

# **An Overview of Teaching and Learning Research with Classroom Communication Systems (CCSs) \*\***

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## **Abstract**

Over two thousand years ago, Socrates realized that people understand more by answering a question, than by being told an answer. Now, science has helped to explain reasons behind this counter-intuitive idea, and shown why it works so well. But, there is a problem with Socratic teaching: it works well only in small classes. The CCS is an invention which ameliorates this problem and makes (forms of) Socratic teaching effective in classes of any size. This paper briefly summarizes five years of CCS research with pedagogical techniques in a range of disciplines, educational levels, and institutional settings.

## **Background - Knowledge, Learning, & Teaching**

In 1979 David Hestenes asked a far-reaching question in a paper entitled, "Wherefore a Science of Teaching?"<sup>1</sup> Nineteen years later the question has lost its shock value. Our understanding of knowledge, learning, & even teaching is deeper and more satisfying. We are beginning to answer Hestenes' question!

A three-page paper is not the place to give an overview of "constructivism"<sup>2,3</sup>, or comparisons between the knowledge structures of experts & novices<sup>4</sup> (tells a lot about how we "know" and "understand"), or "active learning"<sup>5,6</sup>, or how algebraic and geometrical representations together, deepen students' understanding of mathematics<sup>7</sup>. Similarly for "Rule-of-Three" and the "Way-of-Archimedes"<sup>8</sup>, but all these are important steps in beginning to shed light into our very own source of light - the human mind.

## **Brief Description of a CCS**

A CCS is more than a networked classroom but this is a good place to start. A computer network links a teacher's computer to student units - which may be as humble as graphing calculators. Special software controls the system and allows it to function as an integrated tool. In one CCS (Classtalk) the teacher's computer runs two monitors, one with private information, the other with public information for display to the whole class. There are five question types (multiple choice, numeric, short & long text, & algebraic expressions). Student answers are sorted into "bins" in the teacher's computer. For example, in multiple choice there is one bin for each choice. The purpose of binning is to provide a quick way for a teacher to assimilate positions that students in the class have taken. Seat icons mapped on the screen as in the physical classroom contain individual data (name, responses, records, photo, etc.) about students seated there. Bins are color-coded and seats change color to show into which bin a student's answer fell.

Binning can also be more complex. In the case of algebraic expressions, these are parsed, variables identified, random number sets plugged into each variable, and the expressions evaluated. Expressions that evaluate to the same set are assumed to be the same. A sub-binning may look at functional form. Bins may be predefined by the teacher or created on-the-fly from student responses. Histograms show aggregate class response, and teachers typically show these to the class to stimulate discussion. Three different small group collaborative environments exist: individual, consensus, & consensus with dissent (which is modeled after the US Supreme Court). The teacher's computer software operates in three domains, future (curriculum preparation), present (active class), and past (class records). Curriculum may include questions (including binning info., individual student feedback, scoring), quizzes, presentation material, notes, etc..

Future systems are likely to include many more features which promote thinking, active learning,

collaboration, and motivation in classrooms.

## **Stories from some CCS Classrooms**

### **Harvard Introductory Physics**

Eric Mazur is Gordon McKay Professor of Applied Physics and Professor of Physics at Harvard University. He has taught introductory physics at Harvard since 1984 usually in classes of about 250 students. In 1991 Mazur developed Peer Instruction<sup>9</sup>, the basic goals of which are to exploit student interaction during lectures and focus students' attention on underlying concepts. Instead of presenting all material at the same level of detail as covered in textbook or lecture notes, lectures consist of a number of short presentations on key points each followed by a "ConcepTest" - short conceptual questions on the subject being discussed. The students are first given time to formulate answers (and enter them via a CCS) and then asked to discuss their answers with each other. This process (a) forces the students to think through the arguments being developed, and (b) provides them (as well as the teacher) with a way to assess their understanding of the concept.

In this lecturing format Mazur uses about one third of each lecture period for ConcepTests. He does not reduce the amount of material covered in the course, but instead requires students to read the textbook & lecture notes ahead outside lectures. At the beginning of each class students receive a brief quiz (via the CCS) on the reading assignment. Mazur can see before he begins the class how well the assignment has been done.

The advantages of Peer Instruction are numerous. Students report that they understand the subject better, enjoy classes more, do more thinking in classes, come to class better prepared, and feel that the professor is more in touch with their difficulties in the course. In addition gains in conceptual understanding are double those when he taught the course conventionally<sup>10</sup>.

### **Univ. of Massachusetts Physics & Harvard Business School Managerial Economics**

Prof. Elon Kohlberg at the Harvard Business School uses techniques similar to those pioneered by the team at UMass led by Profs. Bill Gerace & Jose Mestre. Both address key issues by presenting relatively difficult conceptual questions likely to cause splits in class position and stimulate discussion in their 100-person classes. In the following example from one of Kohlberg's classes, the first histogram was split more-or-less evenly three ways. Kohlberg said, "I see that there are some differences of opinion on this topic. Would someone whose answer fell into the green bin like to explain your reasoning?" ... then he continued in a similar way for the other bins .... "Now would anyone like to change their answers?" ...the new histogram was split two ways ... "This is interesting, I see we are still in disagreement, ..."

