AC 2007-635: APPLYING 2D/3D VISUALIZATION TECHNOLOGY IN CONSTRUCTION EDUCATION: A CASE STUDY

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Applying 2D/3D Visualization Technology in Construction Education: A Case Study

Abstract

Analytical principles of mechanics and strength of materials introduce students of construction at the sophomore or junior level to the fundamental principles involved in the analysis and design of typical components of structures. Unfortunately, students find it difficult to relate the external forces on a structural element, such as beams, ties, and columns, to the internal forces and deformations of that element. Research shows that computer-based Two-Dimensional/Three-Dimensional (2D/3D) visualization techniques offer new capabilities that can enhance a student's understanding of how structures behave under various types of loading. For instance, computer animation programs allow processes of mechanics to be shown in motion. This paper reports the results of a study on the application of 2D/3D visualization techniques in the teaching of a course in mechanics of materials to the sophomore-level construction students. The main purpose of this study was to evaluate the suitability of 2D/3D visualization techniques toward development of construction students' understanding of structural response to different loads. The impact on student outcomes and future learning environment is also a part of the targeted data as more new technologies, media and tools become available to teach a new generation of students. Students enrolled in the course participated in a survey and provided their evaluations and comments on both the traditional and 2D/3D visualization methods of teaching. The methodology and data of this process may be used for other construction engineering or technology courses in the future.

Introduction

Analytical principles of mechanics and strength of materials introduce students of construction at the sophomore or junior level to the fundamental principles involved in the analysis and design of typical components of structures. Unfortunately, students find it difficult to relate the external forces on a structural element, such as beams, ties, and columns, to the internal forces and deformations of that element. Research shows that computer-based Two-Dimensional/Three-Dimensional (2D/3D) visualization techniques offer new capabilities that can enhance a student's understanding of how structures behave under various types of loading.[1] For instance, computer animation programs allow processes of mechanics to be shown in motion. Therefore, applying 2D/3D visualization techniques to the current mechanics courses, namely Mechanics of Materials, also called Strength of Materials, will provide students a learner-friendly environment, lower the difficulty of students' understanding, and improve the retention rates of students enrolled in the construction curriculums. This paper reports the results of a case study on the application of 2D/3D visualization techniques in the teaching of a course in mechanics of materials to the sophomore-level construction students.

Purpose of Study

To enhance student understanding of structural behavior under load, 2D/3D computer-based visualization techniques are being utilized in teaching civil/construction engineering courses in engineering sciences and mechanics of materials. A study was conducted in Spring 2006 at

Missouri Western State University in a course on mechanics of materials to determine and evaluate effectiveness of 2D/3D visualization techniques in a construction curriculum. Specifically, the main purpose of study was to evaluate the doability and suitability of 2D/3D visualization techniques, media and tools for the mechanics of materials course. The impact on student outcome and future environment is also a part of targeted data. The study was motivated, initially, by the Goal Three of the Five Year Strategic Plan of Missouri Western State University.[2]

> *"Strengthen existing and develop new academic programs, taking into consideration the educational and career needs of students and the economic, social, and cultural needs of the community." (Academic Affairs and Enrollment Management--Goal Three)*

Goal three above is supported by investigating, developing, applying, and enhancing the new technologies and approaches on teaching for new generation students. As a result of the implementation of this study, the directions, techniques, and tools were assessed for teaching of mechanics of materials. Then, the data and methodology of this process may be used for other construction courses in the future.

Methodology of Study

A preliminary methodology included the following steps:

- Understanding the Requirements – Set up a frame of areas (in the course) that can be applied with 2D/3D visualization
- Literature Review – Research the practice of 2D/3D visualization or animation in teaching mechanics of materials course in other institutions.
- Selecting Software – Research various software packages and make a selection.
- Developing Lecture Package – Develop a set of teaching materials with 2D/3D visualization techniques and software.
- Teaching Course – Teach the mechanics of materials course with traditional method for the first half of the semester and then switch to using 2D/3D visualization for the rest of the semester.
- Measuring Outcomes – Ask students enrolled in the course to participate in a survey and provide their evaluations and comments on both traditional method and 2D/3D visualization.
- Writing final report – Write a report to summarize the process and analyze its advantages and disadvantages.

Programs Involved

Many computer programs are available for visualization for a course in mechanics of materials. A detailed review for these programs was implemented based on the following criteria:

- Ability of integration with current textbook and ease of use.
- Possibility of integration with current computer and presentation system.

- Acceptable cost.

Based on the evaluation done by the course instructor, the following programs were selected to use in class.

