

The Keystone Approach: Integration of Methodology and Technology

**M. Vali Siadat, Eugenia Peterson, Cyrill Oseledets,
Ming-Jer Wang, and Guo Quan “Jack” Zhang**
Richard J. Daley College

Introduction

This article is the result of a comprehensive research study investigating the impact of computer-learning technology as well as the impact of a synergistic teaching approach (Keystone Method) on developmental mathematics classes at the college level.

The study focused on mathematics skills of elementary and intermediate algebra students and measured their performance on departmentally designed common midterm and final exams as well as on a national standardized test (COMPASS). An analysis of the data for the period of study shows that students in experimental classes employing the synergistic approach attained higher performance outcomes compared with students taught under traditional methods with the use of technology. The higher outcomes in the experimental classes were not achieved with the attrition of weaker students. Moreover, investigating the impact of technology on traditional teaching in elementary algebra classes, the study found no significant gains in student learning outcomes in classes incorporating technology compared to those that did not use technology.

In recent years, there has been a vast and growing demand for remedial mathematics education among arriving students in colleges and universities across the nation (U.S. Department of Education, 2008). As such, successful mathematics remediation of students has become an important and challenging task for a large number of colleges and universities in the country. A newly published report confirms the alarming statistics that students who enroll in remedial classes at the college are far more likely to drop out than those who do not (Strong American Schools, 2008). Tracking first-time college students from a national survey's 2002 cohort in colleges with disproportionately high enrollments of low-income and minority students, researchers found that upon entry, 72% of students needed at least one remedial math course. And after three years, only 23% of those students had successfully completed the remedial math sequence (McClenney, 2009). These facts pose serious questions about the effectiveness of traditional methods of

remediation of students in developmental math courses at the college.

In the last 15 years, the question of mathematics remediation was extensively studied at the Richard J. Daley College and the result of this research was the development of a new teaching methodology, the Keystone method.

The Keystone method was initially pilot-tested at Richard J. Daley College during 1993–1995 academic years (Sagher & Siadat, 1997; Sagher, Siadat, & Hagedorn, 2000, 2001). The ensuing project was further expanded in 1998 and 1999, funded through a grant from Gabriella and Paul Rosenbaum Foundation (Siadat, Musial, & Sagher, 2000, 2001). The Keystone method has been extensively researched and has won numerous state and national awards (NCIA, 1999; ICCB, 2001).

In the 1998–2000, 2001–2003, and also 2004–2006 studies, the results of the experimental and control groups were compared at the common final exams and clearly showed that the Keystone method of instruction produced superior outcomes in mathematics without sacrificing the classroom retention rates (Siadat, Musial, & Sagher, 2008; Peterson & Siadat, 2009). An interesting and important concomitant of the results was that students in experimental classes improved in their reading comprehension scores compared to those in the control groups. The latter effect is attributed to the students' improved concentration skills.

The present study investigates the impact of computer-learning technology on traditional instructional milieu as well as the integration of technology with an innovative method (Keystone) on student learning in elementary and intermediate algebra classes at the college. The study shows that use of technology alone has insignificant effect on learning, whereas incorporating modern technology into a dynamic teaching methodology can produce significant positive impact on student learning.

Research Background

The Keystone method was developed by Sagher and Siadat (1997) in an attempt to address difficulties in teaching and learning of developmental mathematics in colleges and universities. The Keystone method and its constituent elements are grounded on research in the efficacy of different educational models, cognitive science of learning, and educational psychology. The frequent testing and the insistence on the fast performance and fluency are important ingredients in precision teaching, a method of working with exceptional children. The insistence on satisfactory performance on each unit is connected with mastery learning, and the group work is related to cooperative learning. In the Keystone methodology, all tests and quizzes are frequent, time-restricted, cumulative, and based on homework.

Frequent testing of the subject is an important assessment tool that provides valuable information to the teacher and the student about the learning process. It also effects other educational benefits such as long-term retention and consolidation of knowledge and improvement of memory (Karpicke, Butler, & Roediger III, 2009; Nungester & Duchastel, 1982; Pyc & Rawson, 2010; Roediger III & Karpicke, 2006; Spitzer, 1939). Timed tests teach students to work with full concentration, leading to an improvement of their attention span. Timed tests also train students to improve on their automaticity of basic skills as well as factual and procedural knowledge. Automaticity in these skills frees up space in working (short-term) memory, facilitating the attainment of problem-solving skills (Willingham, 2009). Timed tests are not mere assessment tools; the period of work in high arousal state such as in a timed test, affects long-term memory (Kleinsmith & Kaplan, 1963, 1964). Following the seminal work of Kleinsmith and Kaplan, researchers have found a biological mechanism for improved long-term memory associated with emotional arousal (Cahill, Prins, Weber, & McGaugh, 1994; Cahill, Babinski, Markowitsch, & McGaugh, 1995). Recently, cognitive scientists have also determined that stress within the context of a learning experience, as in timed tests, induces focused attention and improves memory of relevant information (Joëls, Pu, Wiegert, Oitzl, & Krugers, 2006).

Cumulative testing motivates students to review and practice the older topics at all times and deepens their knowledge of the subject matter, which results in higher levels of learning (Dempster, 1992) and attainment of the mastery of the subject. Moreover, cumulative practice of basic skills contributes to an improvement of students' problem-solving skills (Mayfield & Chase, 2002). The fact that all quizzes and tests are homework-based motivates students to do their homework, which reinforces learning. Homework contributes to mathematics achievement of students and is essential for their success (Foyle & Lyman, 1989; Sasser, 1981).

