Keystone Method:
Integration of Methodology and Technology
A Synergistic Model for Teaching and Learning

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Theoretical Background

The Keystone method is a synergistic approach to teaching and learning of mathematics at the college with an extensive use of modern computer technology. Drawing upon the research literature on learning, educational psychology, and causes of student failure in mathematics, this method focuses on the links between students' difficulties in mathematics and specific behaviors, attitudes, and habits that inhibit learning. These include short attention spans, limited time horizons, poor attendance patterns, passivity, failure to learn from errors, inattention to homework assignments, inattention to teacher's statements, and -- underlying all -- a lack of confidence and self-esteem [1,2].

How does the Keystone method address these difficulties? The key element is the continuous monitoring of the students' progress, paralleled with a set of teaching/learning strategies targeted to identified weaknesses [3,4,5]. Carefully designed daily quizzes become an invaluable tool of communication between students and teacher. The instructor's preparation for each class session is informed by quiz results. That quizzes are administered at each class meeting improves class attendance and punctuality. That quizzes are based on homework encourages the students to do their homework assignments for each class. This regimen eliminates the disconnected study spurts and cramming for the tests, encouraging regular study from the very beginning of the term -- which soon becomes a "study habit." Timed restricted quizzes focus students' attention and improve their concentration skills. Finally, the fact that quizzes are cumulative consolidates students' learning and enables them to integrate their knowledge of the topics covered in the course at all times. Computer scoring of quizzes provides statistical data such as the mean and standard deviation for the entire quiz, as well as the item analysis of each question. The teacher not only receives a global view of the class performance overall, but also obtains valuable information on students' performance on each question. The teacher provides immediate feedback, reviews the troublesome questions, and repeats them on the next quiz to encourage attainment of the mastery and learning from mistakes. By achieving a higher level of success each time, the student gets motivated to do better and becomes more self-reliant. Success of students improves their self-esteem.

Students in the Keystone classes are graded on an absolute rather than relative scale [4,5]. There is no grading on curves and there is no quota for the number of A's and B's given. Each student is expected to attain a level of mastery, irrespective of other students' standing in the course. This is academically sound, as well as providing an additional incentive. In the absence of the curve, achievement of one student is not to the detriment of others. Thus, cooperation and collegiality are encouraged, reinforcing the fact that the mathematics class is a shared learning community. This community aspect is critical when, as often happens, students in a class span a wide range of math aptitudes.

The Keystone method is a student-centered and versatile teaching approach [5,6,7]. When the standard deviation of the quiz scores is high (more than 25%) - indicating a serious split in skill levels - the teacher moves from lecture to cooperative learning and peer tutoring. In such circumstances, weaker students are tutored by stronger students. The stronger students benefit in turn by reinforcing their own knowledge. Such peer learning experiences are especially effective at addressing student passivity.

The Keystone approach encourages attentiveness to the instructor's messages. For example, to encourage the study of particular topics often ignored by the students (word problems, for example), the instructor administers dedicated quizzes, i.e., those consisting entirely of word problems. Students learn quickly, via a concrete and strong message, that even the "unpopular" topics cannot be placed in the "forgetting bin." In short, the Keystone approach creates a synergy among various pedagogical techniques parlaying these into a highly effective teaching program for improving student learning [1].

The Role of Technology

Since its inception in 1993 at Richard J. Daley College as a pilot study and later on as a project in 1998, funded through a grant by Gabriella and Paul Rosenbaum Foundation, the Keystone method has been extensively researched and has won numerous state and national awards [10,11,12]. Keystone methodology utilized available computer technology for test construction, administration and statistical analysis of the test results. ScientificWorkPlace typesetting software, Scantron scoring machines and ParScore software programs were used for these purposes. The tests and quizzes had a hybrid construction - they consisted mostly of carefully constructed multiple choice questions in addition to a number of open ended problems [8,9].

In fall 2006 a state of the art 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 the interactive teaching, where teaching techniques are adjusted according to the assessment results during the class period. This interactive design fitted perfectly with the Keystone philosophy. It also allowed for effective coordination of multiple section 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 algorithmic generated homework problems with an on line assistance option which 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 acted as an important diagnostic tool and helped the instructor to better assess the nature of students' difficulties on quizzes, tests and homework. The monitoring technology, such as "Insight Teacher" also made possible to monitor students' progress on assignments and provided a personal feedback when necessary.