- MecMovies[3] – Award winning program of Engineering Education Software developed by University of Missouri at Rolla. The Author of this program has granted the instructor a free use of this program.
- Interactive Structures[4]: Visualizing Structural Behavior – Multi-media instructional reference published by Wiley.

In some cases, the course instructor had to develop some animations for particular components of structures; therefore, several commercial developing software were also used in this study.

- Discreet 3ds max[5] – software for developing 3D models
- Macromedia studio 8[6] – software for developing animation and flash movies.
- Macromedia Director MX[7] – software to integrate interactive audio, video, pictures and text.

Course Development and Delivery

With the software having been selected, the required textbook selected was Mechanics of Materials by F. P. Beer et al (4^{th} edition) [8]. PowerPoint slides were developed for the chapters taught for the second half of the semester to best integrate with the visualization components. The PowerPoint slides were designed with great effort for consideration of configuration, color, animation, and guidelines. However, for the first half of the semester, a traditional blackboard method was used in order to compare with the visualization method.

Outcomes Measurement and Assessment

Students in class were asked to complete a questionnaire to evaluate their learning experiences regarding the traditional teaching method and the visualization method. The Structure of questionnaire is summarized below:

- Respondent's background on prerequisite courses (some students might take courses out of sequence).
- Experience of using visualization in any other courses.
- Rating the efficiency of teaching and learning using visualization
- Comparing the benefits between visualization tools and conventional chalk and board method in terms of both lecture and lab.
- Challenges of learning with visualization.
- Further suggestions.

All the respondents had Statics as a prerequisite but several students did not have Calculus which presented some difficulty in their study. Approximately 50% of respondents had visualization components in their other classes and 90% of respondents rated the visualization components as

very important. In general, applying 2D/3D visualization techniques to the current mechanics courses, namely Mechanics of Materials, will provide students a learner-friendly environment, lower the difficulty of students' understanding, and improve the retention rates of students enrolled in the construction curriculums. However, the traditional chalk board still has its own strengths for students' understanding of course material. Below are detailed students comments in an organization of selected questions followed by summaries of students' feedback.

What are the benefits of using visualization tools instead of conventional chalk and board? Which part of class gets more benefits from visualization? Lecture or problem solving lab?

- Being able to see makes much difference. Labs are the biggest beneficiary.
- It helps to see what is actually happening instead of visualizing the process in your head. It definitely helps with the lecture in understanding how to apply the equations, but it is equally helpful in solving the problems.
- Visualization gives a better picture and is a lot easier to explain for the teacher. It also gives the teacher more room to write on the board when trying to explain.
- It is just that – visualization. If you can see what is going on in the problem you learn better for both lecture and problem solving.
- The visualization gives students a realization of the 3D situation in a 3D order. Lecture part is where the 3D visualization would be more effective. I think problem solving labs should use the conventional chalk and board method. Using visual aid would slow down the problem solving and time is the key when it comes to solving the problem.
- Visualization gives you a better understanding of what you are trying to find. You can learn all the formulas you want but if you don't understand the concept then you are wasting your time. Problem solving in class gives me more benefits because you learn from your mistakes or by others' mistakes.
- When using the visual aids along with PowerPoint slides makes it much easier for students to pay attention to the lecture rather than worry about having to write everything down, unless there maybe other key points that the instructor may stress verbally. I think the lecture portion benefits more from the visualization tools.
- The benefits of using visualization tool over the conventional chalk and board is that you can go back and study the materials. The chalkboard was also a good way to follow problems part by part. Being able to see thing visually give a person a chance to think of the problem in real life. Problem solving benefits more from visualization because that was the part of class that explained what was in the lecture.
- Without visualization the class would be very hard because the students need to see diagrams to fully understand the materials. With visualization tools, students can see the materials that are presented effectively. Things such as animations help students better comprehend what's going on, rather than just looking at a chalk board with no actions and reactions. The lecture and lab both benefit from using visual tools because students can gain a better understanding and see things that they normally wouldn't see on a chalkboard.

What are the benefits of just using conventional chalk and board? Which part of class gets more benefits from chalk and board? Lecture or problem solving lab?

- When we go to the chalkboard we all learn. The teacher is able to break down

different parts of problems that may not have been shown on the visualization. Problem solving gets the most benefit from the chalkboard. Benefits of using the board is that the teacher can make the explanation whatever way he/she wants. Visualizations just have a few examples and might not be the type of examples the teacher would like to use. The chalkboard challenges were my favorite part. I was forced to learn, or else I would stick out like a sore thumb.

