EVALUATION OF A WEB-BASED MATHEMATICAL PROBLEM-SOLVING COURSE USING A CONSTRUCTIVIST APPROACH

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ABSTRACT

This study was conducted to investigate the effectiveness of teaching a mathematical problem solving course via the Web using a constructivist approach. A total of 37 teacher trainees at teacher training institution were sampled. The participants were required to solve authentic mathematics problems in small groups of 4-5 participants based on the Polya's Model via e-conferencing in a Web-based course. The findings showed that there were no significant changes in the participants' attitudes toward mathematics, while the participants' skills in problem solving for "understand the problem" and "devise a plan" based on the Polya's Model were significantly enhanced, though no improvement was apparent for "carry out the plan" and "review." The findings also showed that there were significant improvements in the participants' critical thinking skills. Furthermore, participants with higher initial computer skills were also found to show higher performance in mathematical problem solving as compared to those with lower computer skills. However, there were no significant differences in the participants' achievements in the course based on gender.

1. INTRODUCTION

The Web represents the second wave of digital revolution that began with the introduction of personal computers in the 1980s (Wilson and Lowry 2000). Worldwide, educational institutions are increasingly using the Web as tools for teaching and learning (Downing 2001; McIsaac and Gunawardena 2001; McKimm, Jollie and Cantillon 2003). In Web-based learning, computer mediated communication (CMC) is commonly employed to facilitate social constructivist learning. According to Gunawardena, Lowe and Anderson (1997), CMC denotes the exchanges of messages between groups of course participants through the use of computer network with the aim to discuss topics of similar interests. CMC comprises emails, Usenet, e-conferencing, which could be supported with audio and video connections (Adrianson 2001). Seng, Chun, Siew and Wettasinghe (2003) propose that CMC competency is one of the important skills to be mastered by the new generation of teachers. Research on teaching and learning using the Web and e-conferencing are still ongoing. However, most of these studies especially those in the local set ting appear to concentrate more on application than theory (Hong 2002). Hence, more research in teaching and learning using web-based environment and e-conferencing ought to be con ducted. This research endeavors to contribute to the literature, especially in the local context.

2. RESEARCH OBJECTIVES

This study investigated if Web-based constructivist learning environment would enhance mathematical problem solving skills, critical thinking as well as students' attitudes toward mathematics. It also studied the impacts of demographic characteristics such as gender and levels of initial computer skills on achievements in the course. A Web-based course on mathematical problem solving with e-conferencing component was developed using a constructivist approach. This mathematical problem solving course is a requisite for the Bachelor Degree in Primary Education (PISMP) Program for participants with the equivalent of GCE "A" entry-level and the Diploma in Education Program (KPLI) for participants with degree qualification entry-level offered by the Department of Teacher Education, Ministry of Education, Malaysia.

3. LITERATURE REVIEW

Problem solving is an important component of mathematics education. Researching based on Polya's Problem Solving Model (1981), Lau, Hwa, Lau and Limok (2003) reported that students' achievements deteriorated sig nificantly with increase in the difficulty level of the mathematics problems assigned to them. Furthermore, Brown (2003) found that teachers generally possessed positive attitudes toward problem solving but were rather weak in their abilities to solve problems. Kosiak (2004), in his research on the quality of online mathematical communication, reported that collaborative mathematical problem solving has a positive impact on mathematics achievements. Dockrill (2003) found that students perceived interactive teaching and learning approaches as facilitating the acquisition of critical thinking skills. In general, Web-based teaching has shown potentials in promoting thinking skills (Saba 2000). Utsumi and Mendes (2000) demonstrated significant differences in attitudes toward mathematics based on variables such as types of schools, stage of schooling, age, students' understanding of mathematical problems solved in class, and students' achievement in mathematics. Vaughan (2002), on the other hand, reported that cooperative learning methods improved students' attitudes toward mathematics. Carter (2004), however, found that the use of Web-based learning did not result in significant improvement in achievements and attitudes toward mathematics. Hong (2002) obtained similar results in terms of attitudes toward statistics course. However, Kinney, Stottlemyer, Hatfield, and Roberston (2004) came to the opposite conclusion. Hong (2002) concluded that gender was not significantly correlated with Web-based learning, although there are studies that reported otherwise (Fredericksen et al. 2000). Findings on the relationship between computer competency and achievements were likewise contradictory (Wen and Truell 2002; Hong 2002). Orr (2001) also stated that findings on students' achievements with respect to Web-based learning compared to classroom-based learning were inconclusive.

