Improving Learning and Engagement for Students in Large Classes

Richard Goff[1], Janis Terpenny[2], and Terry Wildman[3]
[1,2]Department of Engineering Education, [3]Center for Excellence in Undergraduate Teaching, Virginia Tech,
Blacksburg, VA 24061 [1]richgoff@vt.edu, [2]terpenny@vt.edu, [3]wiley@vt.edu

Abstract - **Due to increasing student enrollments and limited resources, small classes are evermore being replaced with large lectures. It is therefore essential to quality educational programs to address the challenges of student learning and engagement in large classes. This paper explains connections between basic learning research and practical strategies for engaging students in large engineering classrooms. First, we ground proposed instructional strategies with theory and empirical evidence on such key matters as how students represent ideas in memory, how these representations are elaborated and perfected over time, and how stored information can be retrieved for use. This helps us to understand how students learn to monitor and control their own learning and how large class environments can be approached as sites for significant learning. We discuss how electronic student response devices (clickers) have been useful for generating in-class interaction and active learning in large classes for individual and team activities. How to administer beneficial team-based projects for large classes is also presented, including: real-world problems that require teams to investigate and understand contemporary issues such as sustainability, working with industry, and third-world countries. Finally, personal style and characteristics of faculty who are successful with large classes is discussed.**

Index Terms – Engaging students, Improving learning, Large classes.

INTRODUCTION

Due to increasing student enrollments in engineering over the last few decades and ever increasing demands on faculty time required for excellence in teaching, research and outreach, the thirty-seat classroom, for many courses, has become a thing of the past. To maintain and improve quality educational programs, it is essential that we address the challenges of student learning and engagement in large engineering classes. This paper explains connections between basic learning research and practical strategies for engaging students in large, 150-300 seat, engineering classrooms. We believe it is important to ground proposed instructional strategies with theory and empirical evidence on such key matters as how students represent ideas in memory, how these representations are elaborated and perfected over time, and how stored information can be retrieved for use. It is also important to understand how students learn to monitor and control their own learning. In other words, large class environments need to be approached as sites for significant learning.

With the above ideas in mind, several successful techniques are provided for generating student interaction and active learning in these large classes, including: in-class team activities, electronic student response devices (clickers), and small peer group shared response activities. Discussion is also provided that highlights, not only how to administer beneficial team-based projects for large classes, but the positive impacts of using real-world problems that require student teams to investigate and understand contemporary issues such as sustainability, working with industry, or the needs/challenges of third-world countries. Finally, we reflect on the personal style and characteristics of faculty who successfully interact with large classes.

BASIC LEARNING RESEARCH AND STUDENT ENGAGEMENT

Making practical the connection between learning research and classroom practice need not be as difficult as it may seem. Without burdening practitioners too heavily with the psychological language inherent in much of the learning research, we should be able to develop a basic story line about learning that is relatively easy to act upon. Drawing primarily from cognitive learning theory, this section suggests some of the main elements to consider if we really want students engaged in their own learning.

We might begin with the simple assertion that nothing is learned through a process of *transfer* from one person to another. Certainly much of what is observed in large class environments might suggest that students are there to absorb what is conveyed via lectures. In truth, whatever students gain from presentations is actually constructed by them though selective processing of verbal or textual stimuli. This construction process is the key element in any story line about classroom learning, and this is particularly crucial to consider in large classes where the individual student may not receive the personal attention available in more intimate environments.

So, what does knowledge acquisition look like as an active, constructive process? First, we need to recognize that students are working with multi-faceted memory systems that have amazing capacities but also some potentially debilitating bottlenecks that require strategic action to overcome. A component of memory typically referred to as "short-term" memory is the conscious workspace where new information is held in an active state and processed so that it can be coded into more a permanent knowledge structure. The difficulty is that working memory has both limited capacity and duration, meaning that it is often difficult to hold enough ideas in mind at the same time and for enough time to do the processing needed to store new information into the permanent component of memory. Good lecture techniques can facilitate students' processing efforts, and good teachers are usually aware of the need to encourage and support effective memory strategies.

