# OPTIMIZING COMPUTER-BASED DEVELOPMENTAL MATH LEARNING AT AN ARABIC WOMEN'S UNIVERSITY

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*Developmental* math courses give university students a chance to reestablish basic skills and knowledge needed in college algebra courses. Computer assisted learning can be an integral part of these developmental math courses. Colleges and universities implement computer-based courses in various ways (e.g., self-paced or supervised schedules; computer laboratory or online access; with or without lecture). This paper describes a computer-based developmental math course taught at Zayed University. Discussion of computer-based learning environments is presented in three sections: 1) computer use—access and social use of computers as a tool for learning, 2) individual learning—effects of the computer environment such as software interactivity and feedback, and 3) course design—optimal course structure and assessment methods. Additionally, results of a questionnaire about students' experience in the computer-based math course indicate students' positive attitudes about interacting with and doing work on their laptop computers.

Higher educational institutions throughout the world have seen an extraordinary increase in students who enter college with minimal mathematics skills and negative emotions about mathematics (e.g., math phobia). To meet the needs of this increasing population, many colleges and universities purchase tutorial software or acquire more comprehensive computer-based courseware (i.e., educational software that serves as the main vehicle for teaching a course). However, most educators familiar with the evolution of educational software are aware of the slow progress in development of good quality computer-based learning environments. In fact, much of the early "educational" software was inferior to an average textbook about the same topic—especially when the software merely replicates the contents and pedagogical design of a textbook. Second, just as teaching techniques and learning modalities vary according to age and ability level, even good quality software may not be appropriate for some populations. Third, even when computer-based learning environments could be a significant enhancement to traditional course delivery, barriers to integrating computers in the learning process may come from institutional constraints, ill-informed administrators, inflexible or unskilled teachers, or resistant students.

In general, expertise in selecting, purchasing, and installing educational courseware is no guarantee of its acceptance or efficacy. In addition to specific features of mathematics courseware, it is important to evaluate individual, social, and curricular factors in designing computer-based learning environments. These issues, as well as features associated with implementing a computer-based developmental mathematics course, are discussed in the first three sections of this paper:

1) **Computer Use**— How are computers and software used, and how do they structure learning experiences?
1) **Individual Learning**— How does computer software facilitate individual cognition and learning?
3) **Course Design**— Is the course self-paced? Is feedback on problems, exercises, and homework immediate?

Are quizzes and tests repeatable? Does teacher give lectures? Is assessment individual or in a group context?
The second part of the paper describes a survey of students' opinions about a computer-based mathematics course, referred to below as the "ZU Math101 course." The software for the course was developed and implemented at Zayed University, a post-secondary institution for Arabic women in the United Arab Emirates. Descriptions and viewpoints expressed in this paper apply primarily to students at the *developmental* (basic pre-algebra mathematics) level. Some descriptions apply specifically to the culture and background of students at Zayed University.

## COMPUTER USE

A significant factor in the realizing the potential of the computer-based ZU Math101 course was the university's requirement that all students purchase laptop computers. Although the course could be taught in a computer lab, students' satisfaction and efficiency are considerably enhanced when they have round-the-clock access on their own laptop computer to review concepts, do exercises, and practice tests. An advantage of the ZU Math101 courseware was that it was installed and run without connection to the Internet or a university computer network. Good quality commercial mathematics courseware requiring a network connection doesn't allow as much flexibility, although this disadvantage will be eliminated with the advent of wireless computing and high-speed connection to the Internet from home as well as school.