Current Research

To investigate the synergistic impact of methodology (Keystone) and computer technology (MyMathLab) on student learning in developmental math, we designed an experimental/control study involving students in elementary and intermediate algebra classes at the college. From fall 2006 through spring 2009 more than 17 adjunct and full time faculty members were trained in the management of MyMathLab computer system through group workshops and individual training sessions. All students in experimental and control classes used MyMathLab software for homework 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. 6). The assignment of classes for all students was random, i.e., students took their classes to meet their specific time and work schedule requirements, and not because of peculiarity of teaching techniques.

The teachers in experimental classes administered daily quizzes which 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 student difficulties. In order to encourage students to engage in the review/practice process and achieve mastery, students were allowed to take the post quizzes following each administered in-class quiz. Post quizzes 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 study plan, review the topics and learn from their mistakes.

At each experimental 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 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.

In control classes the instructors taught their classes in traditional ways, mostly by lecture, assigned homework problems on computer and answered student 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.

Finally, departmentally-designed midterm and final exams were administered using MyMathLab software in all sections of beginning and intermediate algebra classes (experimental and control) for six semesters, serving approximately 800 students each semester.

Results

In the following section we analyze student performance outcomes in elementary and intermediate algebra classes taught both under our synergistic system of integrating methodology (Keystone) with computer technology (MyMathLab) and under traditional methods for the academic years 2007-2008.

Figure 1 presents the success rates of students in experimental and control groups in elementary algebra classes for fall 2007. As is seen the pass rate for the experimental groups was 36%, while that of the control groups was 29%. Also the withdrawal rate for the experimental groups was 32% while that of the control groups was 34%. A salient difference in student performance between the two groups, however, was the knowledge gain. While 29% of students in the experimental groups earned As and Bs, only 11% of students in the control groups earned As and Bs. Higher knowledge gain of experimental groups relative to the controls was almost 3 to 1.

Figure 2 reports the success rates of students in experimental and control groups in intermediate algebra classes for fall 2007. As is seen the pass rate for the experimental group was 58%, while that of the control group was 39%. Moreover the withdrawal rate for the experimental group was 23% while that of the control group was 38%. Aside from higher pass rates, and lower withdrawal rates, the students in experimental classes achieved better knowledge gain as evidenced by higher number of As and Bs received. While 42% of students in the experimental groups earned As and Bs, only 22% of students in the control groups earned As and Bs. Better knowledge gain of experimental groups relative to the controls was almost 2 to 1.

Figure 3 displays the average final exam scores of experimental and control classes in elementary algebra for fall 2008. As is clearly seen, in all experimental classes the average scores were higher than the control classes. The overall weighted average was 73.9% for the experimental and 60.6% for the control groups. These gains were achieved with very close retention rates: 64.5 % for the experimental vs. 65.8% for the control groups. We should also mention that the experimental and control groups started off by being very similar in ability levels, as evidenced by very close pre-test scores of 50.8% for the experimental and 51.9% for the control groups.

Figure 4 depicts the average final exam scores of experimental and control classes in intermediate algebra for fall 2008. As is seen, all experimental classes attained the average scores which were higher than the control classes. The overall weighted average was 68.4% for the experimental and 57.3% for the control groups. The gains were achieved with very close retention rates. We should also mention that the experimental and control groups started off by being very similar in ability levels, as evidenced by very close pre-test scores of the two groups. An interesting observation was that one of the control classes (Bar no. 6) was taught by an experimenter faculty who taught his class in traditional ways (to control for teaching effect) and attained the same overall average as the other control teachers.

Finally, Figure 5 demonstrates the Compass test exit scores for elementary algebra students during four semesters from 2006 to 2008. In all semesters, the cutoff Compass score required for moving to the next higher class (intermediate algebra) was 29. As is seen, in the 2006-2007 period when MyMathLab technology had not been implemented, the average Compass score was slightly above the cutoff; in other words students barely made it to the next class. But during the 2007-2008 period with the application of MyMathLab technology and Keystoner methodology, the average Compass scores climbed to 31.5 and 32.9, respectively. These results are indeed staggering, since they represent standard errors exceeding two sigmas in average scores, which is highly significant on the 99% confidence interval. So the students in these classes outperformed more than 99% of their peers at the national level.