These and other well known complexities of memory simply illustrate the need for a greater degree of understanding about what students need to do to effectively utilize their own information processing systems. With short-term memory, learners can overcome the tendency to lose information they have just heard or read with conscious rehearsal strategies, and they can overcome capacity problems by reordering small bits or nuggets of information into larger chunks based on prior experience.

Then, a major issue is the absolute necessity to connect new information to knowledge already stored in one's existing memory networks. What matters is the quality of the connections made between new information and previously stored knowledge. Students must make these connections for themselves, which is why teaching is not simply an act of transmission—rather it involves putting students in a place where they can construct their own well-organized knowledge. This is why we should be arguing that learning within lecture contexts, even in large classes, can and should be characterized as discovery learning. Students, in essence, are creating well-organized knowledge from the fragments made available during class time.

Architecture is clearly an important feature of learning—the architecture of memory that is. Because there is such a vast amount of information to store, both from formal learning contexts and everyday experience, a premium is placed on the ability to create well formed and efficient memory structures. For example, when engineering students learn about design, every design project has its' own set of subtle nuances, but instead of storing separately all the discrete examples, the better learners gradually abstract from the disparate experiences a generalized schema for design that is both efficient and powerful. One great benefit from having such powerful knowledge structures is that these structures provide a generative capacity; that is, students can actually create new knowledge through inferences and elaborative reasoning even in the absence of further instruction.

One of the critical issues in developing powerful knowledge is that it takes time, and it takes planning on the part of curriculum developers. Time is needed because the knowledge created by novices in any field will be incomplete and sometimes flawed by persistent misconceptions. Psychologists learned long ago that complex learning involves a cyclical process that involves returning time and again to the same topics, but each time at a level of increased complexity. Jerome Bruner proposed even as early as the 1960s [1] that a curriculum model known as the "spiral curriculum" effectively takes into account the need to always turn back on what was previously learned to add elaborations, fix misconceptions, and give students the sense of what it really means to create their own knowledge.

These few caveats about complex learning do not tell the whole story of course, but they do point to some of the key challenges we face in meeting the actual learning needs of students. Is it possible that large class environments might be good places to confront some of these learning needs? Traditional wisdom might argue to the contrary, but with technological aids and accompanying small group opportunities large classes just might be places where a consistent story line about learning can be revealed to cohorts of students in a deliberate and well-planned manner. The experiments reported in the remainder of this paper are tentative, but positive steps in that direction.

PRACTICAL STRATEGIES FOR ENGAGING STUDENTS IN LARGE CLASSES

Over the past two years due to increasing demands on faculty time, the first year engineering courses in the Department of Engineering Education at Virginia Tech have transitioned from multiple 30 seat sections that met twice a week delivered by faculty to a once a week 50 minute lecture of 150-300 students delivered by faculty and a once a week 90 minute workshop of 30 students delivered by graduate teaching assistants. This shift in format has necessitated the moving of most all lecture material to the lecture period and most all hands-on and teamwork activities to the workshop period. A paper by Dr. Jenny Lo presented at the Annual Conference and Exposition of the American Society for Engineering Education (ASEE) in 2006 illuminates in detail this transition to large classes [2].

Most of us notice that when classroom size increases, student and faculty interaction decreases. In an effort to improve this decline in interaction a few strategies have been implemented. Because of the large class size, individual response to faculty ad hoc questions is limited and sometimes intimidating to the students. To support the students in constructing their own knowledge by interacting with the material presented the following strategies are being used.

