A Study of the Effects of Using MATLAB as a Pedagogical Tool for Engineering Mathematics Students

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***Abstract*—The paper describes the effects of using MATLAB as a teaching and learning aid for engineering mathematics students. MATLAB has been integrated as a supplement to the traditional classroom teaching and learning. Students enrolled into the first year Integral Calculus course at the University of Ha'il, Saudi Arabia, are the sample of the study. Students used the software in small groups and submitted their work in groups. The aims of the study are to assess the effects of the use of the software on students' attitudes and motivation towards the utilization of technology in the teaching and learning of engineering mathematics and its impact on learning. Qualitative and quantitative data collected from the study revealed that the students have benefitted from the software. The use of the software has enhanced students' conceptual understanding despite their weak mathematical skills. It has been noticed that students' attitudes have been positive and their performance in the course has improved.**

***Index Terms*–MATLAB, CAS, Engineering Mathematics Education, University Calculus, Pedagogy, collaborative small group work.**

I. INTRODUCTION

The calculus course is a starting point for many undergraduate engineering sciences and other important disciplines. Therefore, there is an ever growing concern with regard to the decline of mathematical skills, uneven preparedness, commitment to and enjoyment of studying mathematics of students on entry to engineering disciplines. Engineering students require competence in mathematics to be able to understand and explain concepts. According to the report prepared for the Institute of Physics (IOP) [1], scores of physics and engineering academics believe that undergraduate students, entering university, are unprepared for their fields of major, and are not achieving their full potential, because of a lack of essential mathematical skills.

Like all engineering students, students entering into first-year engineering mathematics at the University of Ha'il, Saudi Arabia, are generally found to possess inadequate mathematical background and skills. Specifically, they have problems in simple arithmetic to algebraic manipulations, sketching graphs of mathematical functions, Trigonometry, Differentiation and Integration. Consequently, they show low motivation towards learning mathematics; some of them fail the course repeatedly; others do not interact with the course contents, and a number of them switch majors and become passive learners. Furthermore, for many students, the calculus concepts are abstract and complex in nature [2] which requires a solid conceptual understanding. The traditional calculus course cannot fully address these issues because it gives an overemphasis on algebraic manipulations and procedures. Therefore, students rely more on memorizing mathematical rules to pass the course rather than understanding the calculus concepts.

II. COMPUTER TECHNOLOGY AND ENGINEERING MATHEMATICS EDUCATION

Engineering mathematics students in the 21st century are compelled to have access to an appropriate computer technology due to the perpetually increasing complexities of the engineering programs. They need to learn the specialized computer software as a tool for problem-solving and learning mathematics. Information and communication technology can play an effective role as a cognitive tool in the teaching and learning of mathematics. The use of such technologies can present mathematics in a more authentic and tangible manner. They support and enliven students in learning of the subject which traditionally has been termed as math phobia as referred to in a book "Mathphobia: The Fear of Learning" [3].

The literature is rich in the identification of issues related to the positive impact of the use of mathematical and computational software in classroom. It has been reported that the integration of advanced computing algebra systems in classroom teaching had positive impact on students' mathematics achievement [4]. However, not many studies have been conducted on the use of MATLAB as a pedagogical tool for engineering mathematics. The effectiveness of the conventional lecture method can be greatly improved by integrating MATLAB in teaching and learning of engineering mathematics [5-10]. This is because MATLAB provides a powerful interactive and dynamic working environment.

"Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" [11]. However, as highlighted by [12], "Education technology is neither inherently effective nor inherently ineffective; instead, its degree of effectiveness depends upon the congruence among the goals of instruction, characteristics of the learners, design of the software, and educator training and decision-making, among other factors."

Therefore, an urgent need for integrating MATLAB as a didactical tool for calculus at the University was necessary. Currently the teaching and learning of mathematics at the University is mostly traditional. The decision of incorporating MATLAB has been made primarily in an attempt to motivate students and help them to develop the necessary mathematical concepts and skills needed to succeed in their engineering majors. In particular, the choice of MATLAB stems from the fact that it is a powerful multi-purpose and widely accessible scientific software package which is currently being used in most, if not all, engineering subjects, and it is gaining its popularity with researchers, educators, practicing engineers and mathematicians. Besides, it is easy to use at the commands level with some elementary programming knowledge. The software also provides excellent visualization capabilities. Hence, mastering MATLAB will certainly help students in other courses as a learning tool as well as it will be beneficial after their graduation.

