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Review on the usage of Software in Engineering Mathematics

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Abstract: Poor performance in Engineering Mathematics is classified as a global issue as educators both locally and internationally faced this scenario. Poor learning environment and class coordination, poor prior knowledge of Mathematics are some of the causes for poor performance in Engineering Mathematics. Thus, to overcome this issue, some recent researchers has incorporated usage of software in learning Engineering Mathematics. Thus, the objective of this study is to review in detail on the researchers who has used software in Linear algebra and differential equation subjects. Maple was used extensively in teaching of Linear algebra. Besides, MATLAB is another software used to teach Linear algebra. Software namely, MATLAB, CoNum, Maple, Maxima and Mathematica are used to teach differential equation subject. Incorporating software boost student's interest in learning Engineering Mathematics, visualize abstract concept, improved understanding of Engineering Mathematics, helped to validate solutions and helped students in achieving better grades. Incorporating software in Engineering Mathematics is a substitution of traditional teaching method. Teaching via. software also overcome poor performance of Engineering Mathematics students.

Key words: Engineering mathematics, Linear algebra, differential equation, software, teaching and learning, classified

INTRODUCTION

Poor performance of students in Mathematics has been a global issue among stakeholders in Engineering Mathematics higher education (Ma and Xu, 2004). A research was conducted to investigate the causes of the poor performance of engineering students in the past four academic sessions. For instance, in the session of 2011/2012, 95% of the students below average and 68% failed Engineering Mathematics IV in the Department of Mechanical Engineering. In the Department of Industrial/Production Engineering, 91% of the students scored below average and 28% failed Engineering Mathematics. Surprisingly, the findings of the study revealed that students have positive attitude towards Engineering Mathematics. Factors that contribute to poor performance in Engineering Mathematics are poor learning environment and present coordination. Splitting the lecture schedule into two or more groups, fair assessment and fair marking of examination scripts are found to be the solution for this study.

Underachievement is mainly related to poor knowledge of Mathematics. Students with poor prior knowledge face more difficulties in understanding at the tertiary level of Engineering Mathematics. This is because the content of Engineering Mathematics, especially, Linear algebra is highly abstract. Students will eventually tend to feel anxious in learning Engineering Mathematics (Godwin *et al*., 2013).

One of the solution to overcome the poor performance of Engineering Mathematics is to include software in the teaching of Engineering Mathematics. Thus, this study will review in detail on the recent researchers who used different software in the teaching of Engineering Mathematics, especially, Linear algebra and differential equation subjects.

MATERIALS AND METHODS

Application of software in Linear algebra: The course of matrix methods of structural analysis seemed to be challenging as many of the students had little exposure to

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programming (Charney, 2008). This course needs the basics of Linear algebra and theory of structures. To minimize the challenges and to provide a firm theoretical basis in the matrix structural analysis, the course namely computer methods of structural analysis I was implemented. Since, Mathcad is commonly used in the structural engineering profession, it was incorporated in the course. Additionally, Mathcad is easy to learn and highly visual. Mathcad was used as a visual matrix manipulation tool and for writing complete structural analysis programs. The computer-based structural analysis subject requires student to understand well the flow of the program and it can only be achieved, if the student experiences the implementation of the theory. Complex structure for instance, cantilever beam which is hardly ever analyzed by the written calculation could be easily done by integrating Mathcad.

Maple was used in nine interactive tutorials in Linear algebra (Kilicman *et al*., 2010). This includes plotting the eigenvector, computing the eigenvalues and solving the Linear system. Subjects such as real analysis and applied mathematical courses consist of applications of eigenvalues and eigenvectors. These difficult topics become easy with the aid of Maple. Incorporating software such as Maple provides a hand-written solution to help students to correct and evaluate their work. ICT tools help students to learn material in-depth and in a resourceful way. Student's skills and ability were improved and they were able to connect concepts during the problem-solving process. Maple aids both theoretical and computational aspects of the Linear algebra courses.

The advanced computer algebra system program, maple was also used in the first year Engineering Mathematics course particularly Linear algebra at the Technical University of Denmark. The challenges and benefit that can come from the implementation of the computer algebra system was discussed (Schmidt *et al*., 2008). Maple was considered an important element in teaching and also viewed as a tool for visualization at lectures. Group exercises as well as compulsory projects were assigned in Maple. During the period of 2007 to 2008, surveys were conducted to find the relationship between study resources and study activities. Textbooks, the Maple Demos, the internet and course materials were classified as study resources while lectures, group exercises, quizzes and compulsory homework were categorized as study activities. Student's feedback was recorded in week 3, 9 and 19 during the academic year which included 26 weeks of 2 semesters. Students participated in group exercises and the total time spent for doing homework exercises was relatively very high. However, there were some challenges that arise in implementing Maple in the Engineering Mathematics curriculum. Both student's attendance for the lecture and student's preparation for classes were on the decline. Maple Demos overtook textbook as study resources by achieving higher results.

