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THE EFFECT OF AN INTELLIGENT TUTORING SYSTEM (ITS) ON STUDENT ACHIEVEMENT IN ALGEBRAIC EXPRESSION

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In this experimental study, use of Computer Assisted Instruction (CAI) followed by use of an Intelligent Tutoring System (CAI+ITS) was compared to the use of CAI (CAI only) in tutoring students on the topic of Algebraic Expression. Two groups of students participated in the study. One group of 32 students studied algebraic expression in a CAI learning environment, while the other group of 30 students was in a CAI and ITS (CAI+ITS) environment. Before the experimental treatment began, subjects were given a pre-test on algebraic expression. A post-test was also given at the end of the study. The experimental treatment was administered in eight sessions with one hour per session. For the first stage of the study, both groups of subjects studied algebraic expression in a CAI environment. In the second stage, subjects from the CAI group continued with a tutoring session using the drill and practice section of the CAI package, whereas subjects from the CAI+ITS environment continued their learning using the ITS tutorial. The results of the study showed that there was a significant difference in the students' achievement in algebraic expression between students who learned with CAI+ITS and who learned with CAI only as the delivery system. The findings of the study indicated that CAI+ITS was more effective in helping students learn algebraic expression as compared to using CAI alone. This study suggests that educators and software developers should focus on the development of ITS based learning tools or integrate ITS elements in courseware development rather than developing a mere CAI tool.

Key Words: intelligent tutoring system, computer assisted instruction, mathematics learning

INTRODUCTION

While CAI may be somewhat effective in helping learners, it does not provide the same kind of personalised attention that a student would receive from a human tutor (Ester, 1994). In order to achieve a more efficient learning environment and to deliver the best learning process, research on ICT in mathematics education is focusing on the area of Artificial Intelligence (AI). Ester (1994) asserted that AI is able to prepare a more human-based interactive learning environment for students. A human based interactive learning environment is important because it involves students in active learning.

Heffernan (2001) stated that as the techniques of AI become widely known and appreciated in the field of educational computing, AI with interests in education has also undergone changes in direction. He also stressed that the overall aim of developing AI is to enable the computer to be effective and act as a knowledgeable agent in the teaching and learning process. A major strand of research has been the design of the so-called Intelligent Tutoring Systems (ITS) which require knowledge representations to provide models of the subject domain, the learner capabilities, and the tutorial pedagogy (Heffernan, 2001). Canfield (2001) defined ITS as a system that is able to diagnose and adapt to students' knowledge and skills. According to Canfield (2001), an ITS is able to provide precise feedback when mistakes are made and able to present new topics when the student is ready to learn. Intelligent tutoring systems are part of a new breed of instructional computer programs.

The objective of an ITS is to provide a teaching process that adapts to the students' needs by exploring and understanding the students' special needs and interests (Kaplan & Rock, 1995). Research in the field of ITS has always had a strong focus on the development of comprehensive student models, based on the assumption that within a problem-solving context, learners' thinking processes can be modelled, traced, and corrected using computers (Siemer-Matravers, 1999).

According to McArthur, Lewis, and Bishay (1994), ITS attempt to capture a method of teaching and learning exemplified by a one-to-one human tutoring interaction. They further assert that one-to-one tutoring allows learning to be highly individualized and consistently yields better outcomes than other methods of teaching. Unlike previous CAI systems, ITS represent some of the knowledge and reasoning of good one-to-one human tutors, and consequently can coach in a much more detailed way than CAI systems.

In relation to this, previous studies have indicated that students always face difficulty in learning algebraic expression in mathematics (Booth, 1984, 1988; Greeno, 1982; Kieran, 1988; Lins, 1990). According to Chick et al. (2001), students who have difficulties in solving mathematics problem such as algebraic-related mathematics problems usually have problems keeping up with classroom instruction. In an effort to help students overcome these learning problems, some studies have discovered the potential of self-paced CAI as a delivery system.

Further exploration need to be conducted whether CAI, ITS or both CAI and ITS would benefit students in the learning. Studies have shown that use of ITS had shown improvement in student's performance in algebra (Abidin and Hartleyt, 1998; Moundridou and Virvou, 2002). Likewise, in Mohammad Naim and Finch's (2001) study on the learning of Technical Education, they had also found that ITS was significantly more effective than conventional CAI. Consistent result was also found in studies conducted by Koedinger et al. (1997).