Finally, research has shown that cooperative group work promotes development of cognitive and interpersonal skills (Felder & Brent, 2007), which contribute to improved learning. Group work also enhances social and academic interaction among students (Slavin, 1995) and fosters student engagement in classroom.

Keystone Method in Practice

The Keystone method is based on well-researched educational practices. It incorporates proven teaching techniques such as short lecture, classroom discussion, cooperative learning, and peer tutoring, along with frequent quizzes with immediate feedback. The most essential and innovative feature of the method is that all these good practices are organized in a learning-effective instructional cycle. The Keystone instructional cycle (Fig. 1) shows the interactive sequence of these components. All the components are carefully planned and designed in order to optimize student learning. The most salient components of this cycle are the frequent quizzes and cooperative learning. All quizzes are timed-restricted, cumulative, and based on homework. The iteration among practice quiz, study plan, and in-class quiz forms the central part of the frequent quizzing component and helps students to focus on solving problems and to apply common procedures and concepts to specific questions.

When there is a significant divergence in student performance, as evidenced by high standard deviation on the tests, the instructor moves from the lecture mode to cooperative learning and peer tutoring. For our present study in beginning and intermediate algebra classes, the typical standard deviation of a test is at the level of 20 on the scale of 100, which shows significant divergence in performance. In this setting, groups of four students from each quartile of the class standings assemble to discuss mathematics, solve problems, and learn from each other. Our model of cooperative group work incorporates individual accountability where each group member is accountable for the entire work assigned to the group. Only upon satisfactory performance of each member, the entire group can earn points. If one of the group members has not done sufficient preparation, he or she will be helped by other group members since there is an incentive for all to succeed as a group. The role of the instructor is not to punish a group for insufficient explanations of one of its members, but to help elucidate and articulate the concepts in order for the group to achieve common understanding of the problem.

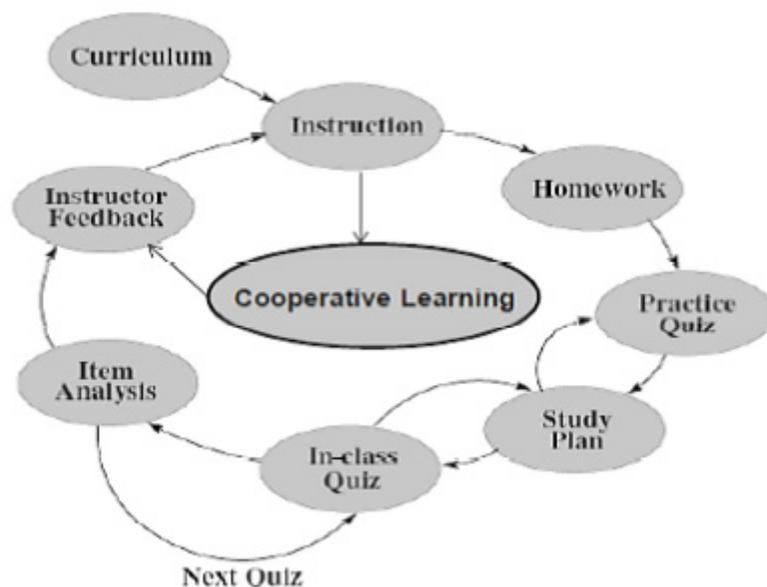


Figure 1. Keystone Instructional Cycle

In the Keystone approach troublesome questions on tests and quizzes are repeated until mastery of the topics is attained. Attainment of mastery aside from improvement of knowledge of students has a motivating by-product. It encourages students to work hard in order to achieve even higher gains. Evidence of recurring achievements improves students' self-confidence in doing mathematics and also enhances their self-esteem.

Finally, in the Keystone assessment system, grading of all tests and quizzes is determined on an absolute scale, rather than on a curve, requiring all students to acquire a certain level of proficiency to earn their grades, irrespective of other students' standings in the class. The fact that a student's own performance determines his/her own measure of success, and not its relation to other students' performance, mitigates classroom anxiety and produces bonding and camaraderie among students. Thus, cooperation and striving for excellence are promoted among all students without anyone's fear of being evaluated at the detriment of others. Moreover, the sense of being a member of a learning community, rather than being adversaries, promotes collegiality and social interaction and improves class participation and attendance.

In short, the Keystone method not only aims to improve student performance towards excellence in mathematics but also trains students to improve their universal skills such as concentration. Improvement of universal skills in students inculcates better work and study habits, which can transfer to other disciplines.

The Role of Computer-Learning Technology

Research literature shows that technology alone cannot educate and "the mere presence of technology in a classroom is no guarantee that students will learn more" (Willingham, 2010). As Albano and Ferrari (2008) rightly observe, "Research in mathematics education has widely shown the complexity of teaching and learning processes, and thus the inadequacy of one-dimensional models, including the belief that simple addition of some technology to standard teaching practices could provide considerable improvements of the outcomes." One large study on the use of technology conducted on first-year general calculus students at a major research university showed that for students who do homework on a computer software program, WeBWork, there was a slight, but nonsignificant improvement, in final exam scores compared to the control group (Hirsch & Weibel, 2003; Lewis & Tucker, 2009; Weibel & Hirsch 2002). In developmental courses, particularly in developmental mathematics classes, technology must be used very judiciously and only as a supplement to the classroom instruction. An interesting research study from the National Study of Developmental Education (Boylan, Bonham, Claxton, & Bliss, 1992) actually identified an inverse relationship between the amount of technology used and pass rates in developmental classes in both colleges and universities. "In essence, where computer technology was used as the only means of instruction, developmental students performed poorly." (Boylan, 2002).

