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Adoption of Wxmaxima Software in the Classroom: Effect on Students' Motivation and Learning of Mathematics

[1,2]*Ahmad Fauzi Mohd Ayub, [1,2]Rohani Ahmad Tarmizi, [1]Kamariah Abu Bakar & [2]Wong Su Luan

[1]Institute for Mathematical Research, Universiti Putra Malaysia 43400 UPM Serdang, Selangor, Malaysia

[2]Faculty of Educational Studies, Universiti Putra Malaysia 43400 UPM Serdang, Selangor, Malaysia

E-mail: afmy@.upm.edu.my

*Corresponding author

ABSTRACT

This study investigates the effect of usage of an open-source software, WxMaxima, on students' achievement in calculus scores and their motivation towards learning mathematics using the software. The study involved of 62 secondary school students (32 in the treatment group, 30 in the control group) in a Malaysian school. ANCOVA analysis showed that that the group with access to WxMaxima achieved significantly better test scores as compared with the group which followed the traditional teaching method. Students in the treatment group were also better motivated towards learning mathematics; they were more attentive and showed more confidence in learning calculus. However, there was no significant difference in terms of 'satisfaction' in learning mathematics between the two groups. The results from this study suggest that the integration of computer technology in the teaching and learning of calculus and of mathematics in general was generally beneficial.

Keywords: Open source software, WxMaxima, mathematics, calculus, motivation.

1. INTRODUCTION

The evolution of information technology, in particular computer technology, has resulted in changes in the teaching and learning of mathematics. The application of information technology has been shown to enhance students' learning (NCTM (2000)). As such, the integration of technological tools such as computers and educational software into classroom teaching and learning is encouraged. This development has stimulated much discussion on how mathematics could be taught effectively and in a manner that is more enjoyable to the student. Hershkovitz and Schwartz (1999) suggest that the paper-and-pencil environment is relatively passive in supporting learning as compared with the ICT integrated environment. According to Knuth and Hartman (2005), integrating technology into the classroom could increase students' motivation for learning, facilitate understanding and provide better opportunity for practice and learning reinforcement of the subject matter. Nevertheless, questions still arise as to the effectiveness of such modern approaches in enhancing students' understanding and learning.

Many different forms of modern technology can be used in teaching and learning mathematics in the classroom. Among the most widely used mathematical software for teaching and learning algebra is the Computer Algebra Systems (CAS), which includes programmes such as Mathematica, Maple and Derive. For geometry, one of the most popularly used applications is the Dynamic Geometry Software (DGS). An important feature in DGS is the drag mode, which encourages interactions between teachers, students and the study subject (Jones (2000)). The software can also be used to explore and visualize mathematics concepts by dragging objects and transforming figures (Ruthven (2005)). Such an approach to learning is beyond the scope of traditional paper-and-pencil geometry. In fact, previous studies investigating effective ways of teaching geometry suggest that DGS could help students visualize geometric concepts and understand geometric rules, generalizations and relationships between the concepts (Jones (2000); Marrades and Gutierrez (2000)). Since such software has to be purchased, their acquisition could be a burden for teachers and students. The monetary cost has in fact been identified as one of the barriers in integrating technology in the teaching and learning mathematics. The introduction of open-source software is one approach to overcoming the problem and offers mathematics school teachers the opportunity to integrate its use into classroom teaching and learning. Software such as *SAGE, GeoGebra, WxMaxima* and others can be downloaded free of charge for use in the mathematics class. WxMaxima is a cross-platform graphical front-end for the computer algebra system Maxima that is based on wxWidgets. It is a symbol-based mathematical software providing a number of functions for algebraic manipulation, calculus operations, matrix and linear algebra, and other mathematical calculations. It provides attractive displays of mathematical output and easy access to Maxima functions through menus and dialogues.

Many researchers have conducted studies to examine the effectiveness of using DGS for teaching and learning mathematics. Among the latest studies is that by Guven (2012) who examined the effect of DGS on the learning of transformation geometry using a pre and post-test quasi-experimental design. The results of a covariance analysis showed that the experimental group outperformed the control group not only in academic achievement but also in the levels of learning transformation geometry. Erbas and Yenmez (2011) designed an experimental study on sixth grade students' learning of polygons and the congruency and similarity of polygons using the *Geometer's Sketchpad*. Findings showed that the computer software enabled substantial improvement in the students' achievement, aroused greater interest and motivation toward learning geometry, as compared with students in the control group. Tutak and Birgin (2008) investigated the effects of computer-assisted instruction on students' geometry achievement in a fourth grade geometry course. They showed that the computer-assisted instruction had a significant effect on the students' geometry achievement as compared to traditional style instruction. In a local study by Ahmad Tarmizi, Mohd Ayub, Abu Bakar and Md. Yunus (2010) found out that students performance utilizing the Autograph software was found to be more superior significantly, compared to the conventional learning mode

