

Innovative Approach to Teaching Applied Structures Courses

Dr. Nicole Martino, Roger Williams University

Dr. Nicole Martino is an assistant professor of engineering at Roger Williams University. Her area of expertise is civil engineering, more specifically structural engineering. Dr. Martino's current research areas include developing innovative tools to improve the learnability of topics in heavy analytical courses, and developing rapid, accurate and efficient bridge deck condition assessment models using ground penetrating radar.

Dr. Amine Ghanem, Roger Williams University

Dr. Ghanem is a Professor at Roger Williams University where he teaches engineering and construction management courses. He holds a Professional Engineer License from California and he is highly involved in professional societies like American Society of Civil Engineering and Construction Management Association of America. Aside from teaching, he has 10 years of experience in the field of construction engineering. He was highly involved in Civil/Construction Management projects, where he performed design, estimate, and schedule for various projects. Also, he assisted in the development of project proposals by securing project specifications from clients and communicating the same to design teams.

APPLICATIONS OF SOLIDWORKS AND MICROSOFT POWERPOINT TO TEACHING STRUCTURAL ANALYSIS COURSES

Abstract

Developing new ways for teaching structures courses to engineering students, in addition to those in an alternate major (construction management, architecture, etc.) is a staple in the curriculum. One of the most common techniques used by instructors to demonstrate various concepts is by using props. While those can be effective, instructors are looking for a more digital approach that students can learn and replicate on their own. Current cohorts of students are incredibly tech savvy, and have the ability to quickly understand how to use computer programs, and the like. The advantages of knowing computer-aided applications include; increasing students' credentials while adding skills needed to attract future employers, and that students can call upon these tools in their future (after college) for help with finding the solution to a difficult problem.

Firstly, this paper presents the methodology used to develop interactive images, using SolidWorks and Microsoft PowerPoint to help students better visualize and understand concepts associated with structures courses. Next, the paper discusses the effectiveness of these tools by providing the results of two student surveys. The first survey asked a cohort of students currently enrolled in a structural analysis course to rate their understanding of a list of topics associated with structural analysis and previous engineering mechanics courses. That cohort of students was then presented with a limited subset of digital animations developed using SolidWorks and Microsoft PowerPoint and was asked to complete the same survey again. One month of time existed between the two surveys. The difference in the two surveys showed an increased level of understanding in every assessed category, based on the students' perception and attitude towards the interactive images. A direct assessment of exam grades also displayed the effectiveness of these tools.

Introduction

Developing new ways for teaching structures courses are essential in fields like engineering, construction management, and architecture. Traditional structural analysis education is often conducted by writing on the board, using transparencies and/or PowerPoint slides. However, some instructors are looking into the benefits of exploring alternative teaching methods to showcase the behavior of structural elements, and to communicate the internal behavior, such as stress, strain, and deformed shapes in a more effective way¹. These alternative teaching methods come in the form of alternative teaching materials, textbooks, and other tools for communicating structural principles that respond to the needs, capabilities, and perspective of students. For example, in a textbook titled "Shaping Structures"², authors extensively utilized graphical techniques for the introduction of static principles and finding forces in structural elements. In a completely different format, "Demonstrating Structural Behavior with Simple Models"³ illustrates a series of hands-on experiments that are designed to provide first-hand experience for observing structural behavior and failures. Kunz argues in his paper⁴ that supplementing abstract

concepts with props, videos, and hands-on activities have shown effectiveness in illuminating difficult concepts.

Fernández-Sánchez and Millán⁵ implemented an alternative approach to teaching structural analysis and design by using classical theory, performing calculations by hand, using a computer program, and using a plastic toy for model trusses to measure strain and stresses. This method showed that students learned more about the behavior of structures with this implementation method compared to the traditional teaching modes.

The use of visual aids in education has also been demonstrated by Hsieh⁶, who combined an intelligent tutoring system, animation, and other presentation tools to better implement his lectures. Students rated the teaching innovations and the learning gains positively after taking these lessons. Romero and Museros⁷ tried a different approach specific to structural analysis courses by mixing experimental models with computer simulations. Their approach was well received by the students and it increased their motivation and satisfaction, again compared to traditional methods.

