WxMaxima Computer Software as an Aid to the Study of Calculus by Students with Different Learning Approaches

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Abstract

This study examined the effectiveness of teaching and learning calculus with the aid of the WxMaxima computer programme, as compared with the traditional method. In a quasi-experimental study, two classes of Malaysian secondary school Form Four students were randomly assigned to the control group (30 students) and the WxMaxima group (32 students). A Study Process Questionnaire (SPQ) was initially used to identify students with deep and surface approaches to learning. The findings indicated that students who were taught using the WxMaxima software performed significantly better than those in the traditional learning group. Further analysis showed that students with the deep learning approach in the experimental group achieved significantly higher post-test scores compared with students in the traditional learning group. However, there was no significant difference between the scores of the control and experimental groups who adopted the surface learning approach. This study implies that the use of WxMaxima could help students learn calculus more effectively, this being especially true among students who use the deep study approach.

1. Introduction

The use of computers can be helpful in the teaching and learning of mathematics. The computer is viewed as a key component in the future of education because of its ability to help promote the development of learning and to create a more attractive and effective learning environment (Mohd Ayub, Mokhtar, Su Luan & Tarmizi, 2010). In Malaysia, the computer has been used primarily to support current methods of teaching, especially in the teaching of science and mathematics (Abu Bakar, Mohd Ayub, Su Luan &
Mathematical softwares such as *Geometer’s Sketchpad, Derive, Cabri, Matlab, Autograph* and others have been used widely in schools all over the world. However, their use in the classroom comes with a cost because these are commercial proprietary products.

Open source software offers school teachers the opportunity to integrate the use of computers into classroom teaching and learning. Softwares such as *SAGE, GeoGebra, WxMaxima* and others can be downloaded free of charge for use in the mathematics class. The use of such mathematical programmes has created a big impact on students’ understanding in mathematics and in their subsequent performance in the subject. The softwares help students to visualize mathematical concepts and make their learning more meaningful. Tarmizi, Ayub, Abu Bakar, and Md.Yunus (2008) showed that students who learnt mathematics with computer technology integrated were more enthusiastic in their lessons and enjoyed them better than their counterparts who were taught using the traditional approach. Baharvand (2001) found that students using the Geometer Sketchpad software performed significantly better than students who learned mathematics conventionally. The students in the former group also showed a more positive attitude towards the subject. Tiwari (2007) who studied the use of mathematical software *Mathematica* in teaching and learning mathematics found that students introduced to the software achieved significantly higher test marks compared with those in the control group. In addition, the software also helped students to visualise abstract mathematical concepts. In an experimental study on the usefulness of the *GeoGebra* software, Abdul Saha, Mohd Ayub and Ahmad Tarmizi (2010) reported that students exposed to *GeoGebra* outperformed students in the traditional teaching-learning strategy group in coordinate geometry.

Identifying the learning approach of a student is important since it helps teachers choose the appropriate teaching methods for different students. Generally, students make a greater attempt to understand topics that capture their interest or if they see the relevance of what they have studied to their daily lives or future careers (Kember, Charlesworth, Davies, McKay, & Stott, 1997). According to the Biggs teaching-learning model (1993), a student’s approach towards the learning process is a combination of his motivation and the strategy adopted during the learning process.

In this study, students’ learning strategies are classified as either deep or surface approaches using the Study Process Questionnaire (SPQ) by Biggs, Kember and Young (2001). The deep approach refers to students’ ability to relate new information to previously acquired knowledge. It also means that students search for relevant meanings as they relate what they have learnt to their daily lives and personal experiences. In other words, students using this approach are able to view learning materials from different aspects to obtain the entire picture. Other characteristics of students with deep approach strategies are their tendency to use meta cognitive skills, and develop learning materials that could form a basis for new ideas, offer other solutions from an inquisitive-critical perspective, and search and discover their ‘inner self’ (Beishuizen & Stoutjesdijk, 1999; Biggs, 1993). These students often become high achievers academically (Brown & Nelson, 1983; Bruch, Pearl, & Giordane, 1986). In contrast, students using the surface learning approach have a tendency to choose the quickest way to accomplish a task. Using this strategy, students acquire learning materials without asking in-depth questions, study the material in a linear manner, are able to relate to minimal aspects of the material or to a problem without showing interest, and learn by rote by relying on memory; they are concerned with the time needed to fulfil the learning task (Biggs, 1993). Students with this learning approach would focus on memorizing the main elements, using minimal meta-cognitive skills.