In the ZU Math101 course students brought their laptops to class, and usually had time after lecture to work on the computer-based exercises and complete their homework. During or after a lecture the teacher demonstrated concepts and problem solving by doing the computer exercises projected onto a white board at the front of the room. Projecting computer-based lessons and exercise problems on a white board enables traditional board work calculations and elaborations alongside or within the projected computer content. Thus one can combine the best of both worlds—traditional flexibility in demonstrating problems by writing on the white board alongside structured presentation of concepts and problems in the projected computer screen. The projected computer lessons can also be advantageous in familiarizing students with the structure and sequence of homework exercises. Additionally, demonstration of a sequence of concepts and exercises to be done on the computer can be effective in getting students' attention. Students taking the ZU Math101 course were highly attuned to learning by observation of interactive activities. This propensity may be related to social characteristics in their culture (i.e., assuming that learning through observation is characteristic of a more socially oriented culture, as compared with cultures where individuals have become habituated to learning in an isolated context).

Another characteristic of computer-based learning is the potential for students to progress at their own pace. More skilled ZU Math101 students could often finish the exercises quickly, and some used the extra time to help other students. Computers sometimes seemed to provide a medium for social support and collaboration, perhaps because the procedural sequence and visual objects are more easily shared between two people than when individuals write on a piece of paper. In some instances the easily shared exercise sequences and objects appeared to facilitate paired tutoring and social support, utilizing a strength in the students' cultural background.

A primary pedagogical goal in designing the ZU Math101 course was to get students to view the computer-based course as something that could facilitate time management, and that would reward them for mastery at their own pace rather than being adept at following academic ritual. To highlight the convenience and efficiency of being able to work on the computer exercises at any time, students were allowed to leave the class after a lecture if they had completed all previous homework.

## INDIVIDUAL LEARNING

Awareness of general characteristics of students is sometimes an important factor in adopting pedagogical strategies. For example, teaching a topic in a "real world" context may not be optimal for everyone: One study that investigated this teaching philosophy found that some adult learners returning to college did not like a rich and meaningful context. These adult learners may already understand the real world utility of the knowledge being learned, and want to focus on more efficiently acquiring particular concepts and skills.

Thus it can be important to consider general characteristics and background of students in designing a curriculum: students taking developmental mathematics classes may have different emotional orientations toward mathematics, or different study skills, compared with more advanced students.

The following list describes how a computer-based learning environment might impact on individual learning. Note that some of the general characteristics of students taking the ZU Math101 courseware are concrete and confirmable. Other characteristics are inferred or assumed to be personality variations in any group of individuals.

1. *Language Comprehension*

For the ZU Math101 students, language comprehension was often an important factor in individual learning. Almost all Zayed University students acquired English as a second language, but many did not regularly speak or read English in their everyday activities. Thus reading a textbook, particularly one that has been made wordier for the sake of making learning more palatable, is often a significant added burden for such students.

Additionally, some students are not motivated to memorize vocabulary and interpret second language descriptions because they know, or think they know, the basic concepts and processes in their first language. In any case, although the logical discourse of mathematics is universal, communication in mathematics, even elementary mathematics, is embedded in complex linguistic expressions (Pimm, 1987). Surprisingly, textbooks do not always deliver straightforward and easily absorbed narrative when presenting what might be thought of as the language-independent logical world of mathematics. Added to the above factors is the fact that many students in a developmental mathematics course are there because they dislike mathematics.

To address these problems, particular care should be made to minimize discursive explanations for students learning in a second language. Accordingly, discursive explanations in the lesson notes of ZU Math101 courseware were minimized and time spent on lecture/note-taking reduced. Notes pages projected during lecture are easily accessed by a mouse-click as the student works on exercises. In general, computer courseware can avoid unnecessary language complexity by utilizing the 'mouse-click' environment to allow quick and easy access to exercise-specific online notes. What's more, interactive multimedia exercises can be a great way to provide primary exposure to concepts and procedures, particularly if the student is not able to process textual materials efficiently.

2. *Interactive Feedback* can have a positive effect on individual learning, especially for developmental mathematics students who lack self-confidence or are intimidated by mathematics. The immediate feedback made possible by computer software is in some ways like having a personal tutor—it can positively affect emotions and motivation as well as facilitate knowledge acquisition. For example, developmental some math students are at times embarrassed by their mistakes and prefer the privacy of computer-based instruction and feedback.