An intelligent educational software was developed and used to implement a system at automatic problem solving in Linear algebra (Do Van *et al*., 2011). The system could solve problems within three domains namely Linear equations system-matrix-determinant, vector space and Linear map. The solutions provided were equal to human's thinking and writing. The algorithms have been implemented in Maple and the solutions through C. The systems were tested by students from the University of Information Technology. Positive feedback was received from the students where they viewed the system to be highly useful in learning Linear algebra.

Since, Linear algebra's subject content was highly abstract with a theoretical feature, many students found that it is difficult to grasp the knowledge and application (Chen, 2013). More time was wasted in solving complex solutions by hand calculations which ended up with students getting bored with the subject. Students were introduced to the computing software particularly MATLAB to convert the mathematical theory into numerical computations. By using the tool, the students managed to obtain the results immediately and accurately. This stimulated their interest in studying Linear algebra. MATLAB was also found to help students to visualize abstract concepts. Thus, this tool strengthened the theory and application and improved their ability in mathematical modeling.

Application of software in differential equation: To enhance the learning effectiveness of numerical methods in the master course of Polymers Engineering at the University of Minho, MATLAB and CoNum Software were incorporated in differential equation course (Carneiro *et al*., 2010). The course was conducted in two different modes, either at the university campus or at student's industrial working place. Students attended classes at the university or sometimes the lecturers traveled to the industrial centre or classes were conducted using video conference. CoNum is an educational software of numerical computation which was developed at the University of Minho and was applied due to its simplicity and user-friendly interfaced programmed from C++ to windows environment. MATLAB, on the other hand is well known in dealing with matrix operations as well as to solve a wide variety of problems. CoNum was used to explore the Runge-Kutta methods and the results

were presented in MATLAB. Three assignments represented 40% of the grade course whereas a final project represents 60% of the total course which were solved using the software. Students were exposed to the ability to use numerical packages and to solve real problems with effective tools. The positive experiences attracted students to continue to work on their tasks.

An exercise involving numerical solutions for a system of ordinary differential equations to find out the difficulties of the algorithm to solve a problem and to identify appropriate parameters for the algorithm was used (Shacham *et al*., 2008). This exercise was used to exemplify that computer solutions can be incorrect or inaccurate and thus, it is necessary to validate it. The Runge-Kutta algorithm for an 'interacting tank's simulation problem was analyzed using mathematical software packages Polymath 6.1 and MATLAB. Firstly, the algorithm was tested in Polymath 6.1 and then the same algorithm was tested in MATLAB to obtain the same result. Secondly, the appropriateness of the default parameter was investigated. Later, the stiffness of the problem was tested and lastly the solution with stiff algorithms and non-stiff algorithms was compared. The exercise was aimed to illustrate that both analysis and validation of the results are the essence in the problem solving and trusting the software package.

The potential of the scientific Software MATLAB was exemplified in laboratory exercise conducted by second-year engineering students at Drexel University (Abichandani *et al*., 2010). ENGR 232 Dynamics Engineering Systems course introduces modeling, simulation and analysis of dynamic systems using the concepts from the theory of ordinary differential equations. Two 1 h lectures and a 2 h laboratory session were conducted every week. Modeling problems based on the concept during lectures were given in the laboratory session. Students needed to answer questions based on the system and also verified the results they obtained. They needed to plot trajectories and conduct the sensitivity analysis. One of the laboratory exercises introduced a geosynchronous satellite orbital entry problem. MATLAB helped students to understand the behavior of the physical system easier instead of the traditional methods. It was concluded that scientific software should be included in all stages of the engineering curriculum, especially, in design projects to provide alternatives and to foster sound analysis.

A study was carried out with 10 engineering technology students to solve ordinary differential equations questions using traditional methods versus software, particularly Maple (Maat and Zakaria, 2011). Integrating Maple enhanced student's understanding, increased their interest in Mathematics and developed their creative thinking. Time was saved with Maple to solve tedious and complex calculations. Therefore, students had the opportunity to interact with other students as well as their lecturers. Maple was an aid of producing interactive activities while learning the lesson. Students were able to link mathematical understanding with real-life engineering applications. Although, students were lacking in basic calculus, yet lecturer managed to build their confidence in solving ordinary differential equations problems.