A study by Sii Ching Hii and Soon Fook Fong (2010) to investigate the effects of two modes of multimedia presentation among students with different learning approaches found positive effects of using multiple channel presentation (text + graphics, pictures + redundancy audio, video and animation) among deep and surface approaches learners. However, deep approach learners showed significantly higher achievement and motivational scores than surface approach learners. Another study by Van Melle and Tomalty (2000) on how computer technology (specifically the use of a multimedia CD-ROM) could
foster the learning of microbiology found that computer technology facilitated the deep approach to learning.

2. Objectives of the study

This study was undertaken with the following objectives:
1. To identify the differences in post-test scores in calculus between students using WxMaxima and those given conventional instruction.
2. To identify differences in post-test scores in calculus between students using WxMaxima and those given conventional instruction in relation to the students’ learning approaches.

The research hypotheses of this study are:
1. There is a significant difference in mid-term test scores between students in the WxMaxima group and students in the control group.
2. There is a significant difference in post-test scores between students in the WxMaxima group and students in the control group.
3. Among students using the deep approach strategy, there is a significant difference in post-test scores between those in the WxMaxima group and those in the control group.
4. Among students using the surface approach learning strategy, there is a significant difference in post-test scores between those in the WxMaxima group and those in the control group.

3. Research Methodology

The target population of this study were Form four students from a national secondary school in Malaysia. A quasi-experimental study with a non-equivalent control group post-test was used for this study. Students were randomly assigned to the control group (32 students) and the WxMaxima group (34 students). The students from each group were categorized into two types of learning styles, viz. deep learning and surface learning. The learning approach among the students was based on the result from the Study Process Questionnaire (SPQ) by Biggs, Kember and Young (2001), a paper and pencil test containing 20 items. The SPQ test was administered three weeks before the actual experimental study.

For the purpose of this research, a module on Calculus based on the Form Four Additional Mathematics syllabus to be completed within eight weeks was prepared by the researcher. Three main topics on Calculus were selected for this study, viz. limits, differentiation and integration. The lesson content of this learning activity module was distributed to the students to use as a guide throughout the instructional process for both groups. Before the actual experiment test started, the treatment group was first introduced to the WxMaxima software. During this phase, the students explored and familiarized themselves with WxMaxima and its functions. The experiment started with all students being taught using the constructivist approach during the teaching and learning process based on the module given to students in both groups. The whole experimental process took eight weeks, with three classes per week (160 min/week). After all the students in both groups had completed the module, they were given a 40 minute post-test.

4. Findings

Based on the results of the Process Questionnaire, 23 of the students from the control group were classified as adopting a deep approach in learning whereas seven students tended towards a surface...
approach in learning. Among the WxMaxima group, 20 students practised the deep approach as compared with 12 who used the surface approach in learning.

Table 1: Factorial design

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<thead>
<tr>
<th></th>
<th>Deep Approach</th>
<th>Surface approach</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Control</td>
<td>23</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>WxMaxima</td>
<td>20</td>
<td>12</td>
<td>32</td>
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</table>

A. Performance Scores for Mid-term Tests

Results from the mid-term test conducted prior to the experiment were used to test the homogeneity of both groups. An independent sample t-test showed that there was no significant difference (t(60) = 1.88, p= 0.065 > 0.05) between the control group (M=58.20, SD= 24.70) and WxMaxima group (M=47.22, SD= 21.25). This showed that students in the study population was homogenous and had the same level of mathematics achievement.