The cases mentioned above are just a few of the many examples where some professors are taking advantage of teaching structural principles in a more motivating, appealing and therefore efficient manner through the use of digital animation and computer software⁷. In addition to utilizing methods like these in the classroom, the authors of this paper are putting forth additional effort to better prepare students for their career after college. This is being accomplished by provided students with instructions describing how to create these interactive images on their own. The idea is that they can become better acquired with the software which could be appealing to future employers, and they can use these skills for verifying the solution to various homework assignments in a variety of classes, and the like outside of college.

Model Development

The topics of the interactive images (recorded PowerPoint presentations) presented to students in the structural analysis course were selected based on the instructor's observations from the previous offering, in addition to, what would benefit the offering of other courses as well. Those topics included shear and moment diagrams, deflections and characteristics of flexure (tension/compression). While shear and moment diagrams are first introduced in engineering mechanics courses, a mastery of shear and moment diagrams and functions is necessary to successfully complete the deflections portion of structural analysis. In addition to quantitatively assessing structures through shear and moment diagrams and functions, a qualitative understanding of structural deflection is required in structural analysis courses as well. While structural analysis courses do not typically use all of the topics taught in previous engineering mechanics courses, the authors of this paper believe it is important to reinforce those topics whenever possible, especially since they will be imperative once the students graduate. Therefore, an image showing characteristics of flexure is included in the interactive images as well.

The computer-aided program selected to develop the models was SolidWorks, for a number of reasons:

- 1) SolidWorks is capable of solving problems commonly found in engineering, such as the analysis of displacement, stresses, shear, bending moment and buckling etc., and presents solutions in a 3D format^{8,9}.
- 2) The use of SolidWorks has shown success in simplifying difficult subjects in statics and strength of materials courses⁴.
- 3) SolidWorks is a program used by a number of engineering professions, promoting communication among the professions.
- 4) SolidWorks is a program introduced at the freshmen level, where both authors are employed and is utilized throughout engineering students' curriculum.

The structures selected for this research were done with the idea in mind that the computer results could easily be checked via hand calculations. The models generated were of a simply supported beam and an overhang beam, two very commonly used structures to demonstrate various concepts in structural analysis and engineering mechanics courses. A uniform and non-uniform distributed load was applied to the entire length of the simply supported beam, and in addition to the distributed loads, a point load was applied at the free end of the cantilever beam for a total of 5 different interactive presentations.

The list below is a general overview describing how the models were developed using SolidWorks:

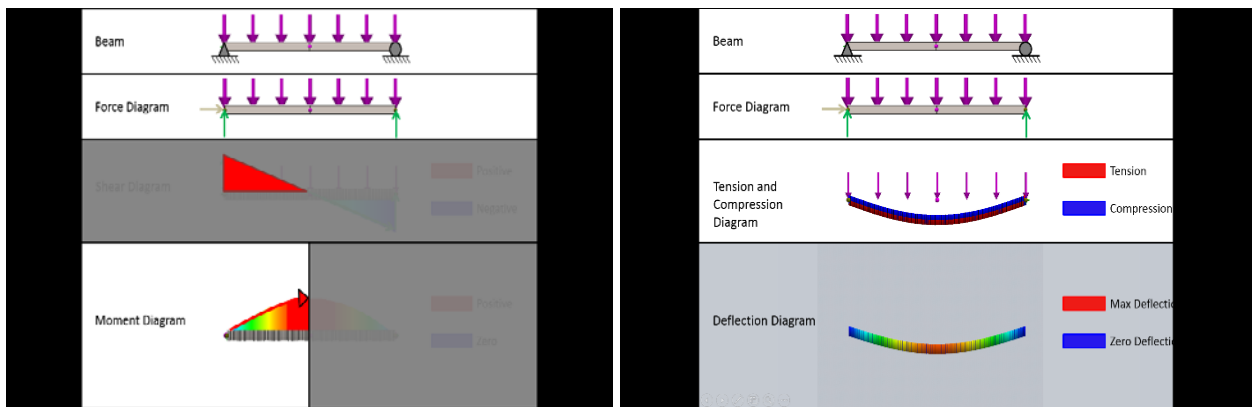
1. Draw a rectangle on the right plane.
2. Draw a smaller rectangle inside of the rectangle drawn in (1).
3. Extrude both rectangles to the desired member length (ex. 120").
4. Assign a material to the member (ex. Alloy steel).
5. Create a "static" simulation, and select the option for SolidWorks to treat the member as a beam.
6. Apply support reactions to the beam (ex. Pin and roller for a simply supported beam).
7. Apply a loading (ex. 10kip point load to the end of a cantilever beam).
8. Run the simulation.
9. Using the "Results" from (8), generate deflection and stress plots, as well as, shear and moment diagrams.