Our experience shows that only through incorporating technology into a dynamic teaching model, we can improve the learning process for all students. Our current study will confirm that Keystone methodology is well suited for integration with computer-learning technology and their combination bears a synergistic effect.

In fall 2006, a computer program, MyMathLab, was used for the first time at Daley College to simplify quiz preparation, administration, and automatic item analysis. This computerization made it possible to provide an immediate feedback of the results of the quizzes to the students and to the instructor and opened a possibility for interactive teaching, where teaching techniques are adjusted according to the assessment results. This interactive design fit perfectly with the Keystone philosophy. It also allowed for effective coordination of multiple-session classes by one Keystone-trained instructor. In particular, the coordinator was able to prepare Keystone quizzes in the coordinator's class, which are automatically distributed to all other classes. This technique significantly simplified implementation of Keystone quiz methodology in multiple-session settings and made the method more practical. Computer technology also allowed for students to do a large number of algorithmically generated homework problems with an online assistance option that acted as an electronic tutor. At all times, grading and item analysis were provided automatically by computer software, freeing the instructor to work on more creative aspects of teaching and learning. Moreover, the instructor was able to not only monitor students' progress on homework and tests at all times, but to also monitor the amount of actual time students spend on different assignments. This aspect of time management served as an important diagnostic tool and helped the instructor to better assess the nature of students' difficulties on quizzes, tests, and homework.

Research Method

In order to investigate the effect of the integration of Keystone methodology and computer learning technology on student learning, we performed an experimental/control study. The study was conducted in elementary and intermediate algebra classes at a community college in Chicago. From fall 2006 through spring 2009, more than 17 adjunct and full-time faculty members (35% full time, 65% adjunct) were trained in the management of the MyMathLab computer system through group workshops and individual training sessions. All students in experimental and control classes (except three control sections that did not incorporate technological support) used MyMathLab software for homework assignments during this period. Additionally, students in experimental classes were given daily quizzes with immediate feedback through item analysis, were able to take the post quizzes to attain mastery of the topics,

and engaged in cooperative group work to improve their problem-solving skills (see the Keystone Instructional Cycle, Fig. 1). Instructors in the control classes were free to choose their own teaching and assessment techniques. Midterm and final exams were administered using MyMathLab software in all sections of beginning and intermediate algebra classes for six semesters, serving approximately 800 students each semester.

In this study, we used two different instruments for measuring student-learning outcomes: a national standard exit test, COMPASS, and the departmentally constructed common midterm and final exams. The cut-off score on the COMPASS test required for all elementary algebra students to advance to the next higher class, intermediate algebra, was 29.0.

(a) Student Learning Outcomes on COMPASS: A random sample of $N = 182$ students in elementary algebra classes was used in spring 2006, before MyMathLab was introduced as a technological medium to the department. At the end of this semester, these students took the COMPASS exit test in order to determine their competency to advance to the next higher class. In fall 2006 and spring 2007, MyMathLab technology was used in the department as a vehicle for students to do their homework on the computer, which provided them with immediate feedback on their answers and an opportunity to use online tutoring. Our sample consisted of $N = 311$ students in elementary algebra classes in fall 2006, and $N = 262$ students in elementary algebra classes in spring 2007. At the end of the semester, these students also took the COMPASS exit test in order to determine their competency to move to the higher math class. Furthermore, to test the effects of technology integrated with methodology, we used a sample of $N = 378$ elementary algebra students taught under the Keystone method with support of MyMathLab technology in fall 2007, and another sample of $N = 252$ elementary algebra students in spring 2008. Again, at the end of the respective semesters, these students took the COMPASS exit test.

(b) Student Learning Outcomes on Departmental Exams: For the experimental group, the study sample consisted of six classes comprising $N = 205$ students in elementary algebra for fall 2008 and spring 2009 semesters and also six classes comprising $N = 221$ students in intermediate algebra during the same period. There were two control groups, one that incorporated technology with instructional activities and the other that did not utilize technology in its coursework. The first control group, which used technology, consisted of eleven classes comprising $N = 333$ students in elementary algebra for both semesters and also eleven classes comprising $N = 354$ students in intermediate algebra for both semesters. The second control group, which did not utilize technology, consisted of three classes comprising $N = 101$ students in elementary algebra classes in fall 2008 and fall 2009 semesters. The assignment of all classes was random, i.e., students took their classes to meet their specific time and

work schedule requirements and not because of a peculiarity of teaching techniques. The teachers in experimental classes administered daily quizzes that were time-restricted, cumulative, and based on homework assignments.

Following each quiz, an automatic item analysis of quiz scores was generated and immediate feedback on class performance on each problem, as well as time spent on each question was provided to all students in class. The instructor then briefly reviewed the low-scoring problems, answered questions, and addressed students' difficulties. In order to encourage students to engage in the review/practice process and achieve mastery, students were allowed to take the postquizzes following each in-class administered quiz. Postquizzes were essentially a different version of the in-class quizzes and allowed students to earn additional points if they attained perfect scores. But in order to attain perfect scores, students had to perform a study plan, review the topics, and learn from their mistakes.