Like textbooks, the ZU Math101 courseware is organized into chapters, each chapter containing a set of exercises, and each exercise containing a set of problems. The course was structured to motivate students by providing timely feedback on several levels: a) immediate feedback on each exercise problem, b) immediate scoring of a completed chapter exercise, c) immediate scoring of test results, and d) regular updates emailed to students' showing details of homework and test results, overall averages, and class standing.

2a. *Feedback at the Individual Problem Level*

Feedback on each problem occurred if the student entered an incorrect response. In most cases the correct answer is displayed, although in some exercises the student may be asked to select another choice. Some educators might ask whether immediate feedback is a relatively unimportant convenience, not much different from looking up answers in the back of a textbook. Moreover, interactive video-game characteristics of computers may sometimes encourage a trial and error guesswork approach to learning that inhibits students' acquisition of methodical study habits. To counteract these tendency students in the ZU Math101 course were required to keep a notebook in which they record all exercise problems and show all calculations.

According to some modern theories, knowledge acquisition can be facilitated by integrating different learning modalities such as the part of the brain involved in visual interactive multimedia and the part of the brain involved in verbal-logical written work. It seems likely that the visual stimulation and interaction tends to make the written part of the task more palatable to students who grew up in a multimedia culture.

Note that another inhibitor to the trial and error guesswork approach was not allowing the student to immediately repeat the same problem—problems are presented sequentially and problem set as a whole had to be repeated. Additionally, each time a problem is presented, the software uses randomization algorithms to select different values. These algorithms usually included numerical constraints to assure selection of values relevant to the concept being tested. In some cases, however, the software selected problem values from a pre-established list of values.

2b. *Feedback at the Exercise Level*

When students completed a chapter exercise the score was displayed on a results page that included a list of all exercise problems that were answered incorrectly, the correct response to each exercise, and the total score for the exercise. Students could print out the results, although the preferred method was to take a screenshot of the results page and email it to the professor. Note that results pages of exercises and tests could not be altered, and they contained two-digit security code calculated using information from the student name, date, and time printed on the page header. Students were able to repeat exercises, doing the same problems until their score was satisfactory and, hopefully, they acquired a sense of mastery.

2c. *Feedback at the Chapter Test Level*

Standard chapter and midterm tests can be a negative factor in motivating students to engage in efforts and logical orientations that facilitate mathematical thinking and learning. Further, developmental mathematics students may not have a good grasp of the reasons for their poor performance on a test. Some of these students lack self-assessment or self-monitoring skills in what they view as a strange and alienating world of mathematics. Thus without readily accessible as well as constant feedback they are often unprepared for chapter tests. The Math101 courseware helped address this problem by allowing students to take practice tests at any time, wherever they took their laptop computers.

The ZU Math101 practice tests were like the real tests, consisting of a subset of the exercise problems. These practice tests gave students accurate feedback on how well they would perform. Initially, students with poor study skills tended to not bother taking the practice tests. However, since the computer-based practice tests were readily available and easy to take, even the less motivated students seemed to acquire greater self-awareness about the relationship between practice and subsequent performance. Note also that students were required to write all test problems and calculations—partial credit was given only if the requisite work was shown on paper.

2d. *Feedback At the Overall Course Performance Level*

A ranked spreadsheet showing all homework and test scores as well as overall class standing was emailed to students at least once a week. Details of scoring and grades, and discussion of their pedagogical effects, are given in section on course design.

**COURSE DESIGN**

The ZU Math101 course structure and software was designed to give students clear and constant feedback about their performance and promote a collaborative 'mastery' type environment. Of course, in addition to the formal structure and features of the course discussed below, basic teaching qualities may be critically important. Outcomes for some students are dependent on the whether the teacher has a supportive personality, enjoys explaining basic concepts and procedures, does not view developmental math students as idiots, and so on.