However, a study by Hull and Brovey (2004) found no significant difference in students' achievement when they used DGS. A study by Spradlin (2009) also showed no significant difference in algebra test results between students exposed to computer assisted learning and those who were taught the conventional way. Similar findings also shown in a study by Abu Bakar, Mohd Ayub and Ahmad Tarmizi (2010) comparing the effectiveness of an open source software, GeoGebra and two courseware (e-transformation and V- transformation). Finding from this study showed that there was no significant difference in the post test scores of each of the three topics included in the software. Thus it can be seen that findings from various studies show no consensus on the benefits of using computer technology to teach mathematics in the classroom.

Besides students' test achievements, psychological factors were also evaluated by researchers in studies on the use of information technology in the classroom. An area that has attracted much interest is students' motivation to learn. Motivation refers to the desire in a person to achieve a goal or perform any tasks (Keller (2010)). It is linked to emotions that are manifested either in a positive sense (interest, joy) or a negative sense (frustration, anger), depending on whether the situation is in line with motivation or not (Hannula (2006)). With regard to the learning of mathematics, especially geometry, Furinghetti and Paola (2008) explains that there are many possibilities available to motivate students through dynamic geometry activities; students can play an active role in rediscovering geometric concepts and theorems by themselves. Appropriate software provides opportunities for self-discovery and thus enhances the effectiveness of learning. Students will not only be able to realize the verification function of proof, but also be motivated to explain why their own conclusions are true, and to show Psychologically, when students perceive learning mathematics as an enjoyable, interactive process, they will be motivated to learn (Middleton and Spanis (1999)). Gabrielle's (2003) study showed that students who were exposed to technology application based on the ARCS Model had significantly higher motivation compared to the control group. Pollanen (2007) also found that students who were enrolled in online courses had a significantly higher level of motivation that those attending conventional classes. Similar findings were also reported by Abu Bakar *et al*. (2010) when comparing students' motivation in learning transformation using computer-assisted instruction. In their study on students' performance and motivation using computer games, however, Kebritchi, Hirumi and Bai (2010) noted that students in the experiment group performed significantly better only in the test but there was no corresponding improvement in terms of their motivation level.

The present study examined the effectiveness of using an open-source mathematical software (WxMaxima) in the teaching and learning of mathematics. It was hypothesized that the hands-on applications of a dynamic geometry software could add excitement and increase motivation to master calculus.

2. RESEARCH OBJECTIVES

The main aim of this study was to identify the effectiveness of using WxMaxima software in the teaching of calculus, compared with the traditional way of teaching. The study also investigated the effect on students' motivation in learning mathematics.

The hypotheses of this study were as follows:

H_1 : There is no significant difference in post-test scores between the experimental group and the control group.

H_2 : There is no significant difference in post-test motivation mean scores for the attention dimension between the experimental group and the control group.

H_3 : There is no significant difference in post-test motivation mean scores for the relevance dimension between the experimental group and the control group.

H_4 : There is no significant difference in post-test motivation mean scores for the confidence dimension between the experimental group and the control group.

H_5 : There is no significant difference in post-test motivation mean scores for the satisfaction dimension between the experimental group and the control group.

H_6 : There is no significant difference in post-test overall mean scores for motivation between the experimental group and the control group.

3. RESEARCH METHODOLOGY

This study used a non-randomized pre-post test quasi experiment to investigate the effectivenes students' achievement and motivation between one group that used WxMaxima software and another group that was taught using the conventional method. This study was conducted at a secondary school in Kuala Lumpur. Two classes from Form 4 were randomly picked and assigned as control group and experiment group. A total of 62 respondents were involved in the study; 32 of them were assigned to the experimental group and 30 were assigned to the control group. For the experiment group, researchers had developed eight modules for learning calculus using WxMaxima to be used throughout the study. The two calculus topics selected for this study were differentation and integration. For the control group, modules were also developed for the study, but this class was taught using conventional teaching methods.