The integration of computer technology into the learning of mathematics could in a way be achieved by establishing cooperative and collaborative environments among students. [13] presented the Social Development Theory, according to the theory, higher intellectual cognition levels develop in students through social collaboration and social behavior. Furthermore, the learning occurs in what [13] called the "Zone of Proximal Development ZPD". ZPD is the distance between student's abilities of doing a task independently and under instructor's or peer's guidance. Therefore, in this study the traditional lecture method was supplemented with computer lab activities in small students groups. A positive impact was reported on the mathematical reasoning of students when they were exposed to CAS "Computer Algebra System" technology integrated in a small group setting [14]. Similarly the peer interaction and achievement in small groups was consistently supported by [15].

III. RESEARCH DESIGN & METHODOLOGY

This paper describes the research study conducted with 81 freshman engineering students at University of Ha'il, Saudi Arabia, over a semester in 2012. The sample of this study is the male students whose first language is Arabic and the course was taught in English. The students were enrolled into the Integral Calculus course which is taught for 4 credit hours. Students must pass the course as it is a pre-requisite for several subsequent courses. The participants are randomly selected and placed in various sections each ranging from 25 to 30. They all have very similar background and must meet the standard criteria set by the university. It is a coordinated course having common syllabus, standard grading policy and exams. For this study, students were randomly assigned to the Instructor-Researcher and the other Instructor. Paper-based exams (two major exams contribute to 20% each and a final exam 50%, assignments 5% and a MATLAB-based test 5%) were used as a criterion for comparing the performance of students taught by two instructors with three sections each.

MATLAB was used for demonstrating Riemann sums, evaluating definite, indefinite and improper integrals, area between two curves, volume of solids of revolution, and various integration techniques etc.

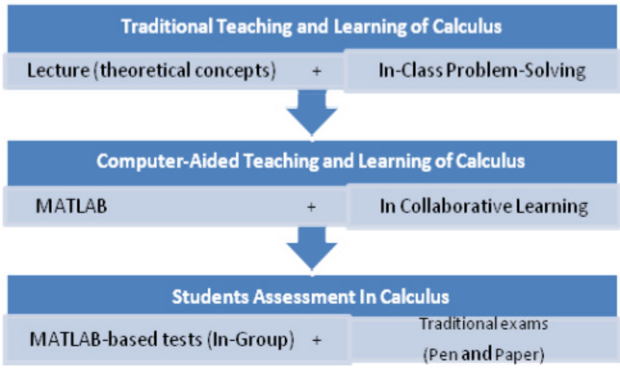

Figure 1. Model for Teaching and Learning of Engineering Mathematics

The study was carried out in a conventional teaching and learning environment where MATLAB was integrated into a traditional calculus course in a small students' group setting. Students used the software in the informal groups of 2 to 3. After every MATLAB session, the students' feedback was received about the difficulties they faced during the use of the software. They also solved the similar problems at the end of each MATLAB session.

Figure 1 shows the model for teaching and learning of mathematics that was formulated and used in this study.

To enhance collaborative learning and problem solving, a MATLAB instructional manual for students was prepared with some Arabic support to facilitate students understanding. The MATLAB manual contains lab activity worksheets for mathematical tasks to be performed in a collaborative environment. Each worksheet contained objective of the lesson, necessary commands and a test. Due to some of the challenges with regard to students' competence in English, the worksheets were prepared in a simple language and the instructions were given in students' native language. The MATLAB tutorials, highlighting the software features and capabilities, were demonstrated in the classroom lectures to motivate students to use MATLAB. Students were given some hands-on training sessions to familiarize them with the software and its syntax. An important aspect of the training was the mathematical problem-solving which was emphasized in classroom and enhanced through the use of MATLAB.

This study was conducted to examine the effects of the use of MATLAB in small groups on:

1. Students motivation and attitudes towards the use of the software in teaching and learning of the Integral Calculus course,
2. Students' performance in the course.

IV. MATLAB AS A PEDAGOGICAL TOOL

Broadly speaking, the software was used as a tool for motivating students towards learning mathematics, exploring calculus concepts and patterns in mathematical rules through experimentation, visualization, multiple representations and demonstrating connections between various course concepts, solving complex textbook problems, checking answers to textbook problems as well as for reviewing the course material for exams.

Students' high motivation to learn and their feeling of success enhanced when they were given access to computer technology [16-17]. "A teacher using technology to motivate students is more powerful and productive than one simply using lectures and textbooks." [18]. The use of MATLAB enhanced students' motivation to learning mathematics, Figures 11 and 12.

