2013 Hawaii University International Conferences
Education & Technology
Math & Engineering Technology
June 10th to June 12th
Ala Moana Hotel, Honolulu, Hawaii

Oral Reviews: Retaining STEM Majors

Dr. Mary Nelson

George Mason University

Oral Reviews: Retaining STEM Majors

According to Organization for Economic Cooperation and Development, in 2009 the United States ranked 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering. (OECD, 2009). In 2006 in South Korea, 38% of all undergraduates received their degrees in natural sciences or engineering. In France, the percent was 47%, in China, 50%, and in Singapore, 67%. In the United States, the corresponding figure was 15%. (AAU, 2006) A general theme of these reports and of Rising above the Gathering Storm (2008,2010) is that the United States urgently needs to increase the number of American students that graduate with degrees in STEM majors if the U.S. is to remain competitive in the world economy.

"Students who fail or are denied entry to calculus face difficult choices, including delays in academic progress, extra costs, and even revision of career choices" [8, p.1]. Seymour [23] reports that about 63% of the students who initially declare majors in mathematics switch to non-science majors. Losses are disproportionately higher among women and students of color in spite of national efforts to both recruit and retain these groups [1, 22, 25]. Since calculus is often the gatekeeper to high status, high paying jobs in science, engineering and technology, American students' futures are limited until we can open these gates.

Introduction of Oral Reviews (Orals)

The Applied Mathematics Department of the University of Colorado at Boulder (CU) has introduced oral reviews to help students open the gates, increasing their understanding, pass rates and retention in calculus. The study of oral reviews that is described here has been on-going at the CU for ten years. Initially, the intent was to strengthen the mathematics understanding of potential engineering students who entered the university under-prepared in mathematics.

The Applied Mathematics department has designed a placement test for all entering students that predicts over 50% of the variance in students' Calculus I course grades. Students scoring less than 18 out of 30 on this test fail the course at over a 90% rate. Many of the department's calculus students are engineering majors who have taken advanced mathematics courses in high school. Unfortunately, students from some urban and rural schools may not have had the same opportunities and are therefore less prepared for a rigorous engineering calculus course. We addressed this problem by providing a two-semester calculus course that focuses on pre-calculus topics as they arise in the calculus course. For example, when trying to determine max/mins, students review factoring methods. We have found that this just-in-time teaching motivates students to learn such pre-calculus skills because they can see the immediate application.

Initial offerings of the two-semester course showed some improvement in pass rates for these under-prepared students. In 2003 we added oral reviews and the results were striking. Oral reviews are voluntary, ungraded one hour sessions with groups of about six students with one facilitator. They take place before each written exam. Students gather outside of class time in a room with ample board space, and are asked conceptual questions about the underlying concepts which will be tested on an upcoming written test. Questions are centered on why certain procedures are used, how the procedures are related to their graphical representations, what constraints are inherent in the procedures and how those constraints are related to the graphs.

Students are sometimes asked to carry out a procedure, but then they are asked to explain why the procedure works. Typically, students would not be asked to find derivatives, but rather to explain "If the derivative of a function is -6 at x = 4, what does that tell you about the function at x = 4?" The emphasis is on understanding big ideas.

Conceptual Framework

Orals are formative assessment grounded in constructivism, where "… students actively construct their own knowledge and understandings. They do this by making connections, building mental schemata, and developing new concepts from previous understandings" [20]. Orals steer students away from memorizing facts and rules while helping them develop flexible understanding of important mathematical concepts through discourse[4, 20]. Students take an active role in their learning.

This approach relies heavily on the importance of discourse in deepening understanding and confronting misconceptions. Our research has shown that when students are able to put their understanding and conjectures into their own words, they gain confidence, learn to defend their reasoning and are better able to apply what they know to novel situations [2, 3, 6, 10, 11, 12]. In orals students negotiate fragile understanding of concepts with their peers and with the facilitator, and they strive to make important connections (Lampert, 5). This in turn results in strong retention of the ideas.