Thus, in order to find out which of the learning environments, the ITS or the CAI environment, is more suitable to help students in their learning of algebraic expression, this study attempts to investigate and compare the effectiveness of a CAI plus ITS (CAI+ITS) based approach and a CAI only approach in the learning of mathematics among secondary school students.

The ITS systems in this study refers to the expert system, Ms Lindquist, that was presented based on dialog-based interaction with student. It was developed by Heffernan (2001). It is able to diagnose the learner's action in order to infer the learner's cognitive state, such as his or her level of knowledge or proficiency. Hence, the CAI+ITS intervention represents a combination of a CAI approach followed by an ITS tutorial in the learning of algebraic expression among the subjects in this study.

METHOD

This study adapted a pre-test post-test control group experimental design. The design of this study is represented in Figure 1. In determining the effectiveness of ITS in helping students learn, this study involves independent variables which include two different combinations of delivery systems, CAI+ITS, and CAI only. The dependent variable is students' achievement in algebraic expression. As illustrated in Figure 1, students were randomly assigned to the experimental group and control group (R). Both groups took the pre-test (O_1)

before the start of the experiment. The two groups later followed a three-hour learning session using the CAI courseware. The students were instructed to go through the tutorial section of the courseware. The researcher monitored the whole process to ensure that students were on the instructed tasks. Once both groups have learnt the content using the courseware, the experimental group were given the treatment, which is in the form of sessions using the ITS tutorial. On the other hand, the control group underwent further learning using the exercise and e-test sections of the CAI courseware. Upon completion of the treatment, both groups of students took the post-test (O_2). For the purpose of referring to the groups, the experimental group is named CAI+ITS group and the control as CAI only group. Pre-test on Algebraic Expression, administered before the experiment, was used as a covariate to control individual differences.

Experimental	R	O_1	X	O_2
Control	R	O_1		O_2

Figure 1: Experimental Design in the Study

This study was conducted over a period of eight school days. Manson and Bramble (1997) pointed out that the longer the time spent, the greater the probability that something could influence the subjects' environment that in turn would affect the results. Duration of eight school days was deemed appropriate to see effects of the experimental treatment. All the subjects in this study sat for the same pre-test and post-test. Thus, threats to internal validity such as maturation, instrumentation bias, history and regression were not serious threats to the internal validity of the study.

The sample consisted of 62 respondents, approximately half of them were males (n=34), while the rest were females (n=28). The respondents were selected among Form One students (equivalent to Grade 7 in the United States) in a secondary school and their ages range between 12 to 13 year olds. Form one students were selected in this study because they had not learnt the topic on algebraic expression, which will only be taught in Form Two (Grade 8) Mathematics in Malaysia. Hence, the subjects in this study can be considered as not having had any knowledge on algebraic expression when this experimental study was administered. This is to ensure that the students did not have prior knowledge in the mathematics content used in this study.

After getting the list of students for the two classes that participated in this study, the researcher randomly assigned the subjects into the two different groups, namely, the CAI+ITS experimental group and the CAI-only control group. The school selected for the study was equipped with more than 100 computers in its computer labs and English is widely used in instruction. The school required all students to attend computer classes. This reduces any inconvenience in carrying out the study that might be due to students' unfamiliarity with the use of computers in learning. During the time that the experiment was conducted, which was in 2003, Malaysia just shifted to the use of English in the teaching of mathematics, which was previously conducted in the Malaysian national language. However, during the transition period, most schools were not teaching fully in English as was determined by the Ministry of Education. Therefore, the school selected also reduces the problem of students not understanding the ITS and CAI contents which were in English.

INSTRUMENTATION

Two equivalent sets of mathematics tests were prepared; a pre-test and post-test. A panel of mathematics teachers who had at least three years of teaching experience was consulted to validate the mathematics tests and to ensure that the items were equivalent. Reliability of the mathematics tests were 0.87.

Each of the tests comprised of 15 items on algebraic expression. The test items were based on the learning outcomes as stated in the syllabus of Form Two Mathematics. The test covered the concept of algebraic terms in two or more unknowns, computations involving multiplication and division of two of more terms, writing algebraic expressions for given situations using letters to represent unknowns and computations involving algebraic expressions. The tests were scored from 0 to 100.