Teaching experiments were conducted to enhance the mathematical thinking powers in learning differential equations through a software (Zeynivannezhad, 2014). A test was conducted prior to the teaching experiments. Questions were designed to identify procedural parts, modeling and interpretation and solutions of the differential equations. Findings showed that, almost all the students did not answer the questions based on graphical solutions. Maxima Software was used to conduct teaching experiments, especially, in drawing graphs. The procedures of drawing graphs and the visualization of the graph enhanced student's conceptual understanding of differential equations.

Application of Mathematica in Engineering Mathematics: Mathematica, a software was integrated into Engineering Mathematics modules, especially, partial differential equations. Although, real engineering examples were taught in the Engineering curriculum, the boundary between the two still existed. By incorporating Mathematica into the Engineering Mathematics module, students have a better understanding on how engineers face real-life scenario and thus, increase their skills and interest towards engineering. Following a pre-test, 136 students were divided into the control group and experimental group. The experimental group conducted 6 laboratories in a 12 weeks period while the control group had extra tutorials. At the end of the course the students performed a post-test. The questions for pre and post-test were the same except for the fact that there were extra subjective questions in the post-test. Mathematica made no difference to the understanding of 'simple' concepts of Engineering Mathematics but it did make a significant difference in the understanding of 'difficult' concepts in Engineering Mathematics.

RESULTS AND DISCUSSION

This research has identified the recent researchers from the period of 2005 till 2014 who has implemented software in teaching Engineering Mathematics. Table 1

Table 1: Incorporating software in Engineering Mathematics

Subject	Researchers	Software
Linear algebra	Charney (2008)	Mathcad
	Schmidt *et al.* (2008)	Maple
	Kilicman *et al.* (2010)	Maple
	Do Van *et al.* (2011)	Maple
	Chen (2013)	MATLAB
Differential equation	Tonkes *et al.* (2005)	MATLAB
	Kovacheva (2007)	Maple
	Shacham *et al.* (2008)	MATLAB and Polymat 6.1
	Abichandani *et al.* (2010)	MATLAB
	Carneiro *et al.* (2010)	MATLAB and CoNum
	Maat and Zakaria (2011)	Maple
	Zeynivannezad (2014)	Maxima
	Adair and Jaeger (2014)	Mathematica

shows the particular subject, researcher, respective software used and the years the researchers conducted their studies.

Maple, Mathcad and MATLAB are the common software used to integrate Linear algebra subject. There are some recent researchers who successfully used software in teaching Linear algebra subject (Charney, 2008; Kilicman *et al.*, 2010; Schmidt *et al.*, 2008; Do Van *et al.*, 2011; Chen, 2013).

Recent researchers had included MATLAB, Maple, Polymat 6.1, CoNum and Maxima in learing differential equation subject. Many recent researchers (Tonkes *et al.*, 2005; Kovacheva, 2007; Carneiro *et al.*, 2010; Shacham *et al.*, 2008; Abichandani *et al.*, 2010; Maat and Zakaria, 2011; Zeynivannezhad, 2014) had included software as a part of study mode in differential equation subject.

CONCLUSION

Generally students achieved better grades in study with the inclusion of computational tool in Linear algebra subject (Schmidt *et al.*, 2008). Besides students commented positively by stating that, it is very useful of including software in the teaching of Linear algebra subject (Schmidt *et al.*, 2008; Van *et al.*, 2011). Integrating software as a part of study process, it created interest for the students to learn the subject (Chen, 2013). In addition student's understanding improved for Linear algebra subject (Kilicman *et al.*, 2010). Software proven help to visualize abstract concepts in Linear algebra subject (Charney, 2008; Chen, 2013). Students gave positive comments (Tonkes *et al.*, 2005) on incorporating software in their learning module. Students were motivated to learn differential equation when software was integrated in their learning (Kovacheva, 2007). Furthermore, students interest boost in learning mathematics (Maat and Zakaria, 2011). Software helped students to validate solutions (Shacham *et al.*, 2008). Real life problem were able to solve easily with the help of software (Carneiro *et al.*, 2010). Other than that, software too helps to visualize abstract concept in differential equations (Tonkes *et al.*, 2005). Students improved their understanding in differential equations subject with the help of computer software (Abichandani *et al.*, 2010; Zeynivannezhad, 2014).

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