4. RESEARCH METHODOLOGY

The study employed the pre-experimental approach without the utilization of control groups (Creswell 1994). Figure 1 shows the research design of the study.

$$O_1 O_2 O_3 \longrightarrow X \longrightarrow O_4 O_5 O_6$$

Figure 1: Research Design

O_1 O_4 : Mathematics achievements test

O_2 O_5 : Questionnaires on attitudes toward mathematics

O_3 O_6 : Questionnaires on competencies in mathematical problem solving

X : Web-based mathematical problem solving course

Quantitative data were collected using questionnaires and tests. The participants were also interviewed. The quantitative data were analyzed statistically while the qualitative data were analyzed using content analysis.

4.1 Participants

The participants of the course comprised of trainee teachers majoring in mathematics education at the Batu Lintang Teacher Institute. Thirty seven trainee teachers were randomly selected from the July 2004 and January 2005 intakes. Eleven of the participants were female and 26 were male, all of them were between 20-30 years of age.

4.2 Web-based mathematical problem solving course

The course aimed to provide trainee teachers with the skills to solve mathematical problems based on Polya's Model. The participants were required to follow the course via the Web without face-to-face interactions between the facilitator (second author) and the participants. All communications were done through e-conferencing. The course consisted of three units - Unit 1: Introduction to problem solving; Unit 2: Mathematical problem solving process; and Unit 3: Problem solving strategies. Unit 3 is further divided into four subunits encompassing strategies such as using tables, drawing diagrams, elimination and working backward.

The constructivist learning environment in this Web-based course was developed based on Jonassen, Peck, and Wilson's Model (1999) as shown in Figure 2. This model enabled the course participants to be actively involved in meaningful learning and had five characteristics, i.e., active, constructive, intentional, authentic and cooperative. Course materials were uploaded to the Web to allow access at any time. The participants were required to have group discussions for the given assignments and had their works uploaded into a public forum to be discussed by participants from other groups. Assessments were done at the end of the course through a mathematical problem solving test.

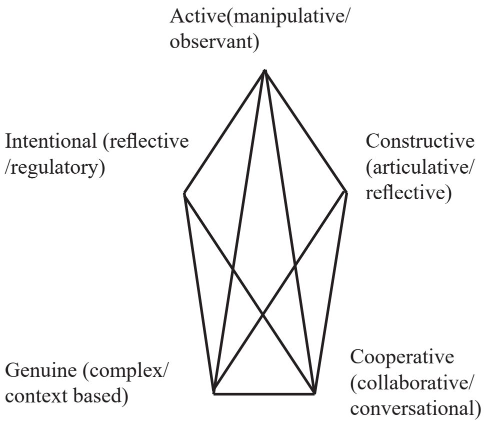

Figure 2: Model for constructivist learning environment

4.3 Research instruments

Collection of data was done through a mathematical problem solving performance test (to measure mathematics achievement, problem solving and critical thinking skills); a questionnaire to determine participants' initial computer and Web skills; a questionnaire on participants' mathematical problem solving skills; and a questionnaire (Aiken Revised Mathematics Attitude Scale) that measures participants' attitudes toward mathematics. The mathematics test and questionnaires were administered to the participants before and after the Web-based course. Follow-up interviews were carried out with the participants at the end of the course.