I. Electronic Student Response Devices (Clickers)

One of the strategies employed has been the use of student response systems. A particularly successful robust device is the Radio Frequency Clicker. This device, similar to a TV remote control in size, in the hands of students allows for individual anonymous response by students in class with the almost instantaneous compilation of response data and display of results back to the students. There were thirteen papers delivered at the ASEE conference in Chicago in June 2006 dealing with the implementation and success using RF Clickers in the classroom and for assessment [3]. These devices prove to be an excellent student engagement tool for large classes. The ability to come up with questions either ahead of time or on the fly during a lecture that can be asked of students and to get a usual 90-100 percent response immediately is a great teaching tool.

Students were informed ahead of time that clickers were also being used to record their attendance. During each lecture, students were asked one or more clicker questions. Some questions asked students to give opinions on former course activities while others sought to gauge students' prior experiences and current knowledge.

An example of a clicker question with the number of responses (in parentheses) is given below:

In terms of knowing what engineers in each field do, which discipline are you least familiar with?

1. *Aerospace and Ocean (6 students)*
2. *Biological Systems Engineering (18 students)*
3. *Chemical Engineering (0 students)*
4. *Civil and Environmental (2 students)*
5. *Computer Science (5 students)*
6. *Electrical and Computer Engineering (2 students)*
7. *Engineering Science and Mechanics (12 students)*
8. *Industrial and Systems Engineering (21 students)*
9. *Materials Science and Engineering (17 students)*
10. *Mechanical Engineering (2 students)*
11. *Mining and Minerals Engineering (34 students)*

Interestingly, the workshop part of the class later in the week included a slide presentation on "Mining and Minerals Engineering".

The clickers provided instantaneous feedback to the instructors and on a number of occasions the instructors took advantage of this opportunity to know students' "prior knowledge" of various topics and address the misconceptions. For example, while discussing the concept of "independent" and "dependent" variables in the context of an engineering experiment, the following clicker question was asked to determine "prior knowledge":

For the following phrase which quantity is the independent variable?

Elapsed time for various piston sizes

A. *Time*
B. *Piston Size*

Student responses in a class of about 150 students were:

A. *40%*
B. *55%*
C. *Invalid response 5%*

After reviewing the class response, the instructors gave a brief explanation of the associated concepts that an experimenter measures the response of a system (dependent variable) to some changes he/she introduces (independent variable) and another question on a similar concept was asked as below:

For the following phrase which quantity is the independent variable?

Varied time and recorded distance

A. *Time*
B. *Distance*

Student response to this question was:

A. *89%*
B. *3%*
C. *Invalid responses 9%*

Clearly, a significant number of students showed a better understanding of the concept. It may also be mentioned that the clicker questions did not take significant amount of class time. Typically, the whole process of asking a single question, recording response, and responding to the response histogram took less than 90 seconds [4].

II. PowerPoint Slides with Gaps and Tablet Computers

Another strategy that has been more easily implemented as a result of the tablet computer initiative in the College of Engineering here at Virginia Tech is that of using PowerPoint Slide shows with gaps. The strategy is not new, as Richard Felder [5] and Siegfried Holzer [6] used Power Points with gaps in the past decade. However, the ability for faculty and students to write directly on the slides and electronically save the results during delivery of the lecture is only now easily done with write-on tablet computers. The results of this strategy, using tablet computers, are just now being gathered for reporting in the near future. One of the authors is using this technique in his 300 seat class this semester with good results.

Keeping student interest in an internet wired classroom where every student has a tablet computer is a real challenge. Instant messaging, DVDs, e-mail, etc. are all potential distractions. These high tech distractions take the students' attention away much more than the doodling, daydreaming or note passing of the past. The more we can use the computers in the classroom to engage the students rather than allow them to surf 'far from shore' the better.

Software such as DyKnow that allows instructor written material to show up wirelessly on students' computers, as well as allowing for students to take electronic notes on these sessions, is being tested in large engineering classrooms this semester by another of the Engineering Education faculty members at Virginia Tech. Results of these studies will certainly be reported during this year.