Once the models were developed, they were made into interactive images using Microsoft PowerPoint. The PowerPoint presentation is what is provided to the cohort and demonstrates the entire structure manipulation, from removing the external supports and applying the appropriate reactions to displaying the final result (shear/moment diagrams, deflections, etc.). A few snippets of one of the PowerPoint presentations are displayed below in Figure 1. The interactive images for a select few cases are displayed in Figure 2. Also, deflection videos of select cases are shown in Figure 3. These representations were used in the classroom to assist the authors in presenting some of the concept, and at the same time students had access to these files on line (Note: An Adobe Reader is required to run the videos).



(a)

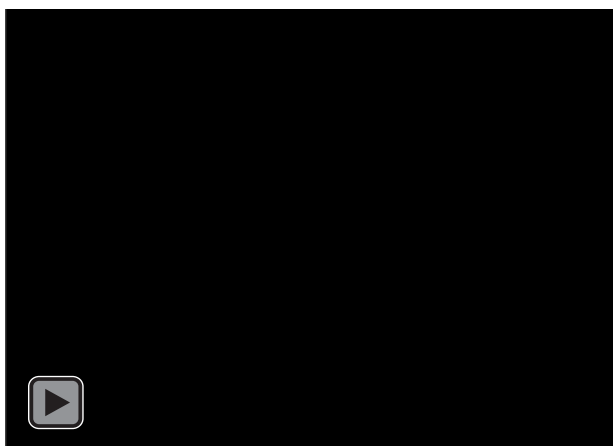
(b)



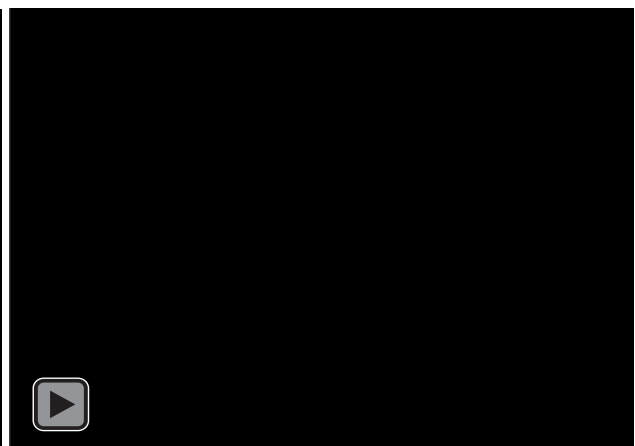
(c)

(d)