4.4 Data analysis

The participants' scores and responses to the test and questionnaires were computed and compared using independent and dependent t-tests.

5. RESULTS

5.1 Attitudes toward mathematics

Table 1 shows that there was no significant improvement in attitudes toward mathematics before (pre-test) and after (post-test) completing the Web-based course (t(36)=1.75, p=0.089). However, the means for the pre-test (M = 82.65) and post-test (M = 84.84) indicated that the participants had positive attitudes toward mathematics.

Table 1: Dependent t-test results: Attitudes toward mathematics

	M	SD	t-value	df	p-value
Pre-test	82.65	12.33	1.75	36	0.089
Post-test	84.84	10.26			

Note: Scores of 60 to 100 on the Aiken Revised Mathematics Attitude Scale indicate positive attitudes toward mathematics

The participants perceived the course as being able to enhance their confidence and motivation to learn mathematical problem solving as indicated by the following response during the interview:

> *After the course, I am more motivated to solve mathematical problems using the various methods. I am interested in problem solving in mathematics. Indeed, I would be using mathematical problem solving in my daily live.*

5.2 Critical thinking skills

On critical thinking scores, the pre-test mean score was 48.16 from a total score of 79. This showed that the participants' critical thinking skills were generally low. The mean score for the post-test was 55.14 indicating Note: Scores of 60 to 100 on the Aiken Revised Mathematics Attitude Scale indicate positive attitudes toward mathematics

Table 2: Dependent t-test results: Critical thinking skills

	M	SD	t-value	df	p-value
Pre-test	48.16	15.06	5.52	36	<0.0005
Post-test	55.14	13.33			

The interview data also showed that the participants believed that the Web-based mathematics problem solving course created opportunities for them to think logically, systematically and critically:

The e-conference was collaborative in nature. We can discuss and assist each other to understand and solve mathematical problems.

5.3 Mathematical problem solving skills

The results in this section refer to Polya's four-steps of problem solving. As shown in Table 3, the mean scores for "understand the problem" before (M = 8.09) and after (M = 8.47) attending the Web-based course were satisfactory. For "devise a plan", the mean score of the participants before attending the course was 7.68 and this score indicated moderate level of competency. The mean score after attending the course was 8.02 showing that the level of competency improved to satisfactory. Scores for the participants before and after attending the course for "carry out the plan" and "review" were between 7.38-7.86. These scores indicated that the participants' skills in "carry out the plan" and "review" were just at the moderate level. There were significant improvements in the problem solving skills of "understand the problem" (t(36)=2.25 and p=0.031) and "devise a plan" (t(36)=2.30 and p=0.028). However, there were no significant increases in the mathematical problem solving skills for "carry out the plan" and "review".

Table 3: Dependent t-test results: Problem solving skills.

		M	SD	t	df	p-value
Understand the problem	Pre-test	8.09	1.06	2.25	36	0.031
	Post-test	8.47	0.89			
Devise a plan	Pre-test	7.68	1.06	2.30	36	0.028
	Post-test	8.02	1.02			
Carry out the plan	Pre-test	7.38	0.84	1.61	36	0.116
	Post-test	7.68	0.99			
Renew	Pre-test	7.66	0.98	1.18	36	0.244
	Post-test	7.86	1.10			

5.4 Demographic characteristics and course achievements

Table 4 shows the independent t-tests results. There were no significant differences in course achievements based on gender (t(35)=0.41, p=0.686). However, the achievements of the groups which had low and moderate initial computer skills differed (t(35)=3.548, p=0.001).