Subjects of the study underwent learning using the CAI courseware and/or the ITS system. The following section elaborates on the teaching materials used.

CAI Courseware

In Malaysia, each of the text books used for a particular school year must be supplemented with a courseware. The CAI courseware comes with the text book and is not for sale separately. For each school year, eight text books are approved and endorsed to be used in schools by the Textbook Division of the Ministry of Education. The CAI courseware selected for use in this study was the one developed by Pelangi Mindedge. Thus, a written permission was obtained from Pelangi Mindedge. For this study, the students were asked to go through the chapter on Algebraic Expressions. The chapter comprises of four contents; concept of algebraic terms in two or more unknowns, computations involving multiplication and division of two or more terms, concept of algebraic expressions, and computations involving algebraic expressions.

The courseware contains six main menus, namely user guide, navigator, contents, e-test, e-journal, and multimedia gallery. To familiarize students with the courseware operations, they were encouraged to explore the user guide menu. The student selected the specified content they want to learn from the navigator or content menu. The chapter is also provided with the exercise corner, website links, simulator, glossary and media gallery. The exercise corner is meant to determine the student's understanding of the concepts taught in the chapter, whilst the e-test section provides students with ten objectives questions that can be randomly selected from the database. Students can try the tutorial from e-test section as many times as they want.

The website link menu provided extra information regarding the mathematics concept. Besides helping students to master the mathematics concept, the courseware provides a simulation game that allows users to learn mathematical concepts by experimenting with numbers. Users can type in numbers and select calculation mode. The answers will then be processed and displayed immediately. The glossary and media gallery sections help students to understand the meaning of mathematics terms used in the courseware.

ITS Software

The ITS-based algebra learning software used in this study was 'Ms Lindquist' created by Heffernan (2001). Permission to use this instrument was obtained from the author. This software is developed to guide students in learning algebra. To start using the program, Ms Lindquist requires students to key in their current level of algebraic knowledge. The selection of levels of algebraic knowledge, as given by the program are (i) one-operator problems; (ii) one-operator involving distance, rate, and time; (iii) two-operator linear forms; (iv) two-operator problems with some involving division and parentheses; and (v) three and four operator problems. Students need to choose their current level of algebraic knowledge before they can start the tutorial session with Ms Lindquist.

After logging into the Ms Lindquist program and making the selection of their current level of algebraic knowledge, students were given an algebra problem and were asked to solve the expression to symbolize the problem. Once the student obtained the correct answer, Ms Lindquist gave the second question based on its analysis of the way the student answered the first question.

Throughout the learning process, Ms Lindquist provided a step-by-step guide to help the student to solve the entire algebraic problem. This is carried out by the dialog-based technique that is built in Ms Lindquist. By the end of the tutoring session, the students were given a feedback of their current level of algebraic knowledge. The system also provided suggestions to the student on ways to perform better in future study of algebra.

In addition, students can leave the system anytime. The system will save all the interactions between the system and the student in the database. Hence, the teacher can check back the students' performance throughout the entire tutoring session. The content of this ITS software focused on algebraic expression, guiding students to write algebraic expressions for given situations using letters to represent unknowns. The researcher had showed the content of the ITS software to panel teachers who developed the test items to ensure that the test items are equivalent to the content in the ITS used in the study. This is to ensure that the coverage of contents in Ms Lindquist is similar to the coverage of contents for the topic 'Algebraic Expression' in the Malaysian Form Two (equivalent to United States Grade 8) Mathematics syllabus.

PROCEDURES OF STUDY

The students' process of learning algebraic expression using the CAI and CAI+ITS approaches is explained in Figure 2. A pre-test was administered before the experimental session began. Both groups of students, the experimental and control group, were provided a session to learn using the CAI courseware selected. There were asked to go through the content on introduction of algebraic terms and followed by algebraic terms in two or more unknowns. After going through the introduction on the concept of algebraic expression, students were asked to go through the section on computations involving multiplication and division of two or more terms.

Once both groups have gone through the learning session using the CAI courseware, the control group was assigned to a CAI-based tutorial whereas the other group sat for the ITS-based tutorial. Students who proceeded to the e-test section of the CAI courseware were required to answer a series of algebraic expression exercises. Based on the students' performance, the courseware provided feedback such as 'poor', 'average', or 'good'.