As noted above, the ZU Math101 software scored each homework exercise and test, although accumulation of scores was done manually in an Excel spreadsheet. Computer automation of cumulative grading and whole-class results was not available for several reasons: 1) the software was still in an early development stage, 2) the software ran individually on students' laptop computers, without network capability to collect and compare scores, 3) scores on tests and homework were sometimes revised due to typos or errors in the computer interpretation of students' responses, 4) partial credit was given for work shown on paper.

In order to provide quick feedback summarizing students' overall performance and class standing, scores were regularly entered into a spreadsheet. Although this data entry included many exercise scores, and required a lot of effort, it appeared to be a significant motivational factor in the ZU Math101 course. The Excel spreadsheet that was regularly emailed to students consisted of three sheets: 1) homework scores, 2) test scores, and 3) overall performance factored from homework and test scores. All three sheets included percent and letter grades that were automatically calculated by spreadsheet functions. Additionally, a spreadsheet macro was created to replace names with ID numbers and save a copy of the spreadsheet with students' performance sorted by class rank. Emailing these whole-class grade sheets at least once a week seemed to be a valuable tool for 1) rewarding hardworking students, and 2) raising awareness of consequences in students who tend to avoid work, and 3) providing corrective feedback for students who are not good at self-monitoring or self-assessment.

Of course there may be negative factors related to ranking students in a class, even when students' identities are not given in the distributed grade sheet. However, since the ZU Math101 course was designed to focus students on mastery rather than competition, positive effects seemed to outweigh any negative factors. Continuous feedback of individual performance and group ranking can reduce ambiguity and worry for students who are insecure about mathematics, or are making efforts to improve poor study skills. Group feedback in the form of automatically calculated Excel spreadsheets helps reduce students' negative attitudes as they perceive that the system reflects everyone's performance in a fair and consistent way (e.g., sometimes the automation in Excel grade sheet functions helps defuse personal emotions associated being judged).

From the above descriptions it might be accurate to characterize ZU Math101 course as having a significantly behavioralist approach in which small increments in each individual's progress are recorded, and continuous feedback is given to individuals and the class as a social group. Computer-assisted learning environments provide increased potential for such close monitoring and continuous feedback on student's performance. Perhaps one reason why traditional academic culture does not monitor behavior that closely is the labor-intensive nature of such monitoring in mass educational systems. The traditional educational culture of using one-shot midterm tests to motivate students and categorize levels of acquired knowledge may be slow to change until systems and people really understand and are comfortable with how to reapportion labor in a technological context.

Another useful potential of mathematics software is the ability to use different values each time a student does an exercise or test problem. Even if two students are working the same problem, the correct answer will be different. Perhaps more importantly the student can repeat a set of exercises with different values. This ability to repeat and improve can help focus a learning environment on *mastery* rather than summary assessment. Experience with ZU Math101 students indicated that students who might appear lazy or unwilling to learn might actually be quite active in trying to achieve when they can repeat exercises and tests. In other words, what a professor may view as laziness or poor motivation may in some cases be a sort of dejection or giving up when the student does not perform well in one-shot exercises and tests.

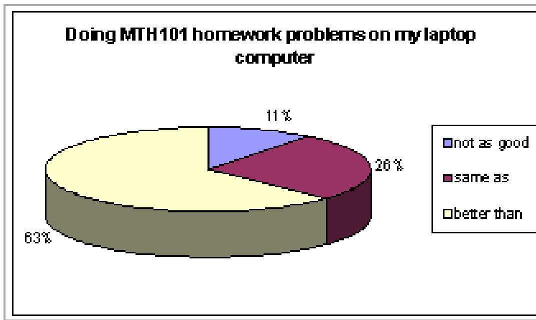
Since the ZU Math101 software scored tests automatically, the instructor allowed students to bring their laptop and repeat tests during his office hours. In some cases this worked well with lower achieving students, who suddenly appeared surprisingly motivated and ambitious about improving their scores (and spent a considerable amount of extra time in this endeavor). There were also, perhaps predictably, some average or better than average students who repeated tests because of previous laxity in studying. Given this course policy, students are more likely to show up during the instructor's office hours, so the professor has less chance to sneak away for a cup of coffee. Additionally, the professor needed to check the test output and review the student's written calculations on problems that were incorrect. One positive consequence was that students ability to immediately review test results with the instructor promoted one-on-one tutoring of students having difficulties in the course (again, requiring more of the instructor's time and effort).