Using student paired discussion is another strategy that allows for peer teaching and directed conversation during class. Asking questions that students work on in pairs or in teams and then respond as a group to the class works well to breakup the lecture and allow for direct student participation during class.

III. Administering Beneficial Team-Based Projects

Numerous studies have shown that the use of real-world problems in undergraduate education reinforces concepts and improves learning in ways not available through traditional methods of lecture or predefined case problems. In addition to higher achievement on graded materials assessing performance against technical learning outcomes, students develop problem solving skills, project management skills, communication and teaming skills, and a sense social responsibility and professionalism through such experiences. For women engineering students, indeed all engineering students, identifying and solving a problem that improves the quality of life and well-being of others, can lead to greater interest in engineering and higher rates of retention.

When collaborating with industry on real-world problems, we have found that it is best for faculty to work cooperatively as a team with industry partners to define, organize, and administer the projects. Although projects come primarily from industry partners, faculty aid in the selection of appropriate projects and edit problem statements with student capabilities in mind. Once launched, industry partners are the main contacts for queries from students regarding the assumptions and general details of projects. Faculty are responsible for providing milestones to students, meeting with student teams to aid progress, responding to teaming issues, suggesting strategies for data collection and assumption making, general encouragement, and for grading interim and final reports.

For large classes, we recommend keeping team sizes to a manageable 3-4 members each with one of these members, selected from within the group, serving as the team leader responsible for overall management of the project as well as for meeting specific deadlines for the completion of the project. Further, the use of the Internet and web sites developed specifically to support the administration of project materials and collaboration with industry partners are invaluable for large classes [7], [8]. Generally, we recommend that industry collaborative projects begin following a kick-off guest lecture from the industry partner. Further, for large classes, we recommend providing teams with a set of diverse problem choices rather than a single problem that all teams will complete. We find personal contact from industry helps motivate and interest students. Typically, 1-2 additional help sessions or guest lectures from industry partners should take place during the course of the project semester.

Guest lectures can be digitally recorded and then placed on the web page for review by students who attended the lecture as well as student groups who may be located remotely from the university hosting the guest lectures. Although left to the discretion of the teams, students generally should meet at least once per week early in the project, more frequently with progress and near due dates. We find that ease of communication is imperative with students typically communicating with industry partners through e-mail, message board, phone, or other methods that they and their contacts deem appropriate. Most students take frequent advantage of the freely provided support from outside collaborators. The message board was implemented to provide an open forum for discussion for the industry-sponsored projects. Studies indicate that message boards significantly improve interaction and elevate the sense of community between class members in larger classes. This in turn improves the motivation levels, the quality of the work, and retention [9].

We have also previously utilized open-ended real problems in the area of assistive technology (AT), or designing solutions for the disabled [10-12]. At the conclusion of the AT design project, each student conceives, models, analyzes, and builds a functional prototype of a mechanical and/or electromechanical device that satisfies an assistive need. Students welcome both the hands-on and personal contribution aspects of their projects. In many cases, projects lead to research extensions, connections within the community, and for some students, inspiration to pursue graduate studies.

We also believe that using human-centric design projects such as those focusing on assistive technology may have a significant impact on the interest and learning of women students. There is a growing body of research that suggests that by addressing gender differences in learning style and perceptions of technology and interests, a more equitable environment in engineering classes could be created by changing the primary activities used to introduce or reinforce concepts [13-18].

Over the last two years, we have partnered freshman engineering students with sophomore industrial design students in collaborative teams to solve an assistive technology problem assuming third-world conditions [19]. This implied the needs had to be addressed through low-technology, affordable materials and fundamental processes. Student teams were to consider daily living situations where humans need assistance due to disabilities of some sort, especially where people need to get materials from "point A to point B". The push-pull assistance problem could be a shopping situation, such as moving groceries from one location to another. Or, it could be an access situation where people need to reach for something, low or high. People may need assistance moving their bodies from one situation to another, such as in and out of a bath-tub. The context could also be recreational or outdoors: garden hauling, weeding, moving building materials, backpacking, or hiking.