At each class session, following instruction and classroom discussion, cooperative group work and peer tutoring of students was conducted. The groups comprised four students from each quartile of the class standings, which engaged in discussion of problems provided by the instructor. The instructor then moved about the class and checked the work of each group by asking a randomly chosen member of the group to thoroughly explain the work done within his/her group. Only upon satisfactory explanation of the work done within the group, the entire group earned credit. For control classes, in the first control group (using technology) the instructors taught their classes in traditional ways, mostly by lecture, and assigned homework problems on computer that provided feedback and online tutoring and answered students' questions. They did not necessarily employ interactive teaching or frequent quizzing with immediate feedback. Also they did not conduct cooperative group work in a structured way, as was done in experimental groups. In the second control group (no technology), the instructors taught their classes in traditional ways, mostly by lecture, assigned

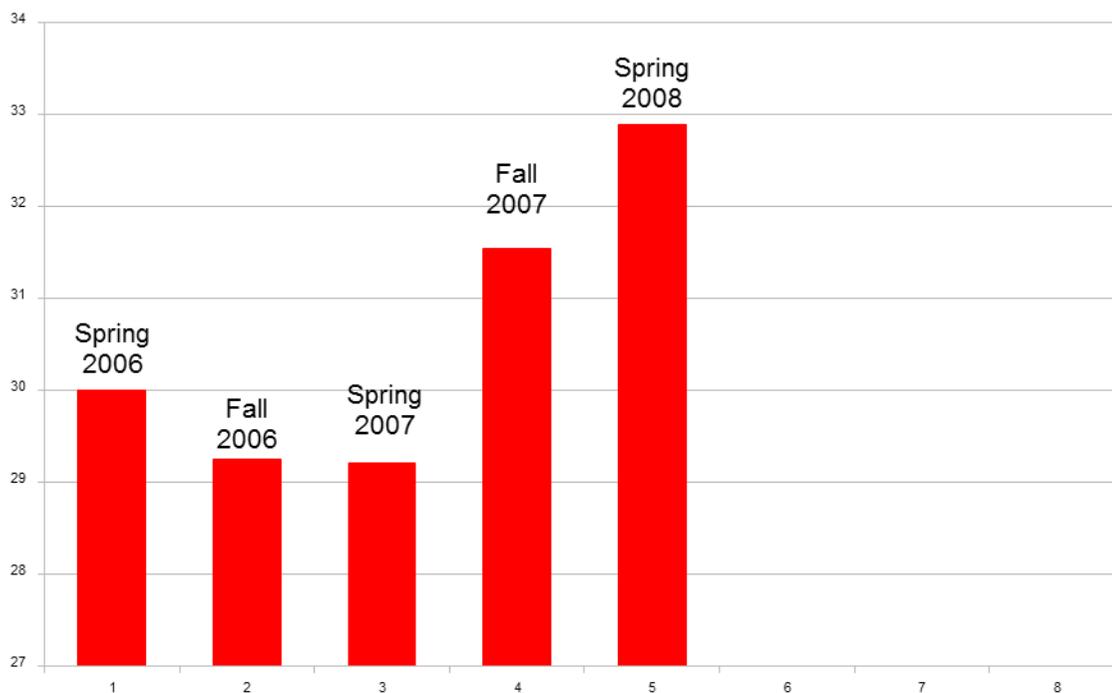
homework problems on paper and administered their own periodic tests.

Results

(a) Student Learning Outcomes on COMPASS: In this section, we will discuss the impact of technology on traditional and innovative teaching as measured by gains in student learning outcomes. Table 1 and Fig. 2 display the comparative COMPASS test exit scores for elementary algebra students for five semesters, from spring 2006 through spring 2008, academic years. As is seen from the table and the graph, in spring 2006, the last semester before MyMathLab computer software was implemented at the department, the elementary algebra students' COMPASS exit test scores had an average of 30.0. In fall 2006, and spring 2007, when MyMathLab technology was implemented, the elementary algebra students' COMPASS exit test scores had averages of 29.24 and 29.21, respectively. Thus, the exit test scores of students in two consecutive semesters showed a very slight, but statistically insignificant decline, upon the introduction of technology. These results demonstrate that a mere introduction of modern technology on traditional teaching does not improve student-learning outcomes. Also, the fact that the cut-off COMPASS test score determining eligibility to advance to the next higher class, intermediate algebra, remained at 29.0 in all semesters, indicates that students taught under traditional methods attained very similar but, minimal, competency to advance to intermediate algebra, in both pretechnology and posttechnology periods. Table 1 and Fig. 2 also exhibit the COMPASS test scores of elementary algebra students who were taught under the Keystone method with the use of MyMathLab technology. As is clearly seen, students' average test scores were 31.53 and 32.89, in fall 2007 and spring 2008, respectively. These scores are highly significant, exceeding 3-sigma standard error, indicating that the Keystone methodology with the utilization of MyMathLab technology produces student outcomes that far exceed those attained solely under traditional teaching with or without the use of technology.

Semesters	Spring 2006	Fall 2006	Spring 2007	Fall 2007	Spring 2008
Compass Test Scores	30.0	29.24	29.21	31.53	32.89
Sample size	N = 182	N = 311	N = 262	N = 378	N = 252
Use of Methodology (Keystone)	No	No	No	Yes	Yes
Use of Technology (MyMathLab)	No	Yes	Yes	Yes	Yes

Table 1. COMPASS Test Results for Elementary Algebra Students



COMPASS Test Results for Elementary Algebra Students

Figure 2. Spring 2006–Spring 2008 Elementary Algebra COMPASS Test Scores

The preceding results confirm that technology produces positive and significant impact on learning only when it is used in conjunction with and in support of innovative teaching methodology.