MATLAB-Aided worksheets for doing mathematical tasks were designed. In teaching a mathematical concept, three stages are involved as shown in Figure 1. Firstly, the topic is taught in a traditional manner followed by students doing some class work and homework assignments, secondly, students will do the similar problems in a computer lab using the MATLAB-based designed worksheets and thirdly, students understanding and performance are assessed in MATLAB-based exams in groups and individually.

The MATLAB-based worksheets used were on software's basics task, basic mathematical operations, graphing, area problem, area between two curves, evaluating integrals (indefinite, definite and improper); exploring patterns; generating solids of revolution and computing volumes; and evaluating integrals by integration methods (by parts, trigonometric substitution and by partial fractions) etc. A sample worksheet is given as appendix III. The adoption of computer technology in teaching and learning of calculus can have positive impact when activities are designed appropriately [2].

A. Patterns

Patterns such as sequential, spatial and temporal and their combinations are frequently encountered in engineering. Mathematics is believed to be the science of patterns. One of the effective and key strategies that the experts use in acquiring knowledge or solving problems is the observation of noticeable and meaningful patterns of information [19].

In this study, mathematical patterns are introduced to students using a worksheet containing several examples that highlight a number of meaningful patterns. This is accomplished through experimentation in which several indefinite integrals are evaluated and students spot a pattern and discover some mathematical rules. The concept of evaluating indefinite integrals by "Integration by parts method" and the "Tabular method" were taught in the classroom with some problem-solving. For evaluating such integrals students not only require a thorough understanding of these integration techniques but also the knowledge of algebraic manipulation involved in the solution. A MATLAB screenshot that illustrates the mathematical patterns that can be noticed in evaluating integrals is shown in figure 2.

In this MATLAB-generated screen, various examples of the integral $\int x^2 e^x dx$. are evaluated by increasing the powers of the polynomial function. A pattern in the output can be easily seen. Through the use of MATLAB, students can explore patterns and get the solution in hardly one step compared to the otherwise multi-step analytical solution.

A number of problems for evaluating definite integrals were demonstrated to students followed by their practice in the computer lab. Following the practice sessions of pattern recognition, students were given the paper-based classroom tests. They found no difficulty in solving the problems taught through the guided discovery using the software.

B. Visualization

Similarly, by taking a number of examples of basic mathematical functions, MATLAB was used to show patterns in graphs. Many students lack visualization skills in math. The visualization of static and dynamic graphs of families of functions such as linear, quadratic, trigonometric and inverse trigonometric were demonstrated to students. Also, the positive and negative regions of a function and calculating area between curves were shown. For generating the volumes of the solids of revolution, an interactive Disks Methods Program developed by Dr. David Hill and his team at Temple University, USA, was used. MATLAB is a powerful tool for interactively creating 2-D and 3-D curves and surfaces of functions with great ease with features such as zoom in, zoom out and rotation to any angle etc. It acted as a tool for reviewing the pre-requisite concepts of the course with great speed and accuracy. Figure 3 and 4 are the illustrations of some of the graphical patterns.