Those who proceeded with the ITS were engaged in a dialogue-based tutorial environment with Ms Lindquist. Based on the students' responses, the ITS provided feedback from time to time to guide them in understanding the concept of algebraic expression. After five hours of tutorial lessons, both groups of students were then given the post-test on the topic `algebraic expression'.

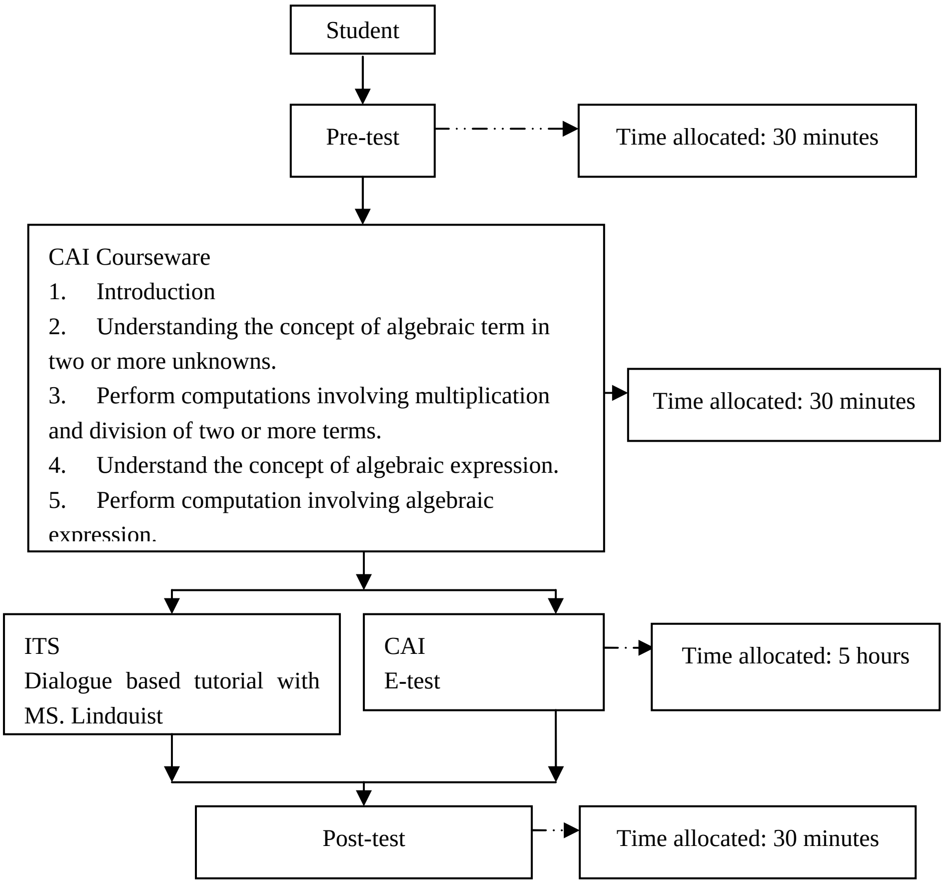

Figure 2: Procedures of Study

FINDINGS

Table 1 shows data for the two groups of respondents. The mean score for pre-test of the experimental group (CAI+ITS group) was 27.60, while the post-test for this group was 51.36. Paired-sample t-test among respondents in CAI +ITS group for pre-test and post-test (t (29) = -9.47, p < .05) indicated that there was significant differences between pre-test and post-test achievements. The mean gain score for this group of respondents was 23.76.

Whereas for the control group (CAI only group), mean score of the pre-test for the respondents was 22.11 and the post-test was as 34.33. A paired sample t-test (t (31) = -13.95, p < .05) indicated that there was a significant difference between pre-test and post-test achievements. The mean gain score for CAI only group was 12.22. Thus, both groups of respondents achieved better results in the post-test as compared to the pre-test. However the CAI+ITS experimental group had shown a greater increase in scores between the post-test and the pre-test.

Table 1: Pre-test and Post-test for CAI+ITS and CAI only approach

Group	*n*	*Pre-test*	*Post-test*	*Mean Gain Score*	*t*	*df*	*Sig*
Experimental Group (CAI+ITS)	30	27.60	51.36	23.76	-9.47	29	.00
Control Group (CAI only)	32	22.11	34.33	12.22	-13.95	31	.00

The assumption for homogeneity of regression slopes was tested to check the interaction between the independent variable (delivery system) and the covariate (pre-test). Table 2 indicated that there is no significant interaction among the two variables (F (1,58) = 154.9, p < 0.05). Thus, assumption of homogeneity of regression slopes is not violated. This indicated that there is no interaction between the pre-test and delivery system on students' achievement.