Ultimately, each team was to develop a working prototype of an object that addresses a simple human need of getting materials or themselves from one point to another. At the conclusion of the project, each team demonstrated their product by having it run/operate/function through two cycles.

Observations and analysis of assessment data indicate there is a discernibly greater quality of the projects of interdisciplinary teams of engineering and industrial design students as compared with engineering only teams. Data also indicates that interdisciplinary teams value and are more amenable to projects that are more complex due to being open ended, human centered, and collaborative as compared with engineering only teams.

As part of an NSF grant for Departmental Reform, the design activities in the first engineering course are focused around the theme of sustainability. In one of the projects, teams of students are given limited materials and charged with researching, designing, and building a prototype of a "promotional invention" of a renewable energy source. Teams are assigned one of four topics that include hydropower, solar, wind and biomass. They present their solutions in the small workshop sessions. The best design from each section is chosen to participate in a sustainable energy fair competition where a panel of judges chooses the first place and two honorable mentions. This worthy activity had the effect of unifying the large classes as well as giving them an element of competition.

IV. Personal Style and Characteristics of Successful Faculty

Teaching large classes is a quite different experience than teaching in a 30 seat classroom. One can have a quiet, low key demeanor in a small class and be engaging and successful. It is also easy to see individual students without much effort and to gauge their level of engagement.

It is critical in large classes of 150-300 students that the lecturer be dynamic and project energy to the audience. If you are not engaging your audience, you are boring them. This in turn allows them to wander mentally and electronically. Moving around the room if possible or at least around the "stage" area is an effective method of capturing their visual attention. Changing tone of voice and gestures will also keep their attention. During the lecture, one should attempt to focus on individuals throughout the audience to gauge their level of attention. If attention is waning, the lecturer must be willing to be flexible and interject activities at that point to regain student engagement. A focused energetic delivery of short lecture segments with intervening time for student activity and feedback is an effective technique that keeps the class moving and causes different mental processes to come into play.

SUMMARY AND CONCLUSIONS

In summary, several engagement strategies have been implemented that are grounded in learning theory. These strategies are creating opportunities for student interaction, student reflection, and student construction of knowledge in a large classroom environment. Just as we are nostalgic when we think of the buggy rides and the mom and pop store, we are nostalgic for the small classroom where we "feel" that better learning takes place. However, with the advent of technology comes efficiency and scalability. Mass transit and large variety stores allow more to move more efficiently and to shop more economically. The experience may be different, but we arrive at our destinations and wear our clothes and eat our meals just the same. Likewise appropriate use of technology and learning strategies in large classes will result in satisfying levels of student learning as in the past.

The strategies presented in this paper are just an overview and a start. They point the direction to many research questions that need to be answered regarding classroom response systems, engaging student projects, interactive tablet software, and other strategies now being implemented in large classrooms.

ACKNOWLEDGMENTS

The authors would like to acknowledge the National Science Foundation for their generous support through the Departmental Level Reform Program grant # 0431779. Also acknowledged are Drs. Jenny Lo and Vinod Lohani, PIs on this grant and course coordinators of the Engineering Exploration course, for initiating and promoting the student response systems as well as Jennifer Mullin, a doctoral student, for creating the engaging sustainable design projects.

REFERENCES

[1] Bruner, J., 1960. *The Process of Education*. Cambridge, MA: Harvard University Press.

