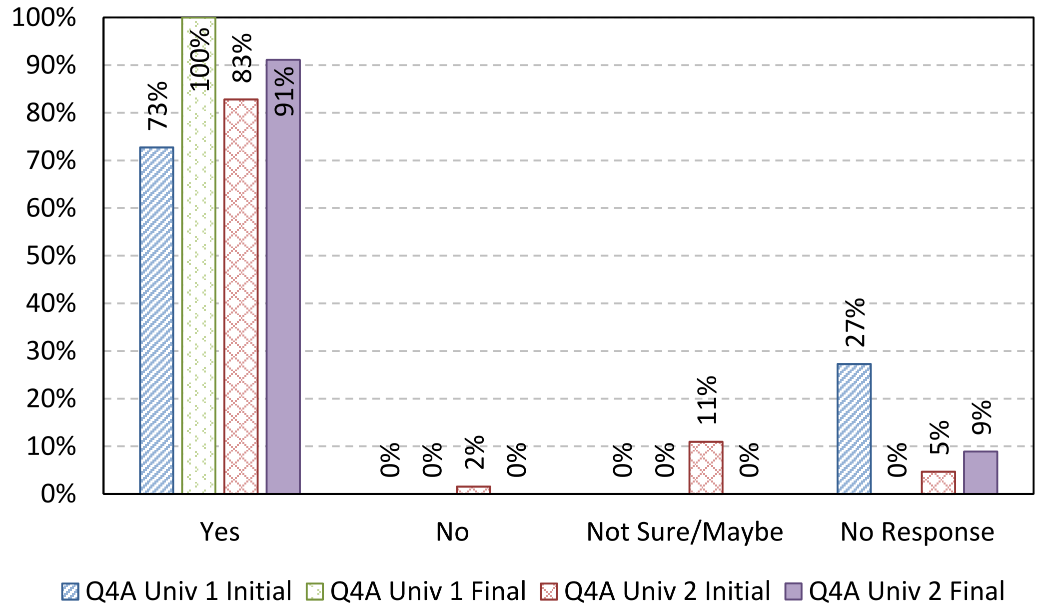

Figure 5 - Comparison of the Initial and Final Survey Responses for Question 4A

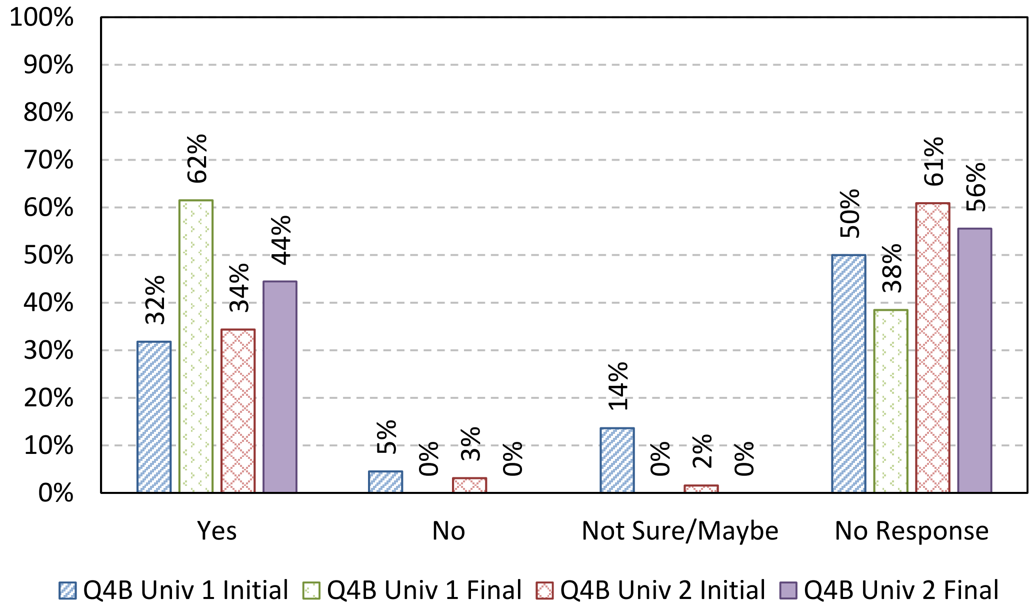

Figure 6 - Comparison of the Initial and Final Survey Responses for Question 4B

The last question, Question 5, asked students if their example structures from Questions 1 and 2 were statically determinate or indeterminate. Results from Question 5 are presented in Table 11. The responses demonstrated that at least half of the class understood this concept well. Additionally, 46% responded correctly for at least one of their examples at University 1. Less than 7% answered completely incorrectly and less than 4% answered with a "Don't Know." This was a vast improvement from the initial survey when only 13 to 14% of students answered correctly, and the majority of students answered incorrectly, did not know, or did not respond. A visual comparison of the initial and final survey data for Question 5 is presented in Figure 7.

Table 11 – Final Survey Responses for Question 5

Response Category	Question 5	
	Univ 1	Univ 2
Correct	50%	60%
Incorrect	0%	7%
Partially Correct	46%	9%
Don't Know	4%	0%
No Response	0%	24%
Class Enrollment:	25	74

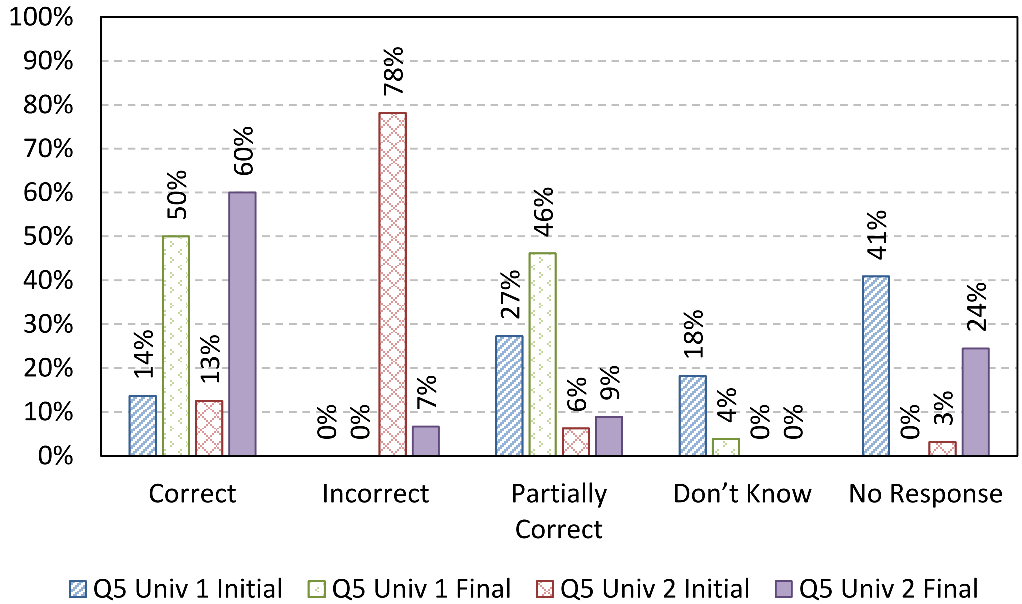

Figure 7 - Comparison of the Initial and Final Survey Responses for Question 5

University 2 had a large number of "No Response" for Question 5 on the final survey as shown in Table 11. This was attributed to the fact that the survey was administered at the end of a class period, near the end of the semester, and students realized participation was optional. However, a high response rate on the final survey for the first three questions at University 2 indicated that students may have gotten tired of answering questions they had already seen earlier in the semester. Obtaining a higher response rate may be possible if the questions were posed as part of the assignment, but requiring participation would forfeit the voluntary nature of the study.

Conclusion and Ongoing Work

The scavenger hunt assignment was implemented in four undergraduate *Structural Analysis* courses at two different universities. The responses from the initial and final surveys revealed gains that many students made in their abilities and their perceived abilities over the semester. Specifically, students improved their skills at identifying various types of structures, constructing free body diagrams, and identifying structure determinacy. Some of the knowledge gains are the result of traditional classwork and lectures. However, the gains related to the diversity of structural examples identified in the post-survey, application of real loads commonly used in the engineering profession, identifying structural determinacy, and the creation of accurate free body diagrams were due to or effectively reviewed by the scavenger hunt assignment.