Conclusions

The result of our study during 2007-2008 academic years in elementary and intermediate algebra classes show that under our synergistic system incorporating MyMathLab technology, students have gained higher outcomes in final exam scores, pass rates, and knowledge gain (as evidenced by higher number of A's and B's received), compared to those in the control classes. The higher outcomes in experimental classes were not achieved with the attrition of weaker students. It is also important to point out that only the correct synthesis of modern technology with methodology leads to measurable improvement in student performance.

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Tables and Graphs

Distribution of the Grades, Experimental versus Control
Beginning Algebra, Fall 2007

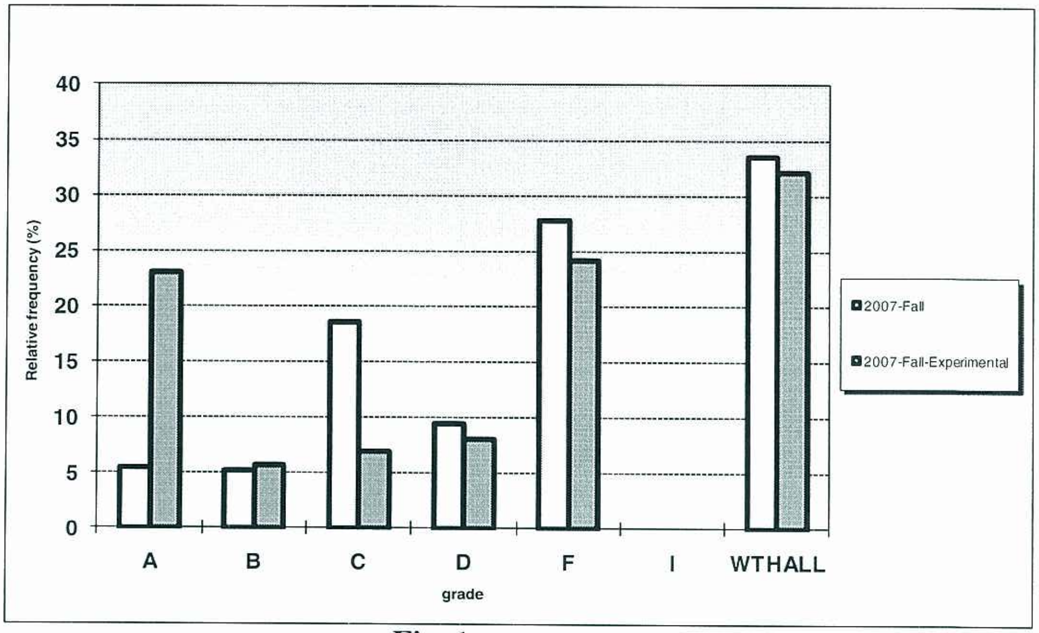

Fig. 1

Distribution of the Grades, Experimental versus Control
Intermediate Algebra, Fall 2007

