# Structural Engineering Education by Incorporating Visual Understanding and Interactive Learning

**Pyo-Yoon Hong**
*School of Engineering, University of Gaum*

## Abstract

More than 90% of the Millennial students agreed to the questions, “I am a visual learner.” and “I like education with entertainments.”[1] Hence, it is desirable to use visual effects in presentations incorporated with interactive classroom activities. Adequately designed visual worksheets for structural concepts may reduce the possible mismatches between the teaching and learning styles by utilizing the synergetic relationship between visual and mathematic understanding for both sensing and intuitive learners. The goal of this paper is to identify the modifications needed to improve structures education to prepare engineering students for the complex real-world problems that the engineering workforce of the future will be facing. In an attempt to address this problem correctly, three visual engineering workbooks have been introduced and integrated with class group work in three structures courses. This paper presents a first-hand experience with the preparation, use, and assessment of the visual workbook projects.

## Keywords

Visual Understanding, Mathematical Understanding, Structural Engineering, Visual Workbook

## Rationale

We teach the Millennial Generation. They are often impatient and easily bored, and thus prefer immediate and interactive feedback. This finding is consistent with research that indicates that they often have short attention spans, hence they desire for concise and entertaining meetings. Therefore, it can be successfully deduced that using visual effects in presentations (going beyond PowerPoint), incorporated with interactive classroom activities, is required to have them attracted and stay focused in engineering classes. Interactive learning is a more hands-on, real-world process of relaying information in classrooms. Instructors have to develop systematic strategies that facilitate student engagement in such a way that students can develop behavioral skills and habits that lead to increased academic achievement and greater involvement with classroom activities. Passive learning relies on listening to teacher’s lecture or rote memorization of information, figures, or equations. But with interactive learning, students are invited to participate in the conversation, through technology or through role-playing group exercises in class. In other words, because we teach a generation of visual learners, traditional podium style teaching (passive learning) should be kept at a minimum in engineering classes and a new teaching methodology must address this characteristic by providing interactive visual components. Additionally, incorporating participant interaction in the classroom environment appears to be a key to maintaining participant attention at every phase of the meeting. Felder and Brent[1] have suggested that there is a mismatch between learning and teaching styles since most students are visual and sensing learners but 90-95% of the content for most courses is verbal and most instructors are intuitive learners. Such a mismatch must be addressed for teaching to be effective. Of course, the author recognizes and acknowledges the value of mathematical approaches in engineering classes and knows that the author and his colleagues have been successfully educated through mostly traditional systems of education. However, adequately designed visual worksheets for structural engineering may reduce the mismatches between the teaching and learning styles by utilizing the synergetic relationship between visual and mathematic understanding for both sensing and intuitive learners. As an attempt to address this problem correctly, three sets of visual engineering worksheets have been introduced and integrated with class group work in two structural engineering classes, Design of Wood Structures, Design of Reinforced Structures and Design of Steel Structures.

**Mathematical Approach and Visual Learners**

In conventional engineering classes, the students' ability to comprehend engineering principles can successfully be obtained by manually solving a series of multiple engineering problems of progressive difficulty. Most engineering textbooks are formatted in a similar fashion. The results of this mathematical approach in engineering education seem to be straightforward, maybe even obvious. However, in this approach, lectures are generally conducted using calculation-intensive platforms and the role of the students in the lecture is relatively limited, and thus they often remain in a passive mode of learning throughout the classes. This factor may result in low levels of motivation, which in turn has caused poor interaction, inadequate understanding and low retention of structural principles. Most of structural engineering textbooks and traditional teaching methodology may have been pushing students toward problem-solving more than toward conceptual understanding. When structural principles are reduced to a series of calculation without apparent link to structural forms, they become miserably boring engineering subjects to students. Engineering students must actively engage in procreative mental activity coupled with interpretation of personal observation and experience in order to develop the genuine understanding of structural concepts and theories that underlies structural forms. But if students remain as passive listeners in engineering classes, such activity is rarely induced. The Millennial students are in nature observers and explorers, and the most effective approach to learning should capitalize on these intrinsic abilities. Hands-on learning is learning by doing. Science must be experienced to be understood. These experiences should allow students to be actively engaged in the manipulation of everyday objects and materials from the real world. Hands-on instruction has a long and successful legacy in the sciences and math.[2] Hands-on activities promote critical thinking, communication, collaboration, and creativity encouraging a lifelong love of learning and motivate students to explore and discover new things.[3] Many cognitive theories propose a method of learning called the discovery method, in which a teacher guides a student through materials and questions related to a problem but allows the student to work out his or her own solution. Hands-on learning unleashes students' potential, sparking the self-instruction experience and the retention will be longer. The critical elements that must be properly addressed and integrated in the proposed teaching methodology are:

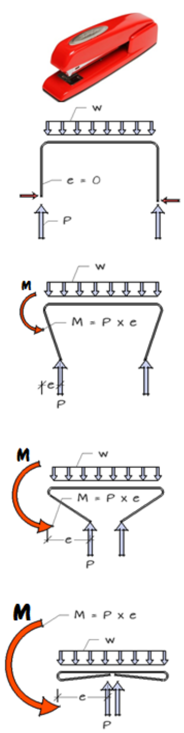


**Fig. 1 Familiarity for Engagement**

1. More opportunities for student's input must be created in classroom environments to enhance engagement level.
2. Lecturer-students engagement can be promoted more effectively through discussions of visual images.
3. Self-direct learning must be stimulated and achieved through stipulated delivery of choices.
4. Lecture portion of engineering class must be shorter and more meaningful.
5. Students learn better when they work together in a small group as a team to solve a problem, complete a small project, or accomplish a common goal.
6. Teaching approaches employing visual understanding must be employed to improve critical thinking for longer retention.
7. Technology, for example computer simulation, must be used to build anticipation and drive attendance by creating excitement or playfulness in learning processes.

**Quantitative and Qualitative Approaches**

Although accuracy and reliability in solving quantitative problems is necessary, a qualitative understanding is required in applying structural concepts and principles to various real-world situations, especially when the structural form is unconventional or innovative. Both quantitative and qualitative understanding of structural performance is necessary for students to adequately conceptualize the design. However, it becomes questionable whether the students have developed the adequate understanding of structural principles if the students are not able to neither understand what underlies quantitative problem-solving procedures nor interpret the solution in structural design context. It was my most frustrating experience to see many bright students in my structural classes, capable of solving complicated quantitative problems, fail to answer on seemingly simple qualitative questions related to their architectural design. Students in structural classes seem to pay more attention to problem solving technique without being without being attentive to the underlying concepts. In an effort to find balance and connection, and increase awareness of the interrelationship between visual and mathematical understanding in the structure classes, two visual workbooks has been developed and used. The visual structural engineering worksheet combines visual understanding with related structural principles expressed in formulae and equations in an organized fashion. Students can now participate in a non-traditional form of hands-on education through the use of visual worksheets strategy. This worksheet approach requires students to become active participants instead of passive learners who listen to lectures or watch films. The worksheet can be considered as 'incomplete' textbook

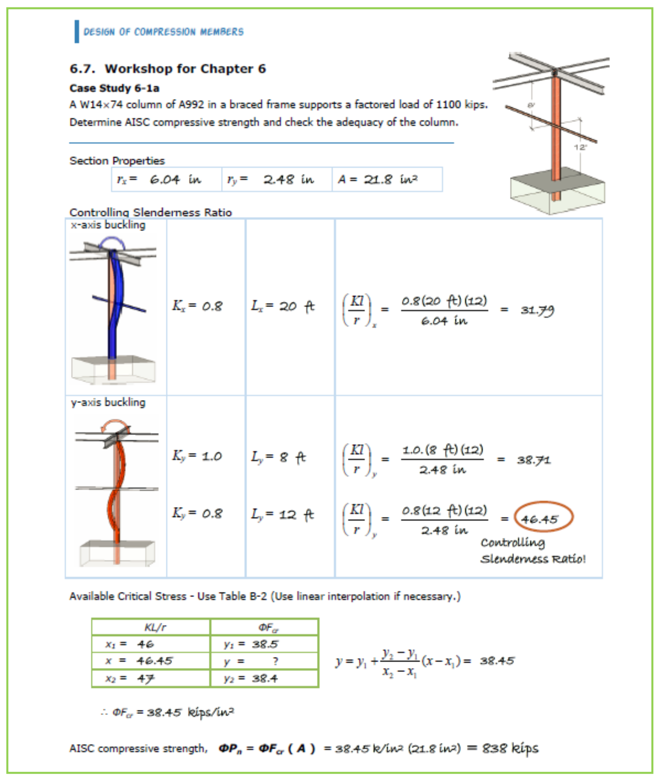


**Figure 2 Column Buckling Visualized in 3-D Space**

and class notebook because students are guided to progressively go through the following three steps: Instructor gives an oral lecture of a complete structural calculation case study. Both instructor and students jointly complete a worksheet by filling in the ‘incomplete’ visual and mathematical elements that were deliberately left blank. Students solve several structural engineering problems in a small group of three as homework or lab exercise on their own.

It is well known that the engagement gap has an even more profound negative impact on students who are coping with learning challenges. As students struggle to connect with what they are being taught without appropriate guides, they fall further behind and become more disconnected. Visual worksheet may be utilized to close the engagement gap by implementing cooperative learning environments and by connecting abstract concepts to the real world situations. Hopefully, these hands-on activities rekindle a love of learning while achieving desired educational outcomes. Effective visual structural engineering worksheets must incorporate the following elements;

1. Discussion of structural engineering concepts and ideas
2. Linking relevant real-world situations to educational symbolism using graphics
3. Working collaboratively with teachers and their peers
4. Thinking divergently to find a variety of ways to solve problems
5. Taking more responsibility in their learning experiences
6. Gaining confidence in their abilities to find solutions and answers on their own