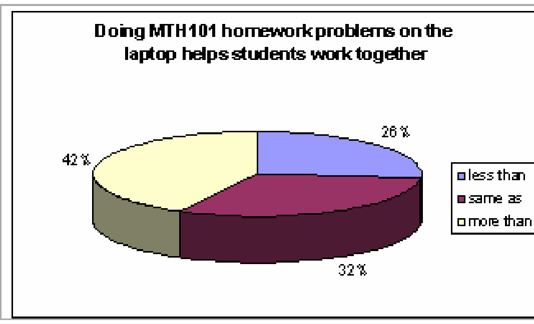
In summary, fulfilling the potentialities and successful features of the computer-based ZU Math101 course was not simply leaving the work to computers. The professor had to commit considerable time and effort, which was rewarded by student satisfaction and smooth operation of the course. Future improvement in intelligent tutoring systems and better quality software from commercial vendors will reduce some of the managerial effort required. On the other hand, positive software features, optimal socio-cultural classroom environments, and supportive teaching strategies, do not always survive commercial and administrative management decision-making processes.

**STUDENT SURVEY**

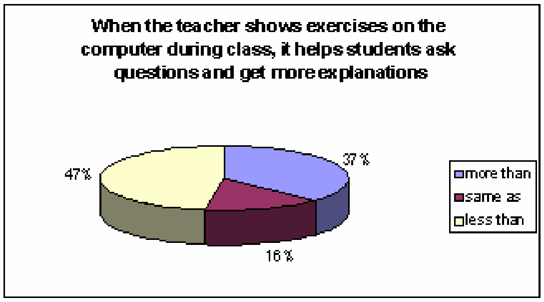
A questionnaire containing ten questions was emailed to students who had taken the ZU Math101 course. Students could choose either English or Arabic versions of the survey. Although the number of students responding was limited (20 surveys returned out of 66 sent), results reveal some interesting trends.

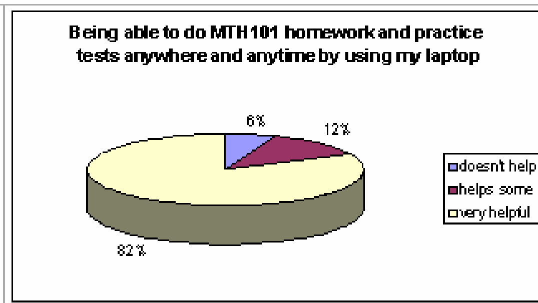
When asked to compare doing homework on their laptop with doing homework in a textbook, most students thought doing homework on their laptop was better (63% better than textbook, 5% same as textbook, 11% not as good as textbook). Students were more evenly divided when asked whether doing homework on the laptop helped them work together with other students, although many thought it did (42% thought laptops helped students work together).



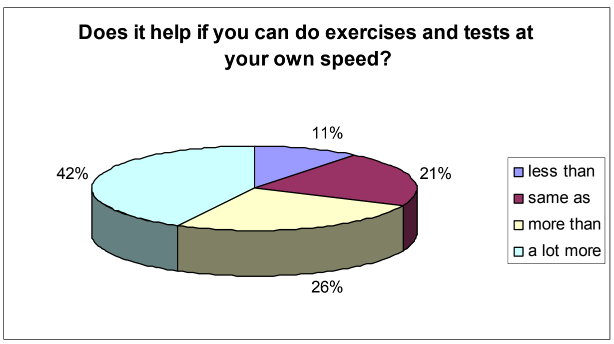

On the other hand, when asked whether class demonstration of exercises using the computer helped students ask questions, most said 'less than a textbook' (37% felt that computer demonstrations evoked more student questions, 16% felt both were same, and 47% felt exercises from a textbook evoked more student questions. This indicates that teachers should not rely too much on letting the computer demonstrate exercise problems. Students may be accustomed to previous classroom experiences and feel more comfortable with picking from textbook problems the 'demonstration by hand' methods.