Table 2: Homogeneity of regression test for gain scores for different delivery systems

Source	*df*	*Mean Square*	*F*	*Sig.*
Between group (Delivery System and Pre-test)	1	154.9	2.170	.15
Within group	58	71.40		

A one-way between-groups analysis of covariance (ANCOVA) was conducted to test the effectiveness of the delivery systems in the learning of algebraic expression between the experimental and the control groups. The independent variable was the type of delivery system; CAI+ITS and CAI only. The dependent variable was the gain score on the Algebraic Expression tests.

The preliminary checks were conducted to ensure that there was no violation of assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. Levene's test showed that result was not significant ($p < 0.05$), thus indicated that variance of the dependent variable is equal between the groups.

The result of the ANCOVA is shown in Table 3. As indicated in the table, there was a statistically significant difference between the two delivery systems on gain scores in the Algebraic Expression tests [$F (1,59) = 26.03$, $p < .05$]. Thus, when pre-test scores were set as a covariate, it is shown that gain score is influenced by the delivery systems. Significant difference was established for students' achievement in the learning of algebraic expression between students who use CAI+ITS and students who use CAI only as their delivery system.

Table 3: ANCOVA of Respondent's Gain Scores for Different Delivery Systems

Source	*df*	*Mean Square*	*F*	*Sig.*
Between Group (Delivery System)	1	1895	26.03	.00
Within group	59	72.81		

DISCUSSION

Finding of this study showed that the CAI+ITS approach was significantly more effective than the CAI only approach on students' achievement in the learning of algebraic expression. This finding provides supporting evidence on the benefits of using CAI+ITS in the learning of mathematics. The findings are consistent to those of Moundridou and Virvou (2002), Abidin and Hartleyt (1998), Mohammad Naim and Finch (2001) and Koedinger et al. (1997).

Hence, CAI+ITS is a better aid in guiding learning as compared to CAI-only approach. This is due to the powerful tools in ITS which provide useful feedbacks to learners. The system evaluates student's answer by comparing the given answer to the answer provided by the students into the system. ITS will then generate explanations based on its evaluation of the given answer. As a result, students can construct new knowledge from the feedbacks provided by the system (Siemer-Matravers, 1999).

Earlier works had also highlighted on the inefficiency of CAI courseware in helping students to learn. Piccolo et al. (2001) and Jain and Getis's studies (2003) reported that respondents in CAI group did not show any significant differences in their achievement as compared to the traditional conventional classroom group. Respondents in the CAI group did not perform as well as respondents from the other group in their post-test. Study by Fuchs et al. (2002) showed that computer-assisted practice added little value beyond tutoring and yielded only moderate effects on story problems and real-world problem solving. Similarly, Wang and Sleeman (1993) reported there were no differences in performance and retention level scores between CAI and conventional instruction. Thus, to add to the cost-effectiveness of CAI, other elements need to be incorporated to ensure that it will indeed be more effective than traditional face-to-face instruction.

CONCLUSION

Results of this study revealed that CAI+ITS has potential in mathematics learning via computer applications. The ITS approach appears to have value as an instructional tool for mathematics learning. The fact that these students achieved better results in the CAI+ITS approach indicates that ITS is viable instructional option. The one-to-one tutoring function in ITS enables it to adapt tutoring strategies according to the needs of the individual student. Thus, educators can spend more time to guide weaker students while others learn via ITS tutorials. ITS does not attempt to change the process of education in any radical way but it recognises the strengths of a human teacher and remove teacher's burden in teaching (Wilkinson-Riddle and Patel, 1998).

CAI systems have been developed for a long time and there are various types of CAI systems being used for guiding learning. In Malaysia, most of the learning tools provided are still in the form of a CAI-based tutorial. However, tools such as FunctionLab (Abidin and Hartley, 1998), WEAR (Moundridou and Virvou, 2002) and Animate (Nathan et al., 1992) have been widely used in other countries. Based on the findings of this study and other studies that focused on the effectiveness of ITS, it is timely that elements of ITS are incorporated in the softwares developed for Malaysian students. This would certainly provide opportunities for students to get personalized tutoring in learning mathematics.