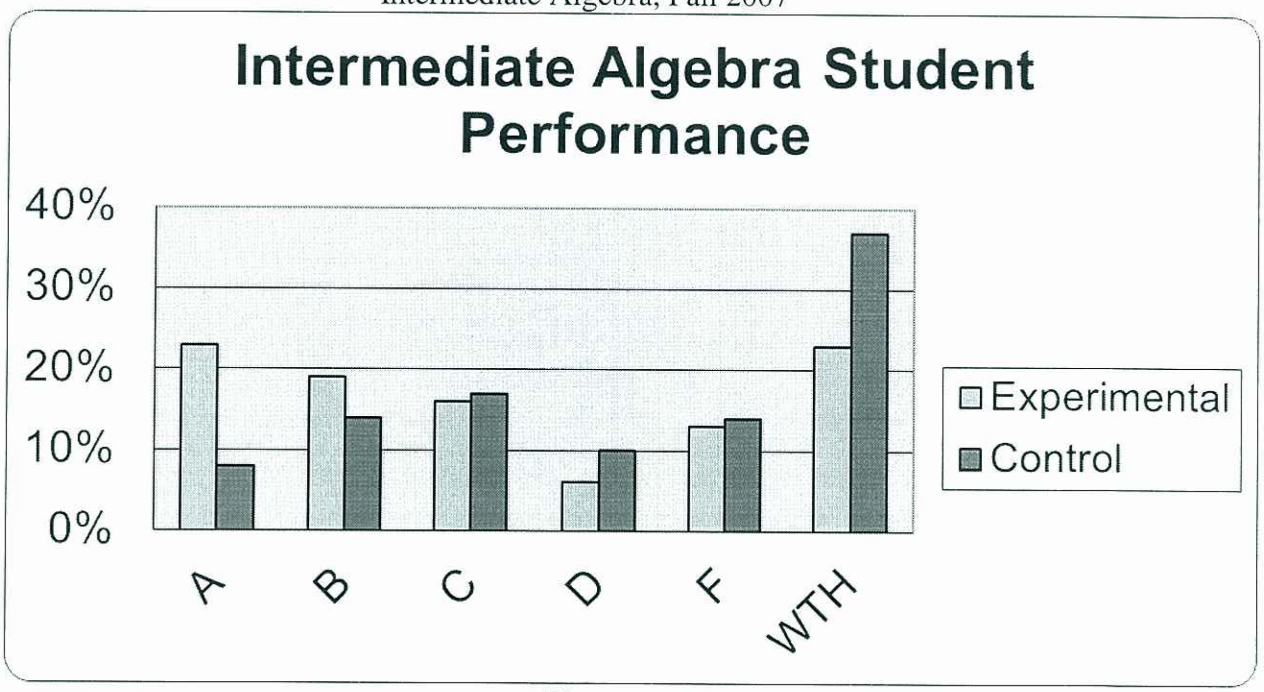

Fig. 2

Beginning Algebra Student Performance on Final Exam
Mean Final Exam Sores, Fall 2008

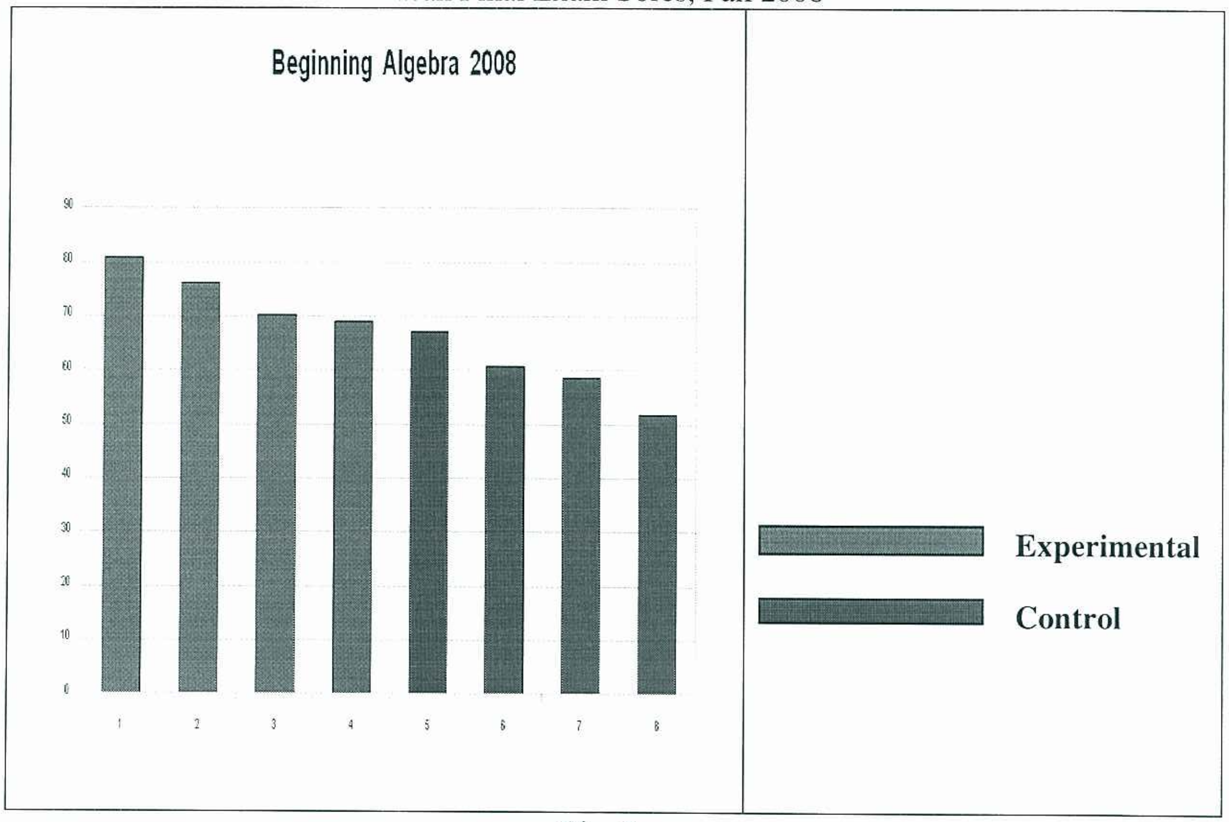

Fig. 3

Intermediate Algebra Student Performance on Final Exam
Mean Final Exam Sores, Fall 2008