An unexpected finding of the research was discovering the importance of teacher caring. Seymour asserts that the unsupportive culture of the sciences is a significant factor in the loss of able students. Students are often fragile and the indifferent attitude of instructors can add to their frustration and discouragement [22]. An unintended, but positive result, of oral reviews is that many students come to believe that their instructors, teaching assistants and learning assistants care about their success. Study data demonstrate that students attend class more and report working harder if they perceive that their instructor is invested in their success.

Though some students are initially apprehensive about orals, after one session they normally get over any misgivings. Oral reviews offer a safe context for students to share emergent knowledge and partial understandings. The voluntary nature of orals generally leads to students attending only if they want to improve their understanding. There is no extra credit or other reward. Students readily help one another. They are clearly excited when together they make sense of a concept and are then able to explain it to their peers. Orals provide the basis for a safe, accepting community for students [18].

Study Results

The treatment class for the original study had 36 students, primarily students identified at-risk of failing calculus because their placement scores were less than 18/30. In contrast, the control group consisted of all students in regular one-semester lecture classes in Fall 2003. Those classes ranged from 96-140 students where only 16% were "at-risk." Analyses showed that there was one standard deviation difference in the mean placement scores of the two groups, Table 1.

Comparison groups	Mean Place Score	Standard deviation	Mean difference
Treatment	16.58	3.977	4.61
Control	21.19	4.546	

Table 1: Significant difference in the placement scores of groups

The study sought to answer several research questions. First, did orals participation improve grades? Initial data compared orals participants in the class to non-participants. Participants' grades were statistically higher on every test. These results were reported to the students after each exam and though less than 50% of the students attended the first orals, by the last test over 90% were attending and over 90% of the students passed Calculus I.

The second question became "How did students in the treatment group do compared to those in regular classes? Since the course grades of the two groups could be attributable to a plethora of confounding factors, a common final was given to establish a less subjective measure, and all exams were graded by the same graders with the same rubrics. On the common final, the treatment students performed significantly better on three separate measures: the overall exam score, the score on procedural questions, and the score on conceptual questions.

The third research question was how did the at-risk students in the treatment class do compared to the at-risk students who remained in the regular classes? A very practical issue was to find how the performance of these groups compared in Calculus II. The study followed students for two years. Treatment at-risk students went on to Calculus II at strikingly higher rates than their counterparts. This dramatic difference demonstrated that at-risk students can succeed in STEM majors (Science, Technology, Engineering and Mathematics). The mean Calculus I course grade (on a 4 point scale) of regular at-risk students was 0.79 (D-), while the treatment at-risk had a mean score of 2.34 (C+). Students must earn a C- in Calculus I in order to enroll in Calculus II. The necessity to retake Calculus I appears to have discouraged the majority of at-risk control students from taking Calculus I a second time. Even those control students who did retake Calculus I frequently failed. Table 2 shows that the percentage of treatment at-risk that passed Calculus II was more than three times that of the at-risk control students after four semesters.

GROUP	Number of at-risk taking the common final	Mean course grade	Standard deviation	% at-risk who took Calculus II (excluding dropped students)	% at-risk passed Calculus II (excluding dropped students)
Treatment at-risk	16	2.34 (C+)	1.30	56%	50%
Control at-risk	61	0.79 (D-)	1.06	20%	16%

Table 2: Comparison of control and treatment students' grades in Calculus I/ success in Calculus II

After two years, retention at the university was compared for the two at-risk groups in the study.

GROUP	At –risk Students	Percent of at-risk **no longer enrolled** at the University
Treatment N=34	N = 21	30%
Regular N=615	N = 98	45%

Table 3: Retention (percent of students leaving University in the first four semesters)

Expansion of Study: CU large classes and beyond

Following evaluation of the data from the initial study, the department opted to offer oral reviews to all fall Calculus I and spring Calculus II students. These classes vary from 96-170 students. Each semester orals are given three times prior to each written unit exam. Over the year, orals participants scored statistically better on at least five of the six exams. (Often there is no statistical difference on the exam based on differentiation techniques.)