Table 4: Demographic characteristics and achievements

		M	SD	t	df	p-value
Gender	Male (n=11)	7.18	7.12	0.41	35	0.686
	Female (n=26)	8.35	8.25			
Initial computer skills	Low (n=16)	3.44	3.18	3.548	35	0.001*
	Moderate (n=21)	11.48	8.60			

*Note : * Significant at $p < 0.05$*

6. DISCUSSIONS

6.1 Attitudes toward mathematics

The findings showed that there was no significant improvement in attitudes toward mathematics. However, findings from the interviews showed that 81.1% of the participants believed that the course was challenging, stimulating and fun for them. The participants also showed positive attitudes toward mathematics. The results of the study indicated that Web-based courses may not necessarily change participants' attitudes toward mathematics; consistent with the results reported by Carter (2004) and Hong (2002).

6.2 Critical Thinking Skills

The outcomes of the study suggested that the course succeeded in enhancing critical thinking skills amongst the participants. The course participants felt that the course gave them the chance to think deeply, logically and systematically, and helped to generate critical thoughts. This finding was consistent with those reported by Lim (2003). The use of authentic problems, e-conferencing and various tools in the Web-based course such as external links to relevant sources enabled the participants to gain new knowledge and they were able to restructure their knowledge scheme. As Chrenka (2001) pointed out, the constructivist framework for learning enables students to restructure their thinking by assisting them to think in increasingly complex ways on the multiple perspectives of a problem and the problem solving process.

6.3 Mathematical problem solving skills

The results showed that there was a significant enhancement in the mathematical problem solving skills of "understand the problem" and "devise a plan" based on the Polya's Model. The participants' skills in "understand the problem" was good before attending the course and it improved further upon completing the course. On "devising a plan", the skills of the participants were at moderate level prior to the course, and they were good at it upon completing the course. There were no significant changes in "carry out the plan" and "review". However, data from the interviews indicated that most participants showed higher interests and motivations toward problem solving in mathematics. Although the participants felt that the problems given were difficult and challenging, they were able to use appropriate strategies to solve them. The participants were able to solve the problems at their own pace and collaborations among participants helped in the problem solving process.

6.4 Demographic characteristics and course achievements

There were no significant differences in achievements in the Web-based course based on gender, consistent with the findings of Hong (2002) and Wang and Newlin (2002). There were, however, significant differences in achievements based on the participants' existing computer skills. The achievements of the participants with moderate computer skills were higher than those with lower computer skills, consistent with the findings of Wang and Newlin (2002), as well as Wen and Truell (2001).

7. CONCLUSIONS

Generally, Web-based courses could successfully enhance participants' course achievements, critical thinking skills and two of the four mathematical problem solving skills (Polya's Model). Participants' existing computer skills could impact on their success in a Web-based course. However, gender is not a factor that could influence success in such courses. The outcomes also suggest that the participants need to be exposed to the use of softwares such as "equation editor", scanner and mathematical graphing software. These computer skills are able to lessen participants' uneasiness in learning through Web-based courses and serve to enhance their confidences as well as motivate them to learn in this new environment. Furthermore, Web-based/ e-conferencing facilitator should ensure that there are interactions among the course participants during the active period of e-conference by giving guidance and moral support to the participants. Additionally, software to monitor participants' involvement in Web-based courses and e-conferencing (such as frequency and length of involvement as well as the web pages accessed by the participants) could be made available to assist facilitators ensure that all participants actively collaborate in the learning activities.

REFERENCES

Adrianson, L. 2001. Gender and computer mediated communication: Group processes in problem-solving. Computers in Human Behavior 17(1): 71-94.

Brown, N.M. 2003. A study of elementary teachers' abilities, attitudes, and beliefs about problem-solving. Unpublished doctoral dissertation, Georgia Southern University, Georgis, US.

Carter, C. 2004. Online instruction self-efficacy beliefs among ccollege students who utilized Web-enhance instruction. Unpublished doctoral dissertation, University of Tennessee, Yennessee.

Chrenka, L. 2001. Misconstructing constructivism. Phi Delta Kappan 82(9): 694-695.

Creswell, J.W. 1994. Research design: Qualitative and quantitative approaches. California: Sage Publication.