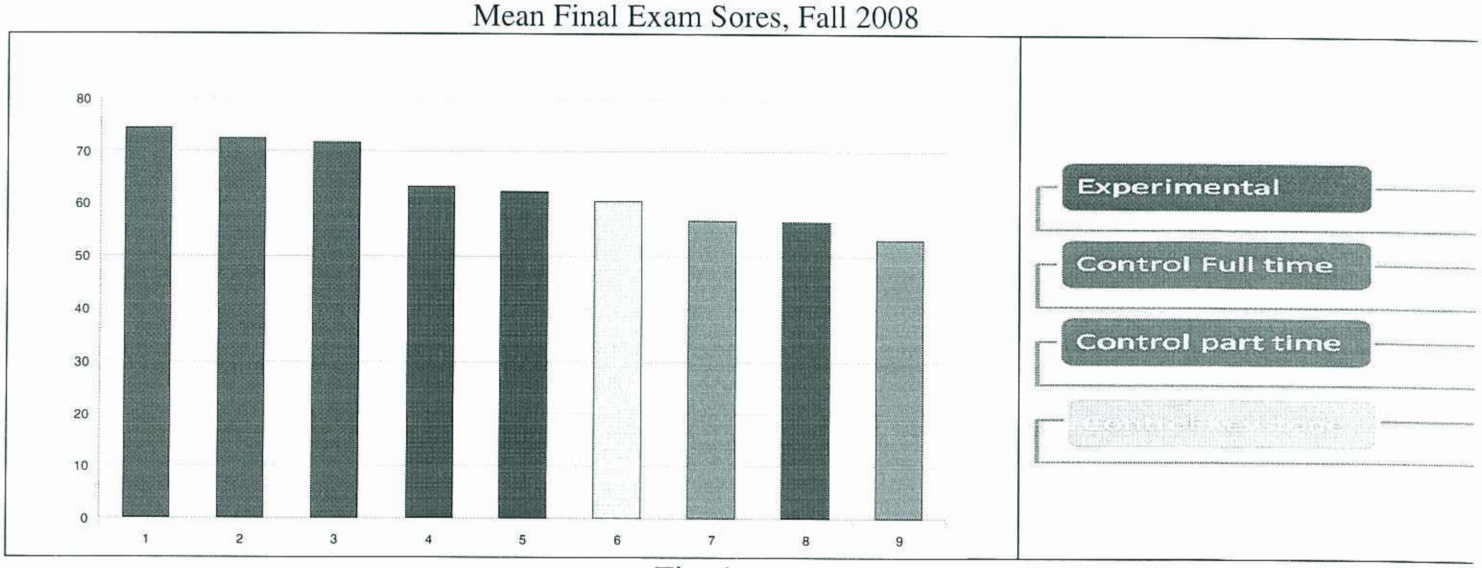

Fig. 4

Note: Control Keystone was a group taught by an instructor who also taught experimental groups in the same semester.