(b) Student Learning Outcomes on Departmental Exams: Student performance is measured on the departmentally constructed pretests, midterm, and final exams during fall 2008 and spring 2009 semesters.

Table 2 presents descriptive statistics on student performance in elementary algebra for both experimental and control classes for fall 2008 and spring 2009 semesters. The weighted average pretest scores for experimental and control classes were 49.5 and 51.1, respectively, indicating that the classes

were similar in prerequisite knowledge. The midterm weighted average scores for experimental and control groups were 61.4 and 55.3, respectively, showing the better performance of experimental over the control groups in spite of the fact that the experimental groups started off with lower pretest scores compared to the controls. The final weighted average scores for experimental and control groups were 73.7 and 61.1, respectively, clearly showing the significant improvement (exceeding the 5-sigma standard deviation, which has a p -value $< 10^{-6}$, for one-tailed Gaussian distribution) of experimental groups over the controls at the end of the semesters (see Fig. 3). The retention rates for experimental and control groups were 65% and 66%, respectively, which are also statistically equivalent.

Elementary Algebra	Pretest Score	Midterm Exam Score	Final Exam Score	Retention Rate
Experimental Classes N = 205	49.5	61.4	73.7	65%
Control Classes N = 333	51.1	55.3	61.1	66%

Table 2. Impact of Methodology on Elementary Algebra as Measured on Departmental Exams (Fall 2008–Spring 2009)

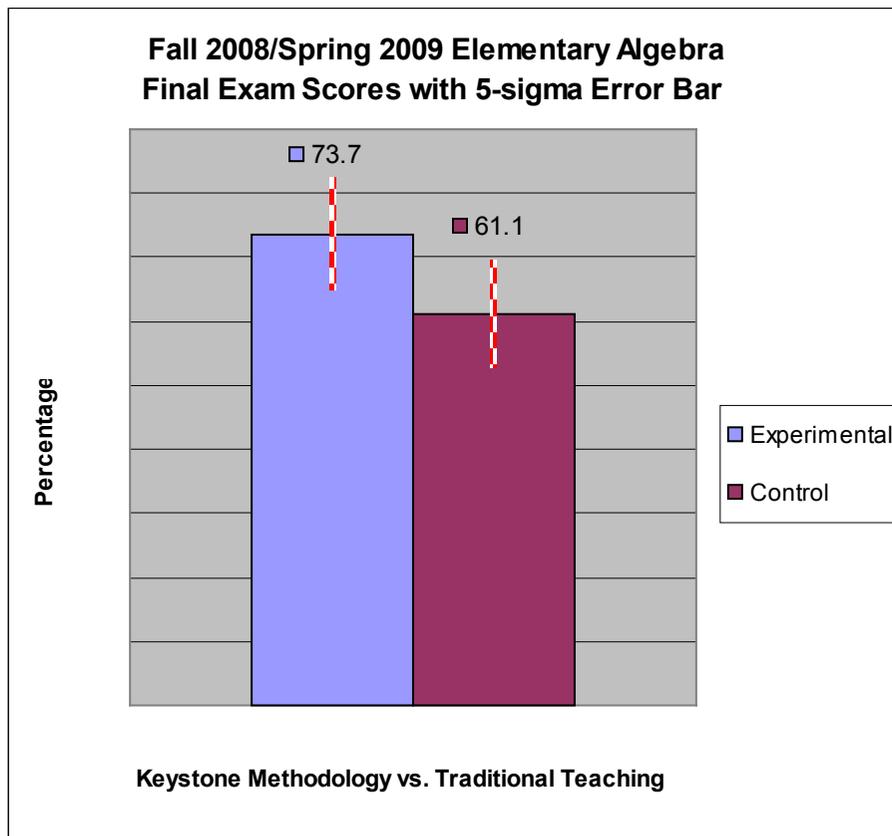


Figure 3. Fall 2008/Spring 2009 Elementary Algebra Final Exam Scores

Table 3 displays descriptive statistics on student performance in intermediate algebra for both experimental and control classes for fall 2008 and spring 2009 semesters. The weighted average pretest scores for experimental and control classes were 75.0 and 76.0, respectively, indicating that the classes were similar in student prerequisite knowledge. The midterm weighted average scores for experimental and control groups were 52.4 and 57.4, respectively, showing the slightly better performance of controls over the experimental groups

nearly halfway into the semester. The final weighted average scores for experimental and control groups were 74.2 and 57.9, respectively, clearly showing the highly significant improvement (exceeding the 5-sigma standard deviation, which has a p -value $< 10^{-6}$, for one-tailed Gaussian distribution) of experimental groups over the controls at the end of the semesters (see Fig. 4). The retention rates for experimental and control groups were 77% and 69%, respectively, showing that experimental groups achieved higher gains with improved classroom retention.