Dockrill, P.M. 2003. Facilitating critical thinking in first year community college students. Master's thesis, St. Francis Xavier University, Canada.

Downing, K. 2001. Information technology, education and health care: Constructivism in the 21st century. Educational Studies 27(3): 229-235.

Fredericksen, E., Pickett, A., Pelz, W., Shea, P. and K. Swan. 2000. Student satisfactions and perceived training with online courses: Principles and examples from the SUNY Learning Network. Journal of Asynchronous Learning Networks 4(2), http://www.aln. org/alnweb/journal/Vol4_issue2/le/Fredericksen/LE-fredericksen.htm.

Gunawardena, C.N., Lowe, C.A. and T. Anderson. 1997. Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. Journal of Educational Computing Research 17(4): 397-431.

Hong, K.S. 2002. Evaluation of a Web-based tertiary statistics course using a problem-based learning approach. Unpublished doctoral dissertation, University of Otago, Dunedin, New Zealand.

Jonassen, D.H., Peck, K.L. and B. G. Wilson. 1999. Learning with technology. NJ: Prentice Hall.

Kinney, D. P., Stottlemyer, J., Hatfield, J. and D. F. Robertson. 2004. A comparison of the characteristics of computer-mediated and lecture students in development mathematics.Research & Teaching in Development Education, http://www.findarticles.com/p/articles/mi_qa4116/is_200410/ai_n9465336.

Kosiak, J.J. 2004. Using asynchronous discussions to facilitate collaborative problem solving in college algebra. Unpublished doctoral dissertation, Montana State University, Bozeman, Montana.

Lau, N.K., Hwa, T.Y., Lau, S.H. and S. Limok. 2003. The thinking processes of mathematics problem solving of form four secondary school students. Institute Learn and Commercialization research report, MARA University of Technology, Sarawak, Malaysia.

Lim, S.K. 2003. Pembelajaran berasaskan Web: Kesan pendekatan konstruktivis berbanding pendekatan langsung. Unpublished doctoral dissertation, University Science Malaysia, Penang, Malaysia.

McIsaac, M. and C. Gunawardena. 2001. Distance education. In Handbook of research for educational communication and technology, edited by D.H. Jonassen, 403-437, http://www. aect.org/Intranet/Publications/edtech/13/index.html.

McKimm, J., Jollie, C. and P. Cantillon. 2003. Web-based learning. British Medical Journal 326(7394): 870-873.

Orr, W. 2001. A significant difference, http://teleeducation.nb. ca/content/articles/English/A-Significant Difference html

Polya, G. 1981. Mathematical discovery: n understanding, learning and teaching problem solving. NY: John Wiley.

Saba, F. 2000. Research in distance education: A status report" International Review of Research in Open and Distance Learning, http://www.irrodl.org/index.php/irrodl/article/view/4/24.

Seng, C.H., Chun, H., Wong, S.K. and C.M. Wettasinghe. 2003. "Teacher training on technology-enhanced instruction-A holistic approach." Educational Technology and Society 6(1).

Utsumi, M.C. and C. R. Mendes. 2000. Researching the attitudes towards mathematics in basic education. Educational Psychology 20(2): 237-243.

Vaughan, W. 2002. Effects of cooperative learning on achievement and attitude among students of color. Journal of Educational Research 95(6): 359-364.

Wang, A.Y. and M. H. Newlin. 2002. Predictors of performance in the virtual classroom. Technological Horizons in Education 29(10), http://www.thejournal.com/magazine/vault/A4023.cfm

Wen, Y.H. and A. D. Truell. 2001. Student achievement and evaluation of fully Internet-dependent learning. Journal of Online Learning 12(1), http://www.iste.org/sigtel/bulletin/12/1/wen.html.

Wilson, B. and M. Lowry. 2000. Constructivist learning on the Web. In Learning Technologies: Reflective and Strategic Thinking, edited by L. Burge, 125-135. San Francisco: Jossey-Bass.