Compare Exam Scores	N	Average	St. Dev
No Orals Exam 1	333	75.1	15.0
Orals Exam 1	134	81.6	10.4
No Orals Exam 2	298	74.5	15.4
Orals Exam 2	162	79.8	12.6
No Orals Exam 3	318	64.4	19.1
Orals Exam 3	138	73.9	15.7

Table 4: Differences in grade averages of orals participants and non-participants Fall Calculus I

Similar results are seen every semester. In addition, overall course grades of orals participants average 0.6 to 1 letter grade higher than non-participants.

# of orals	# of students	Mean	Standard Dev
0	243	1.935	1.33
1	63	2.089	1.15
2	81	2.542	1.03
3	69	2.841	0.85

Table 5: The course grade of students participating in three orals is 9/10 of a letter grade higher than those who participated in no orals.

Additionally, the gains are across all ability groups. Figure 1 shows significant improvement in the course grades of students grouped by their placement scores. For example, students with scores below 19 on the placement test generally fail at an extremely high rate. Those who did not participate in orals averaged 0.5 (a low D). Those who participated in 3 orals averaged 1.7 which is a C- and a grade sufficient for most majors to go on to Calculus II.

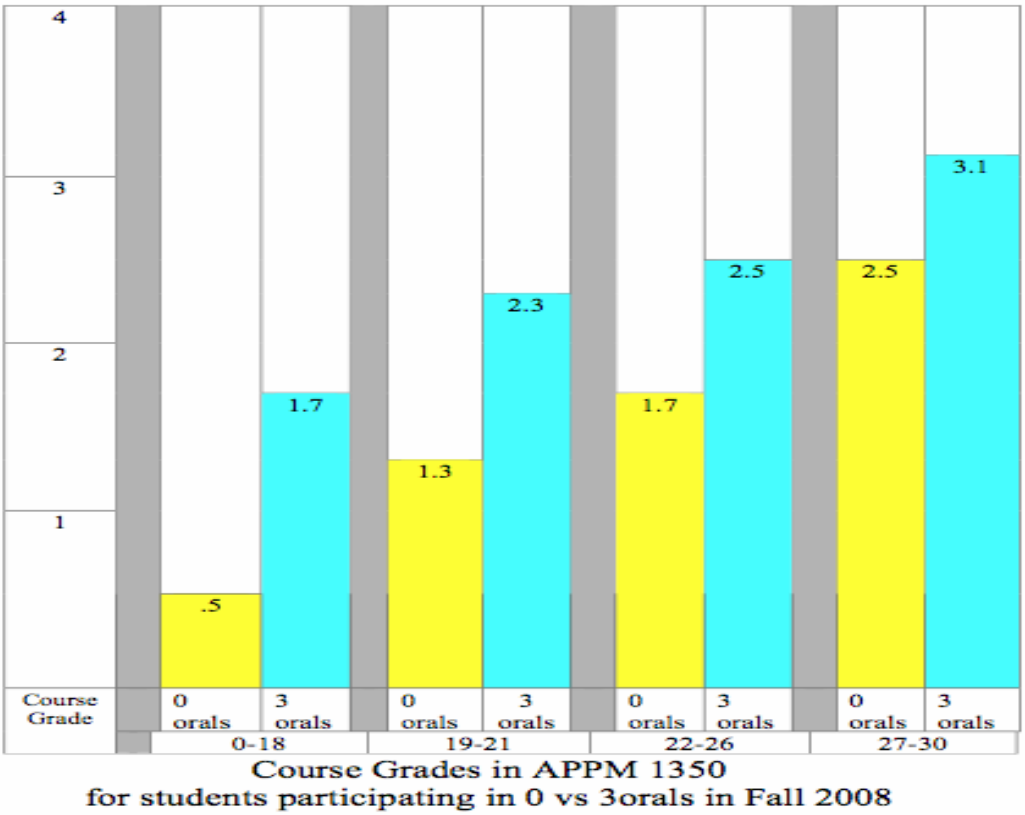
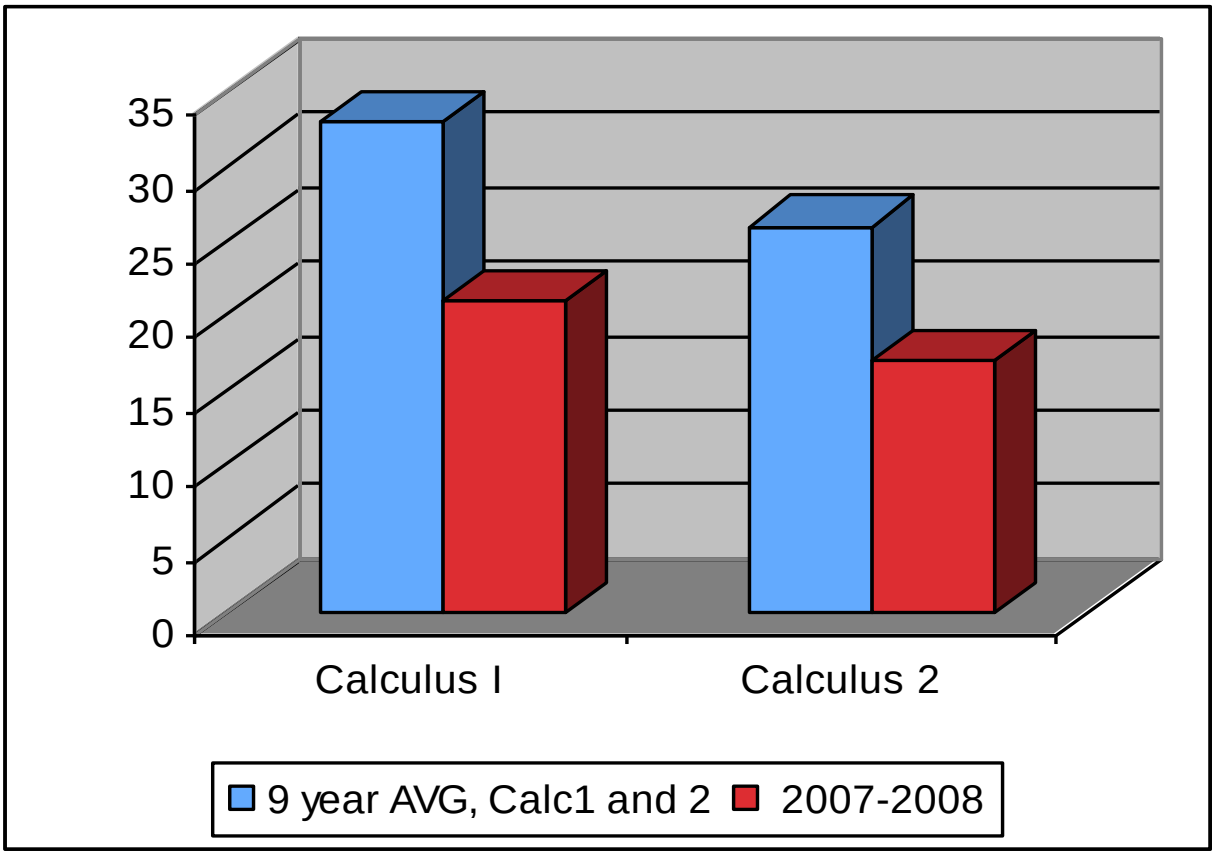


Figure 1: Grades by placement score and number of orals

Ultimately, orals are correlated with lower failure rates, which can lead to greater retention in STEM majors. Though the Applied Mathematics Calculus I failure rate was about 30% for a decade, the failure rate for the past ten years since adding orals has been closer to 22%; and using orals, the Spring Calculus II classes dropped from a ten year average of 26% to only an average 17% failure rate (Figure 2)



Using funding from a TUES II grant, we have been able to begin orals programs in five other universities. As we analyze data from the other locations, we are finding similar results. Table 7 shows results from the first year at George Mason University (GMU). Three sections of Calculus 1 participated in orals with the results below.