Intermediate Algebra	Pretest Score*	Midterm Exam Score	Final Exam Score	Retention Rate
Experimental Classes N = 221	75.0	52.4	74.2	77%
Control Classes N = 354	76.0	57.4	57.9	69%

Table 3. Impact of Methodology on Intermediate Algebra as Measured on Departmental Exams (Fall 2008–Spring 2009)

*Pretest scores represent the average final exam scores of students in their elementary algebra classes

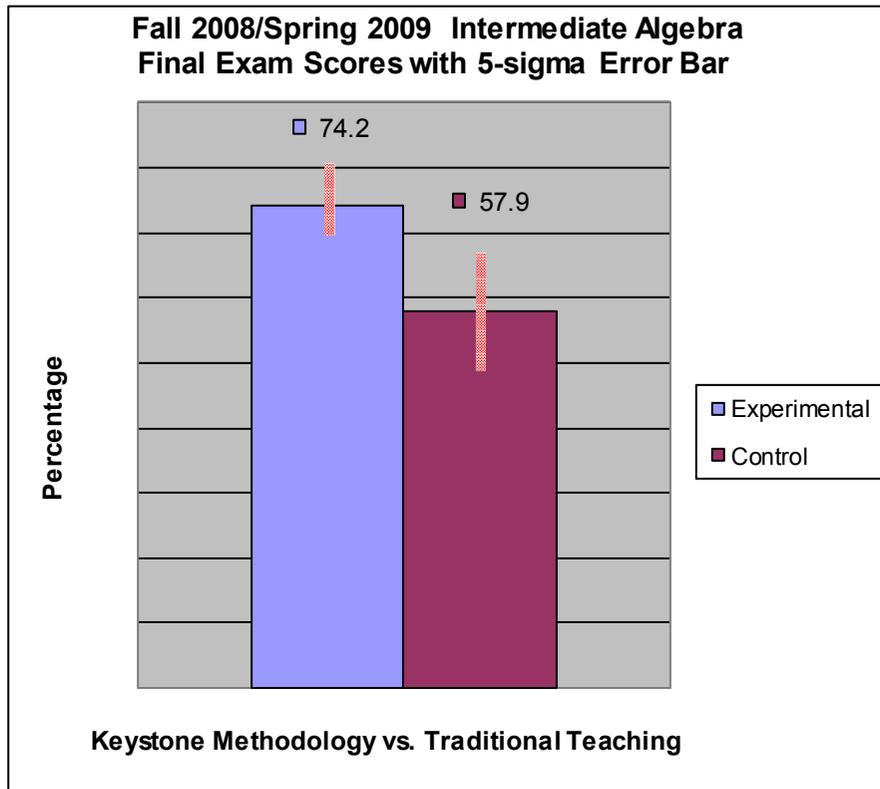


Figure 4. Fall 2008/Spring 2009 Intermediate Algebra Final Exam Scores

Finally, Table 4 and Fig. 5 exhibit the performance outcomes of elementary algebra students taught under traditional approaches, without the use of technology, in fall 2008 and fall 2009 semesters, as well as the performance of elementary algebra students taught under traditional approaches incorporating technology, in fall 2008 and fall 2009 semesters. The student outcomes were measured on departmentally constructed midterm and final exams. As is seen the weighted average pretest, midterm and final exam scores in these classes for the first group (traditional and no technology) were 54.4%, 55.8%, and 59.5%, respectively, with the weighted average retention rate of 77%. For the second group (traditional with technology) the weighted average pretest, midterm, and final exam scores were 47.7%, 57.8%, and 61.0%, respectively, with the weighted av-

erage retention rate (final to initial enrollments) of 83%. The average final exam scores for both groups were very similar and, in fact, statistically equivalent (a 0.41-sigma standard deviation, which has a p -value = 0.341, for one-tailed Gaussian distribution). The slightly higher gains of the technology group over its no-technology counterpart could be attributed to the added computer skills acquired by the former over the latter, since the exams were all administered online in a computer lab. This could have confounded the gains in favor of the technology group. These results indicate that incorporating technology with traditional approaches does not contribute to a significant improvement of student learning outcomes in elementary algebra classes.

Elementary Algebra	Pretest Score Average	Midterm Exam Average	Final Exam Average	Retention Rate
Traditional without Technology N = 101	54.4%	55.8%	59.5%	77%
Traditional with Technology N = 103	47.7%	57.8%	61.0%	83%

Table 4. Impact of Technology on Elementary Algebra as Measured on Departmental Exams (Fall 2008–Fall 2009)

Fall 2008/Fall 2009 Elementary Algebra Traditional Teaching Final Exam Results



Figure 5. Fall 2008/Fall 2009 Results without and with Technology

In Table 5, below, we present a concise summary of the research study for 2006-2009.

Type of Study		Methodology (Keystone)		Technology (MyMathLab)	
		Keystone Experimental Group	Keystone Control Group (No Keystone)	Technology Experimental Group	Technology Control Group (No Technology)
COMPASS Data of Elementary Algebra	Semester	Fall 2007	Fall 2006	Fall 2006	Spring 2006
	Sample Size	378	311	311	182
	Test Scores	31.53	29.24	29.24	30.0
	Semester	Spring 2008	Spring 2007	Spring 2007	
	Sample Size	252	262	262	
	Test Scores	32.89	29.21	29.21	
	Total Size	630	573	573	182
Final Exam Data of Elementary Algebra	Semester	Fall 2008	Fall 2008	Fall 2008	Fall 2008
	Sample Size	133	119	0	36
	Semester	Spring 2009	Spring 2009	Fall 2009	Fall 2009
	Sample Size	72	214	103	65
	Total Size	205	333	103	101
	Test Scores	73.7	61.1	61.0	59.5
Final Exam Data of Intermediate Algebra	Semester	Fall 2008	Fall 2008		
	Sample Size	112	178		
	Semester	Spring 2009	Spring 2009		
	Sample Size	109	176		
	Total Size	221	354		
	Test Scores	74.2	57.9		

Table 5. Summary of Findings for Experimental and Control Groups for the Period of Study

The findings in Table 5 demonstrate that students achieve higher performance outcomes in elementary and intermediate algebra when taught under our synergistic system of methodology and technology compared to those taught under traditional methods with or without the incorporation of technology.