The experimental study was completed in 10 weeks. In the first week, a pre-test was given to the students, who were subsequently given a post-test and survey after completion of the experimental process. Students from both groups were provided with an explanation of the purpose of the study, and received instructions on how to fill out the questionnaire. In this study, the Instructional Materials Motivation Survey (IMMS) by Keller (1987), based on the ARC motivation model, was adapted to measure students' motivation in learning calculus. In this study, motivation concerned the students' motivation to learn in terms of four dimensions. The first dimension, attention (ATT), measured the degree to which the method used in the two groups could initiate and sustain learner motivation during the experiment process. The second scale, relevance (REL), examined whether the students could perceive the value and utility of what was taught. The third scale, confidence (CON), measured the degree to which students felt they could successfully accomplish the goals and tasks laid out during the class. Finally, satisfaction (SAT), measured feelings of accomplishment and intrinsic appeal by the respondents during the lesson. All four scales consisted of six items. For the IMMS, a total of 24 items were used, based on the ARCS model using a 4-point likert scale ranging from 1 (Strongly disagree) to 4 (Strongly agree). This instrument hs been validated by two lecturers who are experts in this field. A pilot study has been conducted before the actual test to test the reliability of the instrument. The cronbach alph for each scale are as follows: attention (.865), relevance (.785), confidence (.831) and satisfaction (.851).

4. FINDINGS

The analysis of the findings was based on the hypotheses of the study. The first hypothesis examined whether using WxMaxima helped students to achieve better test scores compared with students taught the traditional way.

H_1 : There is no significant difference in post-test scores between the experimental group and the control group.

A one-way between-group analyses of covariance (ANCOVA) was conducted to compare the effectiveness of two different types of mathematics teaching. The independent variables were the two groups (WxMaxima group and Traditional group) while dependent variables were the post-test scores after conducting the experiment for 10 weeks. The pre-test scores were used as the covariant in this study. The analysis showed a significance difference ($p<0.05$) between pre-test scores and post-test scores [$F = 22.087$, $p = 0.000$, eta squared = .272] (Table 1 and Table 3). Further analysis also showed that there was a significant difference on post-test scores between the control group and the experimental group [$F (1,59) = 46.8$, $p = .000$; eta squared = .442]. Students taught using WxMaxima scored an average of 59.06 marks as compared with 36.00 marks for students who underwent conventional teaching (Table 2).

Thus, the hypothesis was supported. This finding indicates that, after controlling the pre-test scores, students who had been exposed to the use of WxMaxima achieved significantly better scores as compared with those who had been taught using the conventional method.

TABLE 1: Levene's Test of Equality of Error

F	Df1	Df2	Sig
.025	1	60	.873

TABLE 2: Descriptive Statistics

Group	Mean	Std. Deviation	N
WxMaxima	59.06	18.77	32
Control Group	36.00	16.89	30

TABLE 3: Test between Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	13463.074	2	6731.54	28.441	.000	.491
Intercept	6572.809	1	6572.81	27.770	.000	.320
Pre-test	5227.530	1	5227.53	22.087	.000	.272
Class	11076.336	1	11076.336	46.798	.000	.442
Error	13964.345	59	236.684			
Total	1697000.000	62				
Corrected Total	27427.419	61				

R squared = .491 (Adjusted R Squared = .474)

The next section of the findings examined whether there were any differences in students' motivation during mathematics lessons using WxMaxima compared to those taught by conventional methods. The following discussion will answer hypotheses 2 (H_2) to hypotheses 6 (H_6). Findings indicated that students exposed to WxMaxima were more highly motivated across all the scales (ATT, M=3.71; REL, M=3.49; CONF, M=3.66; SAT, M=3.69; and MOT, M=3.64) than traditional group (ATT m=3.17; REL, M=3.02; CONF, M=3.06; SAT M=3.50, and MOT, M=3.18).

In order to determine the statistical significance of each item between the two groups, an independent sample t-test was conducted (Table 4). For the first dimension (Attention), the results showed statistically significant differences at the $p<.05$ level in four items.

The first item, ATT1 ($p=.000$), indicated that the use of WxMaxima promoted interest and captured the students' attention during mathematics class. The mathematics class taught using WxMaxima also stimulated their curiosity (ATT6, $P = .039$). Two negative items (ATT3, ATT5) showed that students taught using WxMaxima did not find the class dry and unappealing ($p = .002$). The students also did not feel frustrated or irritated when the teacher used WxMaxima during mathematics class ($p = .046$). Overall, the students felt that using WxMaxima could hold their attention in class better as compared with the conventional way of teaching ($p = 0.005$).

The second dimension (relevance) of the statistical analysis showed significance differences on four items (REL1, REL2, REL5 and REL6). For the first item, the respondents felt that when using WxMaxima, they could relate what they had learnt to their previous knowledge ($p = .034$), and the information learnt would be important to them ($p = .043$). WxMaxima could also help them to relate the mathematical content to real-life experiences, i.e. what they had seen, done or thought about in their own life. Accordingly, the respondents did not feel that the mathematics content given in WxMaxima contained no useful information ($p = .018$). Overall, students exposed to WxMaxima perceived that the materials provided in the class was of value and utility to them ($p = .009$).