- Using chalks helps especially when we do problem solving. I also like when the instructor uses the lab time and gave us the opportunity to solve problems on the board. You can see how the problem is worked out step by step for problem solving for better understanding.
- I think there should be more interaction in class like solving problems on board.
- The benefits from chalk and board are for note taking. I find it is easier to stay organized when the instructor writes each step down. Lecture gets the most benefit from chalk and board.
- Problem solving greatly benefits more from the chalk board. Personally I felt as if I was getting a better grasp on the information we were doing in Mechanics of Materials, when the instructor would pick a student to do a portion of the homework problems on the chalk board because it made you do the work as well as if there were any questions or comments the entire class could help in answering them.
- Problem solving is better for visualization – visualization must be implemented during example problems, while chalk is the best for lecture.
- The difficulty of just using conventional chalk and board was that I have a bad hand writing and going back and studying the materials was hard. However, the chalk and board method was good because you can ask questions part by part.
- Conventional chalk and board are beneficial because they help students comprehend quickly and they can also write class notes off the board which they wouldn't be able to do with visualization tools. I believe that lecture is best to use chalk board because lecture is where most note-taking occurs and it is the best to copy notes off the board. It would be difficult to take notes during a lab when using visualization tools because the students wouldn't know exactly what to write down.

Do you think it would be better to combine the visualization tools and conventional chalk and board? Why?

All respondents answered "Yes" with explanations of:

- I thought that was what helped the class understand better. Visualization is good for the 3D, while the chalkboard is good for getting in depth (notes).
- Because I think each has its own benefits. Visualization helped me understand the ideas better but chalkboard is great for breaking down equations into smaller steps.
- Using the visualization tool and giving us the opportunity to do problem solving on the board helps a lot because it would be the best of both worlds.
- The combination is essential to learning. The visualization is good for understanding what actually is happening to the beam where the stress is at when a certain load is applied. The chalk and board is great for the writing and understanding of the formulas. If you have to take extra minutes to explain details from the drawing on the chalkboard, it is more clear to see it from the visualization

- Both the chalk board and the visualization tools are good ways for an instructor to deliver their lectures, and both methods have their own meaning. One may be better than the other at one thing but not as good at something else. By combining the two methods I think it would make it much easier to follow and to learn the lecture materials.
- I think it will be the best to combine the visualization tools and conventional chalk and board because it gives a lot clearer understanding of what's going on in the class. Combining these two methods will cut down on the questions and make everything clearer and easy to understand.
- I think that combining these two methods would be the best way for students to learn because they not only get to see animation of how the structure responds, but they would also be able to take notes off the chalk board so they can have formulas and calculations as well. Visualization tools would help broaden student's knowledge, while the black board would teach them formulas through repetition of calculations and note-taking.

Based on your experience this semester learning with visualization, what, if any, are challenges to using this approach?

- When using just visualization, sometimes the computer does not go as in depth as the teacher does.
- I think challenges of using visualization would be trying to figure out what the visualization is going to do and get a basic picture in my head before the visualization shows me.
- Sometimes it is hard to understand that visualization tool.
- The only challenge I can see that will occur is that some students might not be able to fully grasp the relation between the visualization, the book, and the chalk board. Some students are so used to learning off the chalk board and through note-taking that if using visualization tools, such as animations, they might not fully comprehend what the animation is trying to show or they may become disinterested in the learning process.

Besides the current use of visualization tools (2D colorful pictures, PowerPoint slides, 3D animations), are there other approaches that you think to improve the quality of learning?

- Labs are always good. While I like visualization, nothing beats cracking materials yourself. But I understand that visualization is good for saving money.
- Maybe doing a few more labs so that students could actually see what they have been putting down on paper, like, loading a steel beam to see it bend.
- Everything so far has helped me from the first half of the semester to now. I don't know if it is the visualization or the interaction that the instructor has provided for us. I think the biggest effort has been working on the board.
- Doing more live demonstrations or use more video clips.
- All the visualization tools are very helpful in learning the material. The only thing I think I can come up with is to do more homework problems as a group on the chalkboard
- I think using Excel will be a good teaching tool. Excel gets students ready for the real world job.

Please list the classes that benefit from using visualization.

- Statics
- Concrete Design
- Fluids
- Structural Analysis
- Construction Management
- Wood and Steel Design

Conclusion

This case study shows that applying computer-based 2D/3D visualization techniques to the current mechanics courses provides students a learner-friendly environment, and lowers the difficulty of students' understanding. The students express a desire for increased visualization offerings in the curriculum. However, the traditional chalk board methodology of problem-solving remains a strong delivery method of instruction.

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