Table 7: Comparison of Calculus 1 grades of orals participants vs. non-participants at GMU for three instructors

TEST 1	Instructor 1		Instructor 2		Instructor 3	
	Average	Median	Average	Median	Average	Median
No orals	79	81	73	80	74	80
orals	83	86	82	86	87	90

Oral reviews promise to be useful in other disciplines as well. They are also being used successfully in Mechanical Engineering courses at CU and in Biology courses at GMU, and showed very promising results at a Colorado high school. Our future plans include looking more closely at long term effects of oral assessments as students are followed longitudinally.

The data suggests that encouraging students to articulate their thinking in a safe environment leads to deeper conceptual understanding and this is particularly important for at-risk students. Students who explain their thinking and negotiate meaning with their peers and their instructors are able to apply what they learn more flexibly. The mathematical discourse fostered in orals is also beneficial to the instructor who can use this mathematical talk to determine what students know. In turn, the instructor is better able to scaffold learning individually and for the entire group.

This research has been possible in great part because of the support of the NSF TUES 2 grant, Colorado Momentum.

References

1. Association of American Universities. (2006). *National Defense Education and Innovation Initiative.* Based on data from National Science Board. Science and Engineering Indicators 2004. NSB 04-01. Arlington, VA: National Science Foundation, 2004. Appendix Table 2-33.
2. Goodlier, Edgar. (2002). *Public school math in Atlantic Canada: Preparing the scientists, professionals and engineers of tomorrow*. A letter to the editors of Atlantic Canada Newspapers, October 2002.
3. Dougherty, A. and Cooley, D. (2003). *Prediction of student performance in freshman Calculus.* Department of Applied Mathematics, University of Colorado, Boulder.
4. Bruner, J. (1966). *Toward a theory of instruction.* Cambridge, MA: Harvard University Press.
5. Nelson, M.(2005). *A reform approach to calculus instruction: Effects on retention, grades and understanding*. Dissertation, University of Colorado, Boulder, CO.
6. Nelson, M (2010). *Oral Assessments: Improving Retention, Grades and Understanding.* PRIMUS.
7. Organization for Economic Cooperation and Development,(2009). *Education at a Glance 2009: OECD Indicators*, Table A-3-5.
8. Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, (2008) from the Committee on Science, Engineering and Public Policy, 592 pp., National Academy Press, Washington, D.C., 2007; revisions.
9. Rising above the Gathering Storm, Revisited, (2010). by members of the 2005 "Rising above the Gathering Storm" Committee, 86 pp., National Academy Press, Washington, D.C.
10. Roehler, L. and Cantlon, D. (1997). Scaffolding: A powerful tool in social constructivist Classrooms. In K. Hogan and M. Pressley (Eds.), *Scaffolding student learning: Instructional approaches and issues.* (pp. 6-42). Cambridge, MA: Brookline Books.
11. Seymour, E. (1995). Guest Comment: Why undergraduates leave the sciences, *American Journal of Physics*. 63(3), 199-202.
12. Seymour, E. and Hewitt, N.M. (1997). *Talking about leaving: Why undergraduates*

Leave the sciences. Boulder, Colorado: Westview Press.
13. Treisman, U. (1992). Studying students studying calculus: A look at the lives of minority mathematics students in college. *College Mathematics Journal*, 23(5), 362-72.