Discussion

The question of modern technology in today's higher education is not one of access, since personal computers, the Internet, and advanced software have been widely available on the educational scene for several decades now. The important question lies in the proper use of technology: How can technology be used to help improve teaching and learning? The authors of this article strongly believe that to be effective, modern technology needs to be integrated into innovative instructional practices. Our study shows that only the synergistic approach that incorporates modern technology with the Keystone methodology can produce significant outcomes in student learning in developmental math classes at the college level. Using two different instruments of measurement: a common departmental exams and

a COMPASS test, we have seen that application of technology on traditional teaching does not produce significant outcomes in learning. In contrast, employing the innovative Keystone methodology with state-of-the-art MyMathLab technology produces significant learning outcomes in developmental math classes.

The Keystone model preserves the integrity of classroom instruction while incorporating computer technology as a tool in support of teaching and the teacher. It is not labor-intensive since it frees the teachers from devoting inordinate amounts of time grading homework, constructing multiple versions of quizzes and tests, and tracking student progress. Instead, it allows the instructor to better focus and engage in more creative and productive aspects of teaching and learning.

This study needs to be further expanded to encompass larger samples of students and other colleges with significant enrollments in developmental math classes. Moreover, there needs to be additional studies designed to track cohorts of students in several continuous semesters in order to investigate the retention of students' knowledge in experimental and control classes over time.

References

- Albano, G., & Ferrai, P. L. (2008). "Integrating Technology and Research in Mathematics Education: The Case of e-learning" in F. J. Garcia Penalva (Ed.), *Advances in E-Learning: Experiences and Methodologies*, Hershey, PA: Information Science Reference (IGI Global), 132–148.
- Boylan, H. R. (2002). *What Works: Research-Based Best Practices in Developmental Education*. Published by the Continuous Quality Improvement Network with the National Center for Developmental Education, Appalachian State University, Boone, NC.
- Boylan, H., Bonham, B., Claxton, C., & Bliss, L. (1992, November). *The state of the art in developmental education: Report of a national study*. Paper presented at the First National Conference on Research in Developmental Education, Charlotte, NC.
- Cahill, L., Prins, B., Weber, M., & McGaugh, J. L. (1994). β -Adrenergic activation and memory for emotional events. *Nature*, 371, 702–704.
- Cahill, L., Babinski, R., Markowitsch, H. J., & McGaugh, J. L. (1995). The amygdala and emotional memory. *Nature*, 377, 295–296.
- Dempster, F. N. (1992). Using tests to promote learning: A neglected classroom resource. *Journal of Research and Development in Education*, 25(4), 213–217.
- Felder, R. M., & Brent, R. (2007). "Cooperative Learning," in P.A. Mabrouk, ed., *Active Learning: Models from the Analytical Sciences, ACS Symposium Series 970*, Chapter 4. Washington, DC: American Chemical Society.
- Foyle, H. C., & Lyman, L. (1989). Homework: Research, policy, and implementation. Paper presented at the annual conference of the Association for Supervision and Curriculum Development, Orlando, FL. (ERIC Document Reproduction Service No. ED303919).
- Hirsch, L., & Weibel, C. (2003). Statistical evidence that web-based homework helps. *Focus: The Newsletter of the Mathematical Association of America*, 23(2), 14.
- ICCB (2001). Excellence in learning-centered instruction award—keystone method: A synergistic approach to improving student performance. Conferred by the Illinois Community College Board (ICCB). Presented in Springfield, IL.
- Joëls, M., Pu, Z., Wiegert, O., Oitzl, M. S., & Krugers, H. J. (2006). Learning under stress: How does it work? *TRENDS in Cognitive Sciences*, 10(4), 152–158.
- Karpicke, J. D., Butler, A. C., & Roediger III, H. L. (2009). Metacognitive strategies in student learning: Do students practice retrieval when they study on their own? *Memory*, 17(4), 471–479.
- Kleinsmith, L. J., & Kaplan, S. (1963). Paired-associate learning as a function of arousal and interpolated interval. *Journal of Experimental Psychology*, 65(2), 190–193.
- Kleinsmith, L. J., & Kaplan, S. (1964). Interaction of arousal and recall in nonsense syllable paired-associate learning. *Journal of Experimental Psychology*, 67(2), 124–126.
- Lewis, J., & Tucker, A. (2009). Web-based assessment and testing systems (WATS). *Notices of the American Mathematical Society*, 56(6), 755–757.