[2] Lo, J. , Lohani, V., Griffin, O.H., "Full Implementation of New Format for Freshman Engineering Course at Virginia Tech", *Proceedings of ASEE 2006 Conference and Exposition,* Chicago, IL, June18-21, 2006, CD-Rom Session 2006-982

[3] Multiple Authors, *Proceedings of ASEE 2006 Conference and Exposition,* Chicago, IL, June18-21, 2006, CD-Rom Sessions 2006-142, -2672,-2551, -2383, -2076, -906, -1358,-1997, -1902, -1683,-1675,-1264

[4] Mullin, J, Lo, J., Griffin, O., Lohani, V., "Sustainable Design Projects for Engineering Freshmen" , *Proceedings of ASEE 2006 Conference and Exposition,* Chicago, IL, June18-21, 2006, CD-Rom Session 2006-958

[5] http://www.ncsu.edu/felder-public

[6] http://www.succeed.ufl.edu/innovators/innovator_2/innovator002.html

[7] Terpenny, J.P., Sullivan, W.G., Singh, H., and Sward, K., "Utilizing the Internet to Improve Student Learning in a First Course in Engineering Economy with Real-World Unsolved Problems in Collaboration with Industry", *Proceedings ASEE 2002 Conference and Exposition*, Montréal, Quebec, Canada, June 16-19, 2002, CD-Rom Session 2139, 1-17. (Winner of best paper award in Engineering Economy Division, first runner up in Professional Interest Council III.)

[8] Sward, K., Terpenny, J., and Sullivan, W.G., "Design, Layout, and Tools for Effective Web-based Instruction," *2002 Frontiers in Education Conference*, Boston, Massachusetts, November 6-9, 2002, Session S1E: Web Applications V - Online Learning, 1-6.

[9] Paterson, K.G., "Student Perception of Internet-Based Learning Tools in Environmental Engineering Education" *Journal of Engineering Education*, pp 295-304, 1999.

[10] Gralinski, T. and Terpenny, J.P. "K-12 and University Collaboration: A Vehicle to Improve Curriculum and Female Enrollment in Engineering and Technology," *2003 ASEE Annual Conference*, Nashville, Tennessee, June 22-25, 2003, CD-Rom Session 2692, 1-9.

[11] Terpenny, J., Gao, R., Ritter, J., Fisher, D., Krishnamurty, S., "Senior Design Projects to Aid the Disabled," *Proceedings ASEE 2001 Conference and Exposition*, Albuquerque, New Mexico, June 24-27, 2001, CD-Rom Session 2325, 1-11.

[12] Terpenny, J.P., Goff, R.M., Vernon, M.R., Green, W.R., "Utilizing Assistive Technology Design Projects and Interdisciplinary Teams to Foster Inquiry and Learning in Engineering Design," Special Issue on Learning and Engineering Design, *International Journal of Engineering Education*, vol. 22, no. 3, 2006 (invited).

[13] Welty, Kenneth and Puck, Brenda, "Modeling Athena: Preparing Young Women for Citizenship and Work in a Technological Society", University of Wisconsin-Stout 2001

[14] Power Point Presentation Regarding: Recruiting and Retaining Young Women in Technology Education, http://www.dpi.state.wi.us/dpi/dlsis/cte/tbaddres.html (Wisconsin Dept. of Public Instruction)

[15] Thom, Mary, *BALANCING THE EQUATION:* Where Are Women & Girls in Science, Engineering & Technology?, National Council for Research on Women, 2001, http://www.ncrw.org/research/scifacts.htm

[16] Schwartz, Wendy and Hanson, Katherine, *Equal Mathematics Education for Female Students*, Number 78, 1992, Eric Clearinghouse of Urban Education

[17] Mary R. Anderson-Rowland, Why Aren't There More Women in Engineering: Can We Really Do Anything? *ASEE SW Regional Conference 2002*

[18] Blaisdell, Stephanie, "Factors in the Under Representation of Women in Science and Engineering: A Review of the Literature", *Women in Engineering Program Advocates Network*, Working Paper 95-1, December 1995

[19] Goff, R.M., Terpenny, J.P., Vernon, M.R., Green, W.R., "Evolution of Student Perception in a Human Centered Interdisciplinary Design Project," *Frontiers in Education Conference*, October 28-31, 2006, San Diego.