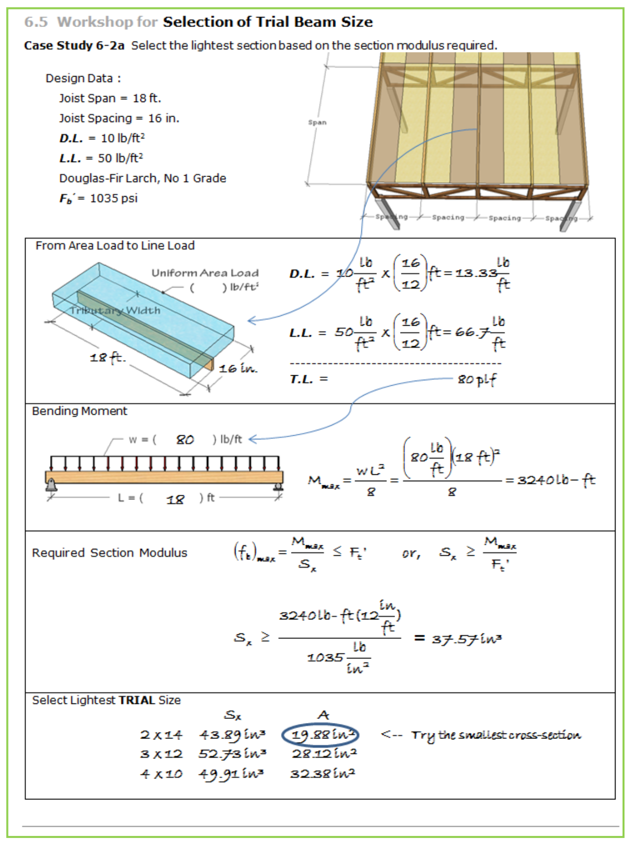

**Figure 3 Beam Design with Tributary Area visualized**

Visual engineering worksheets may engage the student in a total learning experience which enhances the student’s ability to think critically. The students are guided to a process to test a hypothesis, put the process into motion using various hands-on materials, see the process to completion, and then be able to explain the attained results. Hands-on learning enables students to apply not only what they have learned, but more importantly, the process of learning, to various real-world situations. For visual learners, it is critical to let them review and revise class notes during classes or immediately after class while they still remember a good deal of the lecture, to reinforce their knowledge. For the last 5 years, comparison of the exam scores of the students in the 4 different sections (average enrollment of 20) of the same course in the University indicates that the students in the section with the combined qualitative and quantitative approaches performs 5 to 10% better than the ones in the sections with mathematical approach only. Reviews received over the last 5 years reveal that students (average age of 19-20, with a malefemale student ratio of roughly 70:30) give strong approval for these approaches. Another sign of the students' support is that the enrollment for this class, among 4 sections of the same course, becomes full on the very first day of registration while the numbers of enrollment of the other sections still remain low until the last day of registration. However, the teaching methodology requires rigorous assessment in order to measure its genuine effectiveness in structural engineering education.

## Conclusions

1. Carefully designed hands-on class materials provide many students with an engaging opportunity through discussion about the visual elements involved.
2. Using engineering visual worksheets could be more effective in aiding students to understand abstract concepts and improve achievement.
3. Students tend to accomplish their work better when they are encouraged to actively explore and interact with learning process utilizing visual engineering worksheets.
4. Incorporating hands-on learning into classroom lesson not only helps students grasp and retain concepts with greater ease, it makes the entire teaching process most effective.

## References


1. George G. Fenich, et al., "What the Millennial Generation Prefers in Their Meetings, Conventions and Events," *PCMA Education Foundation Grant Funded Research Paper*, (2012).

2. Basista, Beth, and Susann Mathews. "Integrated Science and Mathematics Professional Development Programs," *School Science and Mathematics*, 102.7, 359-370, (2002).

3. Bass, Kristin M., Danielle Yumol, and Julia Hazer. "The Effect of Raft Hands-on Activities on Student Learning, Engagement, and 21st Century Skills," *RAFT Student Impact Stud*, (2011).

4. Ballone, C., "Consulting Your Clients to Leverage the Multi-generational Workforce," *Journal of Practical Consulting*, 2 (1), 9-15, (2007).

5. Davidson, R., "What does Generation y Want from Conferences and Incentive Programs?", *Business Travel and Tourism*, University of Westminster, London, England, (2008).

6. Hanna, E., "Keeping a New Generation Engaged, Satisfied," *Hotel and Motel Managemen* , 224 (4), (2009).

7. Hewlett, S., Sherbin, L., & Sumberg, K., "How Gen Y & Boomers Will Reshape Your Agenda," *Harvard Business Review*, 87 (7/8), 71-76, (2009).

8. Wieck, K. L,. :Managing the Millennials," *Nurse Leader*, pp. 26-29. (2007).



## Pyo-Yoon Hong

Associate Professor, School of Engineering, University of Guam
Ph.D. in Structural Engineering, University of Oklahoma
Professional Engineer in Guam