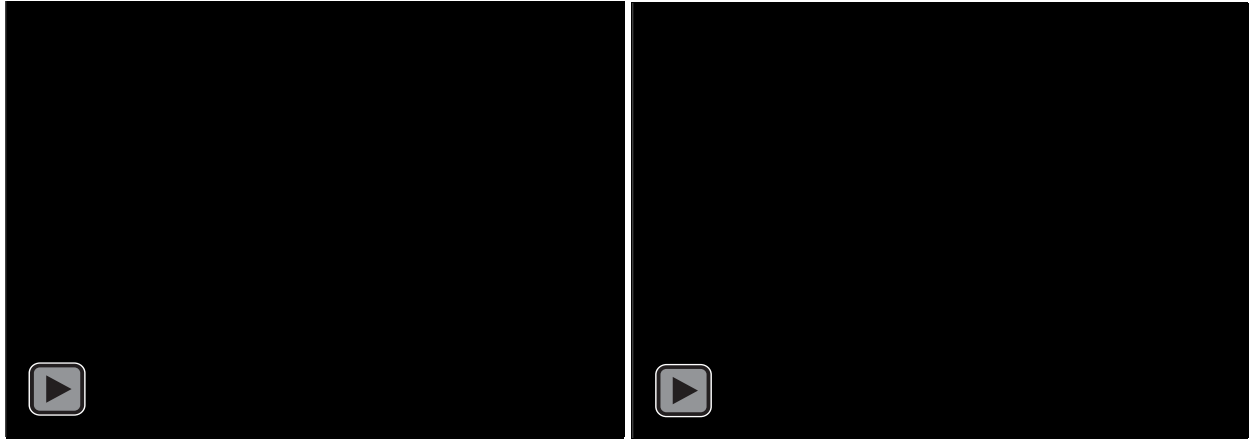
Figure 1. Simply support interactive image (a) Reactions, (b) Shear diagram development, (c) Moment diagram development, (d) Deflection diagram (which is a video) and location of flexural characteristics



(a)



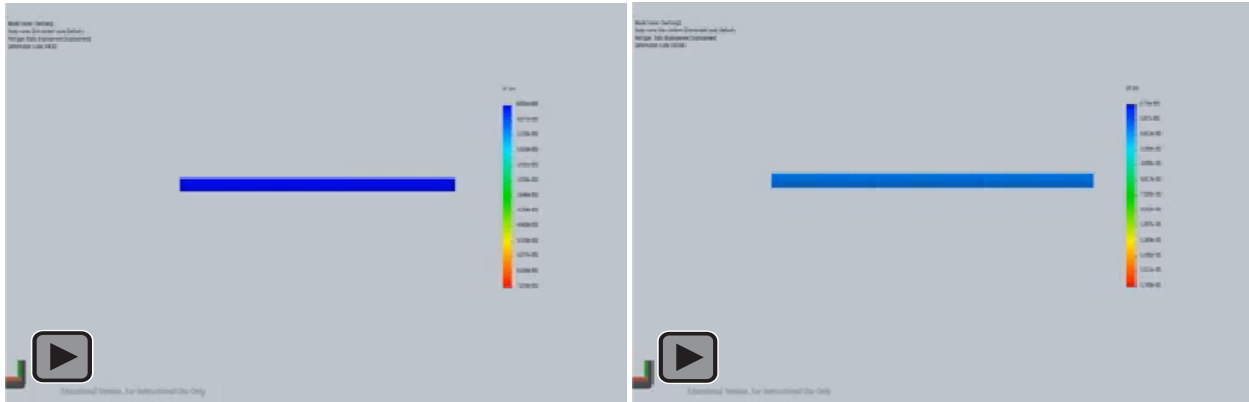
(b)



(c)

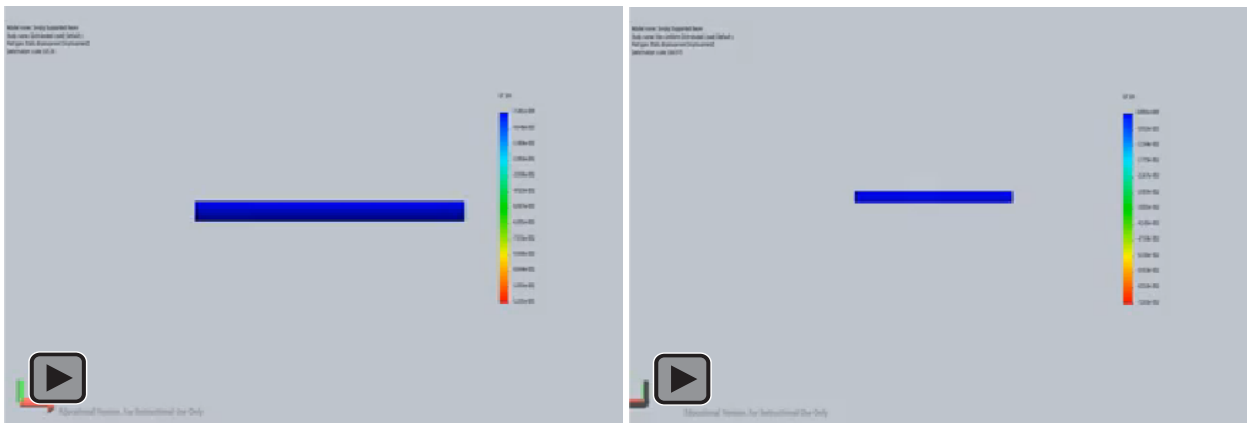
(d)