Compass Test Exit Scores for Beginning Algebra Students
During 2006-2008

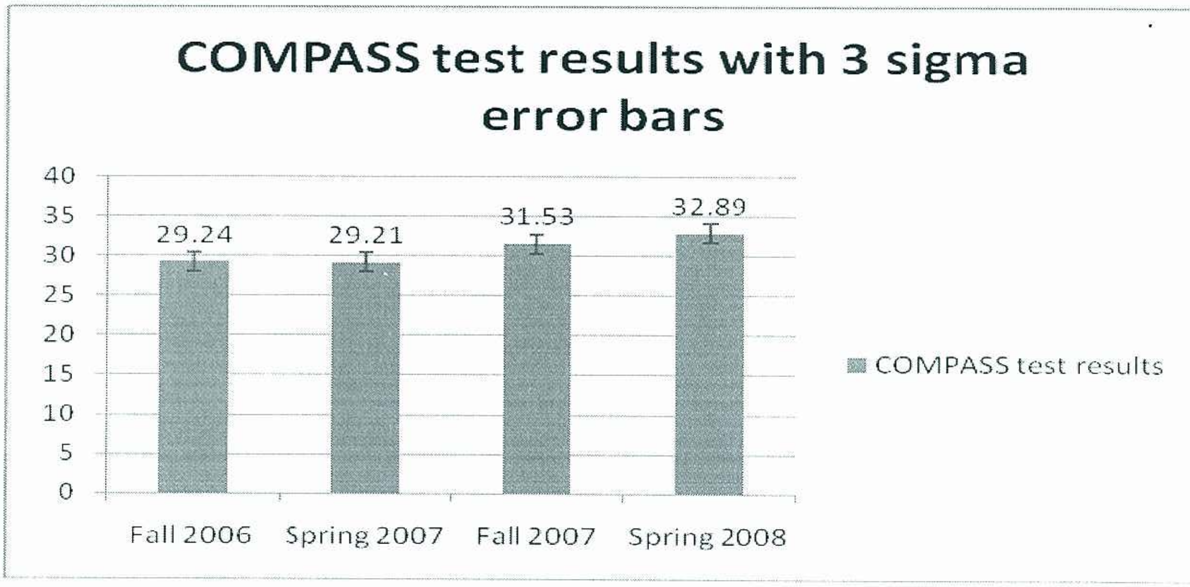

Fig. 5

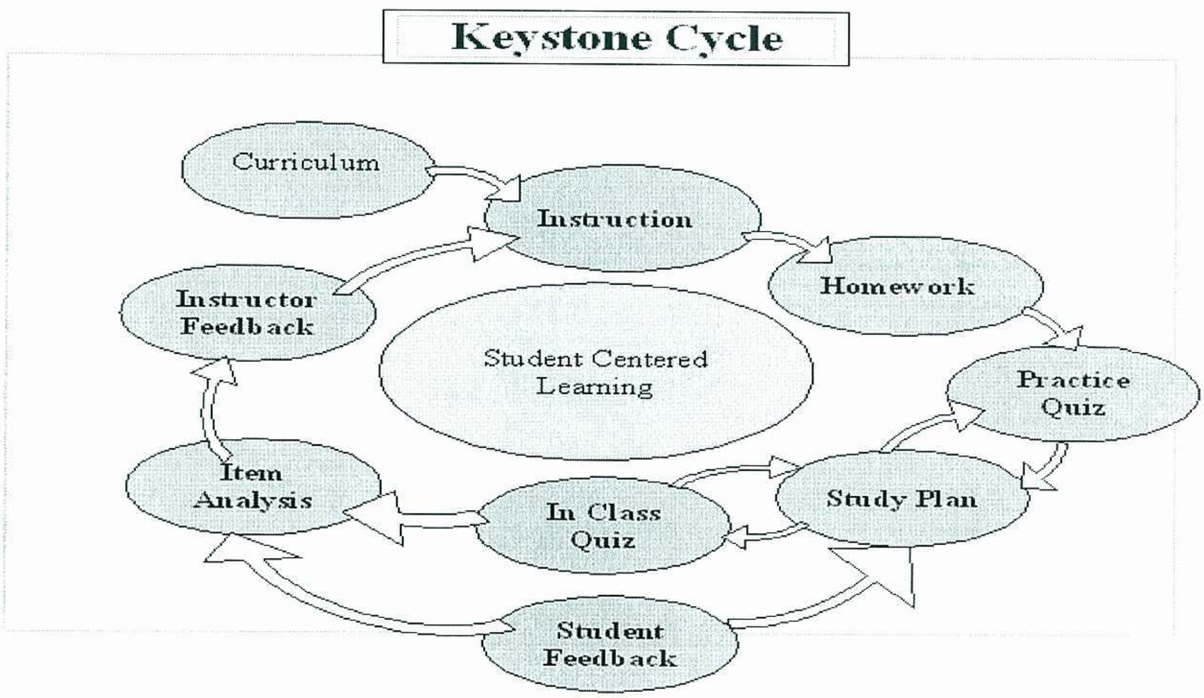

Fig. 6