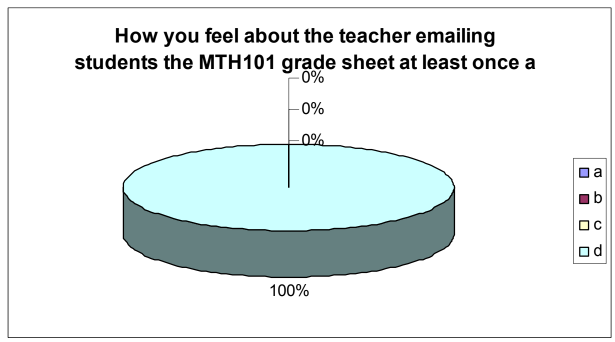


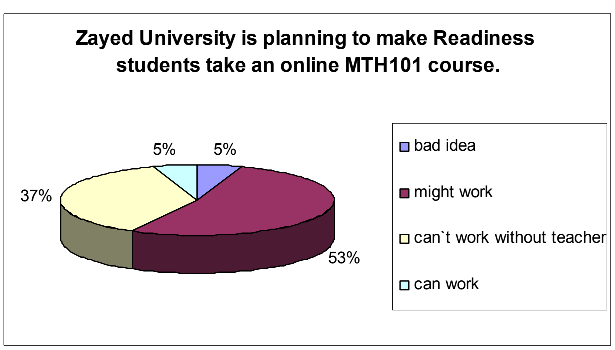

A strongly positive aspect of the ZU Math101 course was students' response to being able to do homework and practice tests anywhere and anytime on their laptop. A large majority of students indicated that this was "very helpful" (82% responded "very helpful", 12% responded "helps some", and 6% responded "does not help").

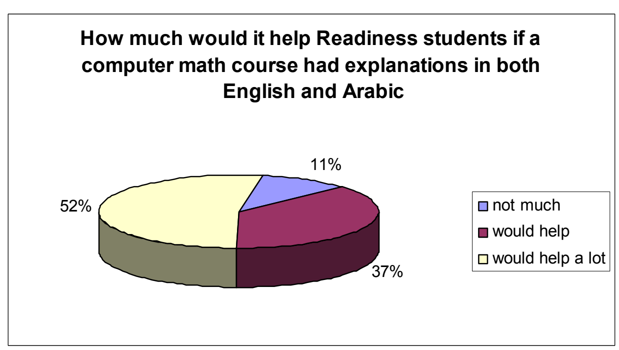
This positive potential is not currently available in some major online math courses which require connection to the Internet or a university Intranet. The next question was similar, asking whether it helped to do exercises and tests at their own speed. Most felt it did, although responses were more mixed than the previous question (68% felt they learned more or a lot more at their own speed, 21% same, and 11% felt that they learned less because it made them lazier).




A question not directly related to computer-based learning drew the most unanimous response: "How do you feel about the teacher emailing students the grade sheet at least once a week." All students chose the response: "Seeing everyone's grades motivates me and helps me do better." The ZU Math101 software graded all homework exercises and tests. However, entering the homework scores into an Excel spreadsheet was time consuming. Before emailing the grade spreadsheets, an Excel macro stripped student names from the spreadsheets, and ordered the overall performance from best to worst. As noted above, this feature of the course may not be suitable in some cultures. Additionally, it may not be available on major courseware delivery systems, and the extra work required to give this motivational feedback should be considered by teachers who use such systems.