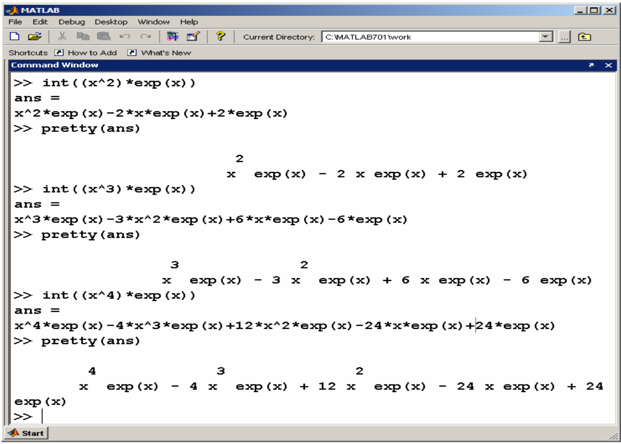

Figure 2. MATLAB demonstration for exploring patterns through experimentation

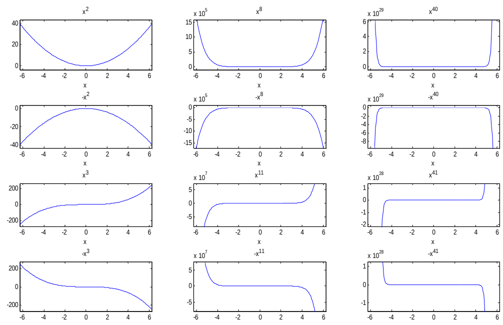

Figure 3. MATLAB-generated graphs of multiple functions

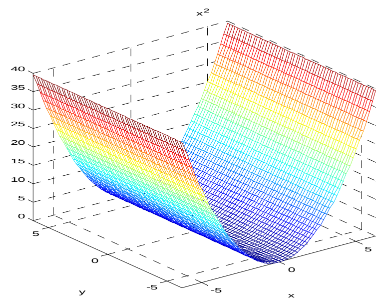

Figure 4. MATLAB generated 3-D graph of x^2

The concept of definite integral presents comprehension difficulties to students if taught traditionally which lack a proper visualization as the area as the Riemann sum [20]. The 'rsums' command in MATLAB provides an interactive visual of Riemann sums for computing area under a curve. An approximation of the integral of the given function can be found by using the slider shown in the bottom of the window in appendix III. By dragging the slider from left to right students can see the dynamic changes occurring in the number of rectangles (regular partitions) and consequent improvement in the approximation of the integral value given at the top of the screen. Also, they can see the relationship between the computer-based visualization to the mathematical meaning of an integral. A good example of the use of MATLAB to visualize certain functions is the example: Find the total signed area bounded by the curve $y = x^3$. and the x-axis for the interval [-2, 2].

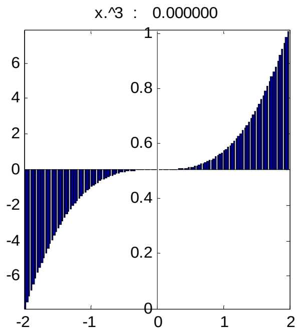

Figure 5. MATLAB-generated graph in which area cancellation is illustrated

Students practiced with a number of functions followed by MATLAB-based test consisting of 2 to 3 problems. Then they were asked to write their understanding and observations of the whole process. This is followed by group discussions where students explain and check their conceptual understanding.

The curriculum reform should put more emphasis on the conceptualization of calculus concepts by supplementing its presentation algebraically, numerically and graphically [2] & [21]. Students examined the course concepts numerically, algebraically as well as graphically as illustrated in figures 6, 7 8 and 9.

V. INSTRUMENTATION FOR DATA COLLECTION AND DISCUSSION

To study the effects of the use of MATLAB in small groups, the quantitative and qualitative data were collected.

Quantitative data were recorded through students' post-study survey questionnaires, paper-based and MATLAB-based examinations. The questionnaires consisted of 29 questions relating to statements about students' motivation and attitudes towards mathematics and their attitudes towards the use of MATLAB for calculus in collaborative setting. The Likert-style scale response format "strongly agree (5) to neutral (1)" was used. Out of 81 students, 77 sat for the final exam and a total of 66 students completed the end-of-semester questionnaires.

The qualitative data collected through students focused group interviews, group discussions with students, and

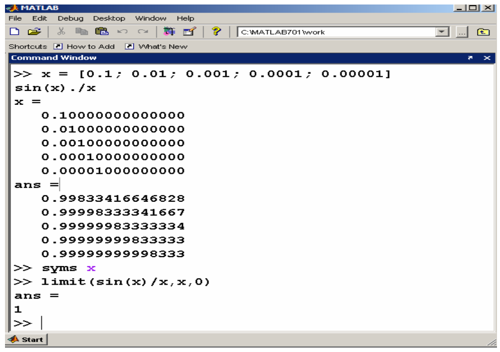

Figure 6. MATLAB generated numerical data of the limit of a function and its evaluation

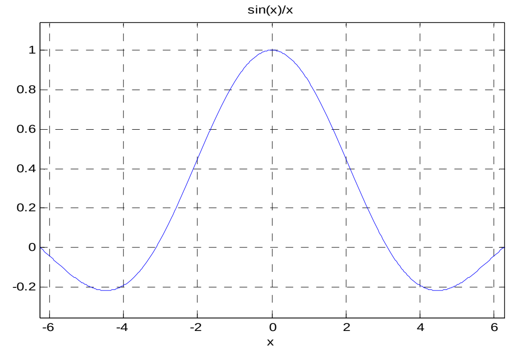

Figure 7. MATLAB generated plot for the function $\frac{\sin x}{x}$

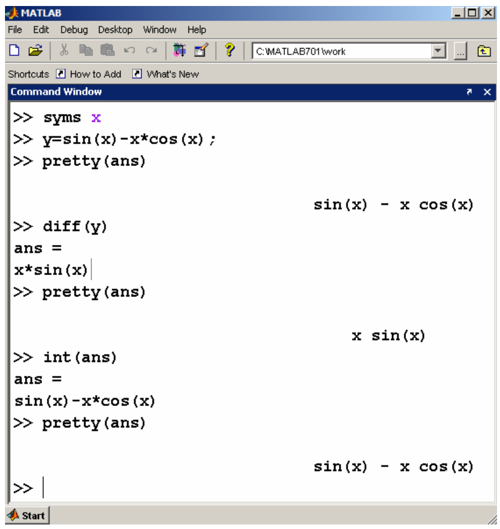

Figure 8. MATLAB generated screen to demonstrate symbolic relationship between a derivative and its integral