Table 2: Independent sample t-test comparing the Mid-term test results between the control group and the WxMaxima group

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<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>T</th>
<th>Df</th>
<th>Significance</th>
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</thead>
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<tr>
<td>Control</td>
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<td>24.70</td>
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<td>.065</td>
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<tr>
<td>WxMaxima</td>
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</tbody>
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B. Performance Scores for Post-tests

The next hypothesis concerned the effect of using WxMaxima in the students’ performance. The independent sample t test comparing the post-test results of the two groups showed that there was a significant difference between mean performance scores of the control group (M=36.00, SD= 16.89) and WxMaxima group (M=59.06, SD= 18.77; t(60) = 5.074, p= 0.000 < 0.05). This finding indicated that students who had learned calculus using WxMaxima performed significantly better in their post-test as compared with students who underwent the traditional learning.

Table 3: Independent-t test comparing the Post-test results between the control group and the WxMaxima group

<table>
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</table>
C. Differences in the Post-test scores of students utilizing *WxMaxima* and conventional instruction among the group employing the deep study approach

The third hypothesis was tested by comparing the post-test performance among students using the deep approach learning strategy. The independent-t test showed that the *WxMaxima* group (M=62.75, SD=19.63) performed better than the control group (M=36.09, SD=16.44). This significant difference (t(41) = 4.84; P = 0.000 < 0.05) indicated that students using the deep approach learning style benefited from *WxMaxima* having been introduced into the teaching and learning of calculus.

Table 4: Independent-t test comparing the post-test results between students utilizing *WxMaxima* and conventional instruction among the group using the deep study strategy

<table>
<thead>
<tr>
<th></th>
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D. Differences in post-test scores of students utilizing *WxMaxima* and conventional instruction among the group employing the surface study approach

A similar analysis was conducted on students who used the surface learning approach. The test analysis showed that there was no significant difference between students in the control group (M=35.71, SD=19.67) and those in the *WxMaxima* group (M=52.92, SD=16.16). The t-test result (t(17) = 2.07; P = 0.054 > 0.05) showed that students who adopted the surface learning approach did not show a statistically significant gain from the use of the *WxMaxima* programme when answering questions related to the calculus topics pertaining to limit, differentiation and integration.

Table 5: Independent sample t-test comparing the post-test results between students utilizing *WxMaxima* and conventional instruction among the group using the surface study strategy

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<tbody>
<tr>
<td>Control Group</td>
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<td>35.71</td>
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<td>17</td>
<td>.054</td>
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5. Conclusion

Mathematics teaching and learning processes in school have gone through changes in terms of pedagogy and teaching aids. The use of teaching aids such as mathematical computer software can help students improve their understanding of complex mathematical concepts. The integration of mathematical software in teaching and learning could also help students to perform calculations more quickly and help them visualize difficult mathematical concepts. Nevertheless, the intended adoption of commercially available mathematical software may be limited by financial constraints. A significant barrier in implementing technology in teaching and learning is the willingness of teachers and students to purchase such commercial software for their own use. Open source mathematical software goes a long way towards easing this restriction. There are many mathematical programmes that can be downloaded free
from various sites on the Internet but the adequacy and effectiveness of such materials have yet to be fully explored and evaluated.

This study sought to investigate the effectiveness of using \textit{WxMaxima}, an open source software, in teaching and learning calculus. In agreement with the previous studies of Baharvand (2001), Tiwari (2007) and Abdul Saha, Mohd Ayub and Ahmad Tarmizi (2010), this study found that students benefited from \textit{WxMaxima} in learning calculus. Further analysis also showed that students with deep surface learning styles performed better than those with the same learning style who were taught conventionally. On the other hand, students with a surface learning approach did not show a significant difference in their test results. Nevertheless, the improvement in test performance attributed to \textit{WxMaxima} was substantial, but lay just outside the threshold of significance ($P=0.054$). Statistical significance could have been attained had the sample size been larger. The findings from this study suggest that \textit{WxMaxima} is also capable of helping students visualize abstract mathematic concepts, and to relate new knowledge to what they have learned previously. This is especially true among students who adopt the deep learning strategy.

This study also suggests that by systematic planning and using an appropriate pedagogical approach, open source mathematical softwares such as \textit{WxMaxima} could serve as useful aids in the teaching of mathematics at the Malaysia secondary school level.

6. References