REFERENCES

Abidin, B., & Hartley, J. R. (1998). Developing mathematical problem solving skills. *Journal Of Computer Assisted Learning*, 14, 278-291.

Booth, L. R. (1984). Algebra: Children's strategies and errors. Windsor, UK: NFER-Nelson.

Booth, L. R. (1988). Children's difficulties in beginning algebra. In A. F. Coxford, (ed.), The Ideas of Algebra K-12, 20–32. Reston, VA: National Council of Teachers of Mathematics.

Canfield, W. (2001). ALEKS: A web-based intelligent tutoring system. *Mathematics and Computer Education*, *35*(2), 152-158.

Chick, H., Stacey, K., Vincent, Ji. & Vincent, Jo. (2001). Proceedings of the 12th ICMI study conference: The future of the teaching and learning of algebra. Melbourne: The University of Melbourne.

Ester, D. P. (1994). CAI, lecture, and student learning style: The differential effects of instructional method. *Journal of Research on Computing in Education*, 27(2), 129-140.

Fuchs, L.S., Fuchs, D., Hamlett, C.L., and Appleton, A.C. (2002).Explicitly Teaching for Transfer: Effects on the Mathematical Problem-Solving Performance of Students with Mathematics Disabilities. *Learning Disabilities Research & Practice*, 17(2), 90 –106.

Greeno, J. G. (1982, March 19). A cognitive learning analysis of algebra. Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Heffernan, N. T. (2001). Intelligent tutoring systems have forgotten the tutor: Adding a cognitive model of an experienced human tutor. Dissertation and Technical Report, Carnegie Mellon University. Accessed 12th January 2007 from http://www.algebratutor.org/pubs.html.

Jain, C. & Getis, A. (2003). The effectiveness of internet-based instruction: An experiment in physical geography. *Journal of Geography in Higher Education*, 27(2), 153 -167.

Kaplan, R., & Rock, D. (1995). New directions for intelligent tutoring. *AI Expert*, 1(2), 30 - 40.

Kieran, C. (1988). Two different approaches among algebra learners. In A.F. Coxford, (ed.), The Ideas of Algebra. K-12, pp. 91–96. National Council of Teachers of Mathematics, Reston, VA; Lawrence Erlbaum.

Koedinger, K. R., Anderson, J. R., & Hadley, W. H. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, *8*, 30 - 43.

Lins, R. L. (1990). A framework of understanding what algebraic thinking is. In G. P. C Booker & T. N. Mendicuti, (eds.), pp. 93–101.Proceedings of the Fourteenth International Conference of the International Group for the Psychology Of Mathematics Education, Mexico City.

Manson, E. J. & Bramble, W. J. (1997). *Research in education and the behavioral sciences: Concepts and methods.* Los Angeles: A Time Mirror Company.

McArthur, D., Lewis, M., & Bishay, M. (1994). The role of artificial intelligence in education. Retrieved January 25, 2004, from http://www.rand.org/education/mcarthur/papers/role.htm.

Mohammad Naim, Y. & Finch, C. R. (2001). Effectiveness of Computer-Assisted Instruction in Technical Education: A Meta- Analysis. In J. T. Kapes (ed.), *28* (2), 5 – 19.

Moundridou, M. & Virvou, M. (2002). Evaluating the personal effect of an interface agent in tutoring system. *Journal of Computer Assisted Learning*, 18, 253 – 261.

Piccoli, G., Ahmad, R., & Ives, B. (2001). Web-based virtual learning environment: A research framework and a preliminary assessment of effectiveness in basic IT skills training. MIS Quarterly, 25(4), 401 – 426.

Siemer-Matravers, J. (1999). Intelligent tutoring systems and learning as a social activity. *Educational Technology*, September, 29 - 32.

Wang, S. & Sleeman, P. J. (1993). A comparison of the relative effectiveness of computer-assisted instruction and conventional methods for teaching an operations management course in a School of Business. *International Journal of Instructional Media*, *20*(3), 225 – 234.

Wilkinson-Riddle, G. J., & Patel, A. (1998). Strategies for the creation, design and implementation of effective interactive computer-aided learning software in numerate business subjects- The Byzantium experience. *Information Services & Use*, 18(1–2), 127-135.