The third dimension in ARCS motivation model was to measure the students' confidence in learning mathematics. Responses to three items, CONF1, CONF2 and CONF5 (the latter two being negative items) were statistically significant and indicated a favorable outcome in the group using WxMaxima. Students shown a good impression towards mathematics as they agreed with the statement "When I first looked at this lesson, I had the impression that it would be easy for me" ($p = .000$). Students using WxMaxima did not find the mathematics lesson as difficult as they had expected ($p= .000$), or that the exercises provided were too difficult ($p = .007$). Overall, they felt very confident in learning mathematics using WxMaxima, compared to those in the control group ($p = .000$).

The final dimension was intended to measure the satisfaction level in learning mathematics for both groups. An independent sample t-test analysis indicated that there were no significance differences in all items in the survey, and in the overall satisfaction for both groups. Generally, the findings indicated that there were significance differences in overall mean scores for students' attention, relation and confidence in mathematics class using WxMaxima as compared with those in the control group (Table 4).

The overall mean score for motivation showed that students exposed to WxMaxima during calculus class were more motivated compared to the students who were taught using conventional methods. However, there was no significant difference found in the overall mean outcome for satisfaction.

TABLE 4: Independent Sample T-Test for Students' Motivation between Experiment and Control Group

	Experiment Group		**Control group**		**P (significance value)**
	Mean	SD	Mean	SD	
ATT1	3.72	.96	3.17	1.05	.035*
ATT2	3.34	1.00	3.00	0.95	.171
ATT3*	1.97	1.06	2.90	1.18	.002*
ATT4	3.88	.79	3.60	1.19	.293
ATT5*	2.50	1.22	3.07	0.94	.046*
ATT6	3.78	.94	3.27	0.98	.039*
Overall Attention	3.71	.747	3.17	.696	.005*
REL1	3.41	.798	2.90	1.029	.034*
REL2	4.00	.984	3.37	.999	.015*
REL3	3.09	1.09	3.03	1.07	.826
REL4	3.31	.931	2.87	.937	.065
REL5*	1.78	.870	2.43	1.223	.018*
REL6	2.91	.963	2.40	.968	.043*
Overall Relation	3.49	0.683	3.02	0.682	.009*
CONF1	3.88	.976	2.50	1.137	.000*
CONF2*	2.22	.870	3.17	1.117	.000*
CONF3	3.38	.871	3.47	.937	.692
CONF4	3.41	1.073	3.57	.817	.513
CONF5*	2.25	.842	2.93	1.081	.007*
Overall Confidence	3.66	.559	3.06	0.61	.000*
SAT1	3.38	1.070	3.23	.935	.682
SAT2	3.66	1.035	3.23	1.006	.108
SAT3	3.84	1.019	3.90	.960	.824
SAT4	3.97	.933	3.67	1.061	.238
SAT5	3.63	.833	3.47	1.042	.510
Overall Satisfaction	3.69	.668	3.50	0.74	.283
Overall Motivation	3.64	.571	3.18	.520	.002*

*Significant at 0.05

5. DISCUSSION

The incorporation of technology such as WxMaxima into the classroom provides opportunities to engage students in more innovative ways of learning. The appropriate use of technology could get more students to think and reason mathematically. The result of this study showed that the experimental group outperformed the control group in the mastery of the two topics covered in the evaluation, namely differentiation and integration. This showed that integrating WxMaxima in classroom lessons could improve the performance of the students in calculus and in learning mathematics in general. The findings in this study are consistent with those from past research (Guven (2012); Erbas and Yenmez (2011); Tutak and Birgin (2008)).

Another aspect in this study examined the students' motivation when exposed to WxMaxima in the classroom. Students' motivation is an important pre-requisite for successful learning. According to Monteith (2004), the impact of computers on teaching and learning could be gauged from consistent reports of students' enhanced motivation to learn when computer technology is used. In this study, students using WxMaxima were more motivated learning mathematics compared with those in the control group. Middleton and Spanis (1999), Gabrielle (2003), Pollanen (2007) and Kamariah Abu Bakar *et al*. (2010) reported similar findings where the use of information technology successfully motivated students in the learning process.

6. CONCLUSION

The integration of computer technology in learning mathematics should be encouraged, and mathematics teachers in Malaysian schools should attempt to make the best use of whatever appropriate software that is available, including open-source software which is offered without cost. The use of computer technology in the classroom encourages more active student participation, hence reinforcing learning. Although the present study was conducted in a secondary school, there is no reason why the advantages of computer technology would not benefit the learning of mathematics at all levels, from the primary school to the higher education level. At universities and teacher training colleges, mathematics pedagogy courses should incorporate the effective use of computer software in teaching mathematics

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