When comparing the students' abilities on the scavenger hunt assignment and on the surveys, obvious improvements were made over the course of the semester. Additionally, many of the structures and loads given as responses in the final survey were unique to the scavenger hunt because example problems and homework assignments used in class focused on the types of structures typically found in textbooks (i.e., common beams, frames, and trusses).

Free body diagrams were discussed in detail in prerequisite *Statics* classes; however, when free body diagrams were associated with real world structures during the initial survey, about one-third of students could not identify the importance of free body diagrams as they relate to the structural engineering profession. Results from the final survey indicated that the students understood the importance of free body diagrams and most could draw an accurate diagram for a variety of different structures. The scavenger hunt assignment likely reinforced the importance of free body diagrams beyond what was presented during lecture.

An additional benefit of the scavenger hunt assignment was allowing the students to explore load types and magnitudes in more detail. While the responses varied significantly, the discussions during the in-class presentations and responses on the final survey showed knowledge gains related to understanding realistic loads applied to structures. As noted previously, only general load types were covered in class, therefore many of the gains were attributed to this assignment.

The concept of determinacy is fundamental to a *Structural Analysis* course; however, past experience has shown that many students never grasp the concept. This was confirmed with the initial survey results. The large increase in the percentage of students who could completely or partially identify this concept on the final survey showed a benefit of the scavenger hunt assignment. The independent scavenger hunt method of reviewing a previous concept and asking the students to apply it to the real world seemed effective in long term retention of engineering fundamentals. However, administering the survey to the same students again during their senior year may yield insight regarding what abilities have been retained, enhanced with further education, or lost over time.

Initial survey results indicated that the scavenger hunt assignment effectively reviews basic structural engineering concepts. Future research related to this assignment will include additional data collection and data analysis related to when the assignment is presented to students over the course of the semester. Furthermore, implementation of the initial and final surveys in a control group classroom (i.e., a group of students at a third university who do not complete the scavenger hunt assignment between completion of the surveys) may yield further insight related to the effectiveness of the scavenger hunt assignment. Future work will also consider methods to better equip students to correctly identify structures and structural connections frequently missed on the scavenger hunt assignment. The authors plan to measure the effectiveness of the scavenger hunt assignment in a more introductory *Engineering Mechanics* and/or *Statics* course. In these courses, students are first introduced to structures, loads, and free body diagrams. Use of a scavenger hunt assignment earlier in the curriculum may better prepare students for future studies related to structural engineering.

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Appendix A

Structural Analysis (Theory) Scavenger Hunt

Homework:

Due:

You may complete this assignment with one other student.

Take a tour of campus and/or town to find the following structural members or connections. A particular structure may only be used once in your findings; in other words, you must identify seven unique structures during the scavenger hunt.

1. Bridge truss
2. Roof truss
3. Beam with a pin
4. Beam with a roller (or rocker)
5. Structure with a fixed connection
6. Flag pole
7. Cable or wire (used structurally)

For each structure,

Take a picture of the structure, and identify the connection types (roller, pin, etc.). Paste your pictures into a WORD document with a brief explanation of the structure and where you found it.

For at least three of the above structures or connections, also do the following:

1) Estimate the typical loads it might experience. Use engineering judgment.
2) Then, using this typical load, draw the free body diagram for the structure in static equilibrium.
3) Finally, consider: Could you solve this static equilibrium condition? If not, what prevents you from doing this? Based on your response, is the structure statically determinate or indeterminate?

(**<u>Hint</u>**: Look on campus and on nearby walking/biking trails. You may also consider visiting other local structures in the downtown area.)

<u>In-Class Presentation</u>

With your partner, prepare a 3 to 5-minute presentation to showcase your findings for one of the above structures or connections, explaining where the structure is located and your explanation of the free-body diagram as prompted above. ***PowerPoint*** should be used during the presentations.