Figure 2. Interactive images of select cases (a) Overhang with distributed load, (b) Overhang with non-uniform distributed load, (c) Simply supported beam with distributed load, (d) Simply supported beam with non-uniform distributed load



(a)

(b)



(c)

(d)

Figure 3. Deflection Videos of select cases (a) Overhang with distributed load, (b) Overhang with non-uniform distributed load, (c) Simply supported beam with distributed load, (d) Simply supported beam with non-uniform distributed load

Assessment

To assess the effectiveness of these interactive images, the cohort (16 students) currently enrolled in a structural analysis was asked to rate (on a scale of 1-5, 1 indicating the topic was not understood, 5 indicating the topic was well understood) their understanding of topics presented in structural analysis course, midway through the Fall 2015 semester. About 5 weeks later, the students were presented with the interactive images for all of the loading scenarios described earlier, and then asked to retake the survey. The results of both surveys, that all 16 students completed, can be viewed in graphical form in Figure 4.

Based on these results, students had a good understanding of most of the topics, in which they scored 4 or above. It is very interesting that each topic's understanding improved even though the interactive images were not provided for all topics. Perhaps the students anticipated an improvement in the other topics if the interactive presentations were provided. However, it is important to note that the topics which were covered in the interactive presentations like deflection and bending underwent a substantial increase, especially when compared to 3-D equilibrium and sliding friction. The surveys provided the authors an understanding of the students' perception and attitude towards the interactive images.