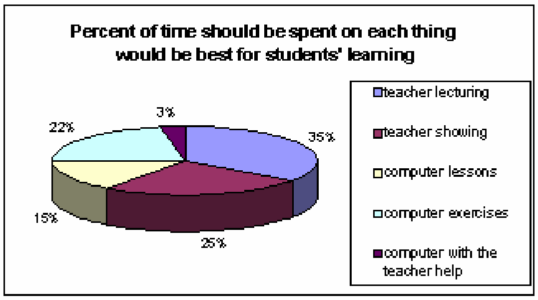


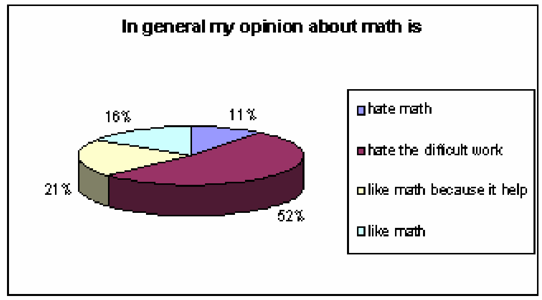




The next question was interesting in relation to the university's plans for changing the developmental math course. Students were asked what they thought about the university's plan to implement an online MTH101 course at an earlier stage in the students' academic path (i.e., within, rather than after, the college entry preparation program). Responses indicated that most students thought it might work but were doubtful (57%), while somewhat fewer students (37%) thought it would not work well unless there was a teacher with regular classes. One student thought it would work, and one thought it was a bad idea.

Most students thought it would help if a computer math course had explanations in both English and Arabic (52% felt it would help a lot, 37% felt it would help, and 11% felt it would not help much). Students may not have had to deal with mathematics terms in English before they come to the university.

The next question asked students to give the percent of each activity that would be best for students learning. Averages for each category were as follows:




**CONCLUSION**

Contrary to common perceptions about computer-based education, the overall structure of ZU Math101 course included considerable personal teacher involvement. The descriptions above indicate several curricular features alongside the computer-based courseware that are important for a particular type of student population. An optimal mix of teaching strategies involved easy access to the computer software, instant feedback and scoring by the computer, interpersonal coaching and motivation by the professor, and social reinforcement consisting of constant feedback on students' performance related to the group. Lastly, in addition to facilitating quality time in the teacher-learner relationship, some of the successful features of a computer-based course noted above can provide rewarding feedback for the instructor:

<u>Comments  from students evaluations of the ZU Math101 course</u>

"The instructor is a great teacher. He teaches us different ways of solving the problems and then he chooses the easiest one for us. He cooperates with us in class and even if we go to his office."

"He was an excellent teacher. He was helping the students in this course. We love math from his way of teaching."

**REFERENCES**

Burns, H., Parlett, J.W., and Redfield, C.L. (1991). <u>Intelligent tutoring systems: Evolutions in design.</u> Hillsdale, NJ: Lawrence Erlbaum Associates.

CSBE (1992). <u>California State Board of Education: Mathematics framework for public schools.</u> Sacramento, CA: California Department of Education.

Cumming, G. (1994). The teacher-learner-computer triangle in CALL frameworks for interaction and advice. . <u>Computer Assisted Language Learning, 7</u>(2), 107-123.

Lajoie, S.P., and Derry, S.J. (1993). <u>Computers as cognitive tools.</u> Hillsdale, N.J.: Lawrence Erlbaum Associates.

NCTM (2000). <u>Principles and standards for school mathematics.</u> Reston, VA: National Council of Teachers of Mathematics.

Perkins, D.N., Schwartz, J.L., West, M.M., and Wiske, M.S. (1995). <u>Software goes to school: teaching for understanding with new technologies.</u> New York: Oxford University Press.

Pimm, D.  (1987). <u>Speaking mathematically: communication in mathematics classrooms .</u> New York: Routledge, Chapman, and Hall.

Polson, M.C., and Richardson, J.J. (1988). <u>Intelligent tutoring systems.</u> Hillsdale, NJ: Lawrence Erlbaum Associates.

Psotka, J., Massey, L.D., and Mutter, S. (1988). <u>Intelligent tutoring systems: Lessons learned.</u> Hillsdale, NJ: Lawrence Erlbaum Associates.