At this point a good-looking young man in the front row - his face flushed red - said, "You can see we don't know where you're going with this. Why don't you just tell us what you want?"

Elon replied, "Suppose you were in a town & wanted to find a bar. If I told you where it was, you might learn less about the town than if you had to find it for yourself, - you also may have less fun doing it."

The young man hesitated, pulled out a scratch pad and began writing. A few minutes later he presented an argument that produced unanimity in the class.

**Tabb Middle School, Tabb Virginia, 8th Grade - Math**

Jan Andrews is an 8th grade math teacher. Students push to get into her class to enter their homework on a networked calculator. Jan uses a free-form five-question skeleton set for collecting homework. Every day she identifies five of the previous night's homework problems on the board. She uses a free text binning because of its simplicity and manually checks exceptions as they come in. Five minutes after the start of class she knows who did their homework, who had problems, & what these are. She will deal with them before moving onto new material.

### **Sandhills Community College, Pinehurst, North Carolina - Physics**

Profs. Rick Swanson & Chris Roddy run a class/lab of 20 students. They intersperse lecture with questions, measurements, & discussion that can go in different directions depending on students' understanding. Students have TI-92s which they use to take data or plug into the CCS network. Swanson & Roddy cite a noticeably more positive classroom environment and students like knowing how they're doing compared to others, in a non-threatening environment. Test scores have gone up 10-15%.

### **University of Texas at El Paso, Political Science**

Prof. Bob Webking teaches a 550 student class in Political Science in the poorest congressional district in the USA. As he pauses to ask a question one can hear a pin drop in the lecture hall. He uses a CCS to have students express their initial "common-sense" opinions. Then, through continued questioning he leads them to see pitfalls that can result from naïve points of view, points of view to which the students are already aware that they are subject.

### **McIntosh Elementary School, Newport News, Virginia, 5th Grade Reading Comprehension**

Carol Wiatt is a 5th grade reading teacher at a school attended by children from economically disadvantaged families. She uses a CCS to have students input their interpretations of a reading exercise. She shows them the histogram on a TV screen and holds a class discussion about the different answers. On other days they answer puzzles. Students get so involved they barely realize that they're reading the puzzles. At the beginning of the 96-97 school year only 56% of children from her three 5th grade classes were expected to pass the state-mandated reading comprehension test. At the end of the year 89% passed with over 30% of the students growing 5 years (2nd to 7th grade level) in reading comprehension.

## **Conclusions**

There appear to be three clear lessons from this work:

1. Good questions asked in the right context have a remarkable property to transform a classroom. The environment becomes more lively and active. The atmosphere changes and becomes more "happy"! Students report that they understand the subject better which is confirmed by quantitative studies. They work harder in class, but enjoy it more. There is also evidence that they do more work out of class. Teachers become more aware of student problems with the subject matter.
2. The benefits of a classroom communication system (CCS) extend over a remarkable range

of disciplines, educational levels, and institutions. From 5th grade reading in an inner-city to Harvard Business School, is quite a range. Currently (to our knowledge) the disciplines included are physics, chemistry, math, biology, sociology, economics, political science, & reading comprehension.

3. From a mathematics perspective, the pedagogy dovetails remarkably well with the discovery-based learning & exploration techniques pioneered with computer & calculator graphing and computer symbolic manipulation. These techniques are often associated with questions that encourage divergent thinking. In the math classroom, a CCS gives the added power to encourage convergent thinking by all students.

But the work is only in its infancy, there is much to do!

## References

1. Hestenes, David O., "Wherefore a Science of Teaching?", *The Physics Teacher*, 17, 235-242, 1979.
2. Jaworski, Barbara., "Constructivism and Teaching — The Socio-Cultural Context", Oxford University, Dept. of Educ. Studies, Seminar given to the Mathematics Teaching and Learning Enquiry Group, Manchester, U.K. January, 1993.
3. von Glasersfeld E. "Learning as a Constructive Activity". In C. Janvier (Ed) *Problems of representation in the teaching and learning of mathematics*. Lawrence Erlbaum, Hillsdale, NJ., 1987.
4. Larkin, J.H., McDermott, J., Simon, D.P., & Simon, H.A., "Expert and Novice Performance in Solving Physics Problems," *Science* 208, 1335-1342, 1980.
5. Bonwell, Charles C., & Eison, James A., "Creating Excitement in the Classroom", ASHE-ERIC Higher Education Report No.1, Washington, D.C., The George Washington Univ. School of Educ. & Human Development, 1991.
6. Hake, R.R., "Interactive-engagement vs Traditional Methods: A Six-Thousand Student Survey of Mechanics Test Data for Introductory Physics Courses", *American Journal of Physics*, 1996.
7. Waits, Bert K., & Demanna, Franklin, in "Teaching & Learning Mathematics in the 1990s, NCTM Yearbook - 1990.
8. Hughes-Hallett, Deborah et al, in "Calculus", textbook produced by the Consortium based at Harvard, pub. John Wiley & Sons. - 1996
9. Mazur, Eric, "Peer Instruction - A User's Manual", book published by Prentice Hall, 1997.
10. Dufresne, R.J., Gerace, W.J., Leonard, W.J., Mestre, J.P., and Wenk, L., "Classtalk: A Classroom Communication System for Active Learning, *Journal of Computing in Higher Education*, 7, 3-47, 1996.