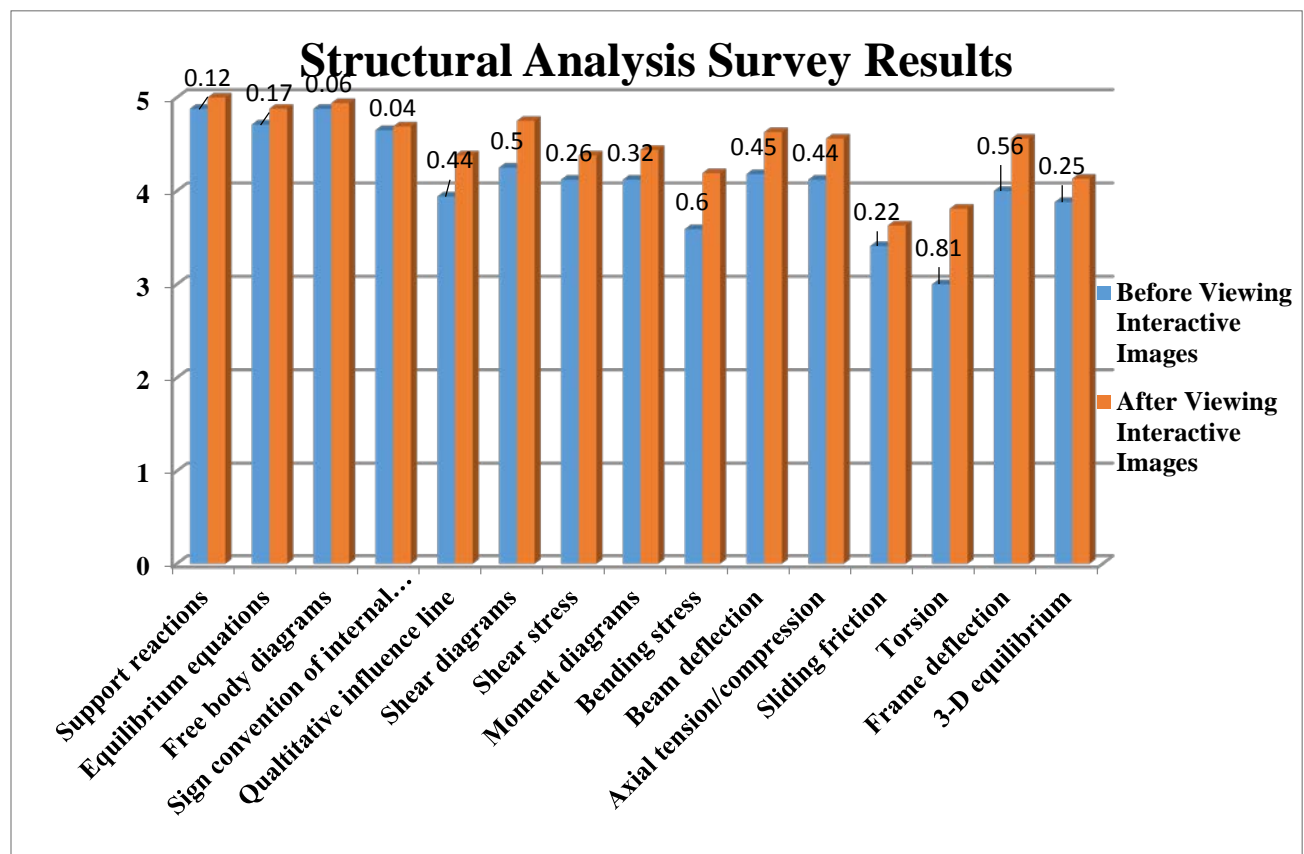


Figure 4. Graphical representation of survey results

To complement the assessment discussed above, the authors decided to track the students' performance of specific topics that students were tested on by creating a signature assignment in

the form of examination problems in their structural analysis course. It should be noted that the interactive images were provided after students took exam 3 and before students took exam 4. Students' performance in the following topics were evaluated in each exam: support reactions, equilibrium equations, free body diagrams, sign convention of internal forces, shear diagrams, and moment diagrams. The results of this direct assessment are shown in Table 1. A significant increase in performance is evident from exam 3 to exam 4 (more than 6% improvement of the average grade), versus only 2% from exam 2 to exam 3. One can make the argument that this improvement can be the result of a learning curve that came with practice and students being exposed to these topics for longer period of time. To isolate this factor, the authors compared students' performance between exam 3 and 4 from the previous year. It was noticed that the improvement was just 3.5% (results not shown). Although survey results showed that students already had a good understanding in most of the topics, however the exams results showed that there is room for improvements.

Table 1 Students' performance on the signature assignment

	Exam 2	Exam 3	Exam 4
Grades Average	72.4/100	74.4/100	80.9/100
Relevant Topics Covered	85/100 points require the use of shear/moment functions and diagrams	60/100 points require the use of shear/moment functions and diagrams	165/200 points require the use of shear/moment functions and diagrams
Other Topics	Free body diagrams, support reactions, equilibrium equations.		

Conclusions and Future Work

The project described in this paper has set out to develop visual aids for structures courses taught in engineering and related fields like construction management and architecture. In a previous study, authors conducted a survey to develop a fine understanding of which concepts in these courses are of greatest struggle to students. As described above, the initial models have been developed to improve the instructor's delivery of notoriously difficult concepts, with the output of the models verified with hand computations. Based on the students' performance in both assessments, the authors noticed an improvement in their understanding of the topics that the models have been developed for. Actually the results of the second survey showed a positive perception of the interactive images as every category showed improvement even though interactive images was not provided.

In addition to the interactive images, instructional videos have been developed so that any student can recreate the results shown in Figures 1 and 2, and apply the techniques to any member and its particular loading condition. This will provide students with a better understanding of the software, as engineering students need to use it frequently throughout their courses, while encouraging them to develop these models for their own visual comprehension of various concepts. Finally, these models are fantastic tools for verifying answers to homework problems. The authors also plan to expand their library of members and loading conditions.

Once the library of interactive images is fully developed, the visual aids will be used in the statics, engineering mechanics, and structural analysis courses.

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