- Mayfield, K. H., & Chase, P. N. (2002). The effects of cumulative practice on mathematics problem solving. *Journal of Applied Behavior Analysis*, 35(2), 105–123.
- McClenney, K. (2009). Helping community-college students succeed: A moral imperative. *Chronicle of Higher Education*, 55(33), A60.
- NCIA (1999). Exemplary initiatives in the classroom award—keystone project. Conferred by the National Council of Instructional Administrators (NCIA). Presented in Nashville, TN.
- Nungester, R. J., & Duchastel, P. C. (1982). Testing versus review: Effects on retention. *Journal of Educational Psychology*, 74(1), 18–22.
- Peterson, E., & Siadat, M. V. (2009). Combination of formative and summative assessment instruments in elementary algebra classes: A prescription for success. *Journal of Applied Research in Community College*, 16(2), 92–102.
- Pyc, M. A., & Rawson, K. A. (2010). Why testing improves memory: Mediator effectiveness hypothesis. *Science*, 330(6002), p.335.
- Roediger III, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, 17(3), 249–255.
- Sagher, Y., & Siadat, M. V. (1997). Building study and work skills in a college mathematics classroom. (ERIC Document Reproduction Service No. ED 449834).
- Sagher, Y., Siadat, M. V., & Hagedorn, L. (2000). Building study skills in a college mathematics classroom. *The Journal of General Education*, 49(2), 132–155.
- Sagher, Y., Siadat, M. V., & Hagedorn, L. (2001). Sound instruction: Ready to use classroom practice. California, New York, Tennessee: Rapid Intellect Group.
- Sasser, J. E. (1981). The effect of homework assignments on the mathematics achievement of college students in freshman algebra. (ERIC Document Reproduction Service No. ED 206495/SE035577).
- Siadat, M. V., Musial, P. M., & Sagher, Y. (summer 2000). Mathematics: Keystone to student learning. *Academic Exchange Quarterly*, 4(2), 15–22.
- Siadat, M. V., Sagher, Y., & Musial, P. M. (2001). Sound instruction: Ready to use classroom practice. California, New York, Tennessee: Rapid Intellect Group.
- Siadat, M. V., Musial, P. M., & Sagher, Y. (2008). Keystone method: A learning paradigm in mathematics. *Problems, Resources, and Issues in Mathematics Undergraduate Studies (PRIMUS)*, 18(4), 337–348.
- Slavin, R. E. (1995). *Cooperative learning: Theory, research, and practice* (2nd ed.). Needham Heights, MA: Allyn and Bacon.
- Spitzer, H. F. (1939). Studies in retention. *Journal of Educational Psychology*, 30(9), 641–656.
- Strong American Schools (2008). Diploma to nowhere: Strong American schools unveil new research on the cost of college remediation for unprepared U.S. students and taxpayers. Washington, DC.
- U.S. Department of Education (2008). Foundation for success: The final report of the national mathematics advisory panel in mathematics. Washington, DC.
- Weibel, C., & Hirsch, L. (2002). Webwork effectiveness in Rutgers calculus. <http://www.math.rutgers.edu/~weibel/webwork.html>.
- Willingham, D. T. (2009). Why don't students like school? Because the mind is not designed for thinking. *American Educator*, 33(1), 4–13.
- Willingham, D. T. (2010). Have technology and multitasking rewired how students learn? *American Educator*, 34(2), 23–28.



M. Vali Siadat is professor of mathematics and a department chair at Richard J. Daley College. He has two doctorates in mathematics, a PhD in pure mathematics and a DA in mathematics education. He has more than twenty publications in mathematics and mathematics education and has had numerous presentations at regional and national mathematics meetings. He is the recipient of several national awards, including the Carnegie Foundation for the Advancement of Teaching, Illinois Professor of the Year Award, and the Mathematical Association of America's Deborah and Franklin Tepper Haimo Award.



Eugenia Peterson is an associate professor of mathematics at Richard J. Daley College. She holds a PhD degree in physics and mathematics, an MS in chemical engineering, and a MAT in secondary education. She joined the Daley College Mathematics and Science Departments in 1998. Her tenure project was based on the research in developmental mathematics classes. She has had several presentations and publications related to science and mathematics education.



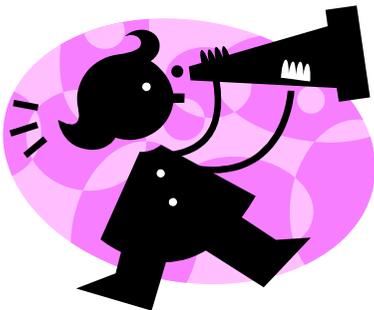
Cyrill Oseledets is a tenured assistant professor in the Department of Mathematics at Richard J. Daley College. He holds a PhD in pure mathematics from the University of California, Riverside, and a developmental specialist degree from the Kellogg Institute at the Appalachian State University. He was formerly a full-time mathematics professor at Syracuse University.



Ming-Jer Wang has been teaching mathematics and physics at Richard J. Daley College as a tenured full-time faculty. He holds a PhD in experimental nuclear physics from Case Western Reserve University with the thesis experiments carried out at Fermi National Accelerator Laboratory and Los Alamos National Laboratory. He has also worked on experimental projects at UCLA and Saclay National Laboratory in France. His contributions to this study are experimental design, experiment coordination, and data analysis.



Guo Quan (Jack) Zhang is a tenured full-time faculty member in the mathematics department at Richard J. Daley College. He obtained his PhD in applied mathematics from the Illinois Institute of Technology in 2007. His research interests are statistics and mathematics education.



The *MathAMATYC Educator* is looking for “LUCKY LARRY”!

Who is “Lucky Larry” (or Lucky Lucy?) These are examples of student work where the student got the correct answer, but used an incorrect technique or process! If you encounter these while you are grading student work, please take a moment and send them off to editor, Pete Wildman, at petewildman@comcast.net or Production Manager, George Alexander, at galexander@matcmadison.edu. Many of our readers use these as learning tools in their classrooms. Furthermore, they can just be fun and interesting!