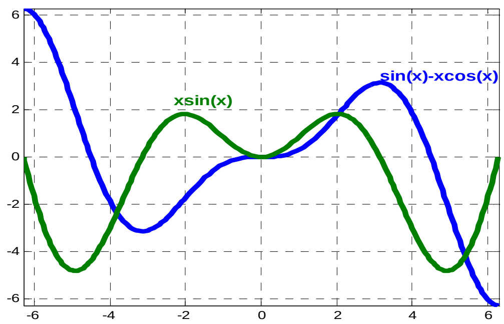

Figure 9. MATLAB generated screen to demonstrate graphical relationship between a functions and its derivative

video recordings of the MATLAB sessions as well as the observation of in-lab students learning. Interviews were conducted with some selected individual students as well as with the small groups of students. These were held during the entire semester to see students' perceptions about the use of the software and to bring necessary changes in the way it was used. The qualitative data can be triangulated with quantitative data by using a Mixed-method for data collection and analysis in a single study for a thorough understanding of the effects of the intervention [22].

A. *Video Recordings of MATLAB Lab Activity*

In this study, video recording was used as one of the resources for developing data. The use of this approach was triangulated through the other data collection sources such as students' survey questionnaires, interviews, focused group discussions and observations. The use of video technology is important in capturing and assessing complex human behaviors and relationships that influence the learning process. A number of video recordings of the students' MATLAB activity sessions were performed and analyzed. This was aimed at assessing students' involvement in use of the software, their interaction with their peers in the computer lab as well as to see their motivation and interest in learning the course. The video capturing of the learning episodes and their ongoing analyses helped to understand students learning processes and the related challenges. This has further facilitated the improvement of the subsequent activities. The students learning episodes were guided by the MATLAB-Aided worksheets related to the research questions formulated for this study.

A combination of approaches, namely, part-to-whole deductive and the manifest-content were used for examining and analyzing the video recorded data. The analyses included discourse such as conversations between students and the teacher, students-students, group-group, and the students' behavioral aspects to understand the events on the basis of the set research questions.

The analyses and interpretation of the videos highlighted the following features:

1. An increase in motivation towards the subject was observed manifested by the active involvement of students in the learning process.
2. Students-centered learning environment was established where the students were doing mathematics through experimentation and discovery.
3. A collaborative learning environment was quite noticeable among students as they were learning in pairs of two while they were communicating with other groups of students. Another added advantage that was noticed is the overcoming of the second language barrier as students were free to communicate in their native language.
4. Initially students experienced some syntactical difficulties which were gradually reduced as more and more sessions were held.

Students' verbal and non-verbal interactions were analyzed for patterns. They never felt bored and the use of software increased their interest and motivation towards learning. The kind of active participation and interest shown by students in the computer lab is not usually observed in the traditional classrooms. In this study, an attempt is made to use video technology as a qualitative method to inform research in computer-aided mathematical learning and human-machine learning.

Figure 10. MATLAB-Aided mathematical tasks in a collaborative environment at the University of Ha'il

B. *Focused Group Discussions, Interviews, Views and Opinions of Students*

Group discussions were held with selected students who liked the software a lot and very much supported incorporating a compulsory component for teaching and learning the software. Some students suggested that the software be taught as a course prior to taking the calculus course. They expressed a concern that simultaneous learning of the software as well as learning of mathematics is a heavy task. Students liked the visualization of graphs the most followed by exploring the patterns in indefinite integrals. They also liked the program for generating the volume of the solids of revolution. The quick computation capability was also preferred by many students.

About 13% of the students who did not like the tool at all; they categorically opposed the idea of using it for learning mathematics. They held firmly to their past beliefs of learning of mathematics traditionally. These students believe that the software will not help them in learning mathematics. Some students, however, liked the graphing capability of the software but still liked to use the pen-paper method. Part of the reason for their disliking the software was probably due to the traditional nature of exams at the university without having access to any computer software.

Students' views about the use of the software and its usefulness were recorded through interviews (both structured and unstructured) some of which are listed below:

- The software should be use more and more.
- It is good that the software gives the answer not the steps. Because there are different ways of solving a problem in math. In our course, there are lots of rules and ways of doing a problem.
- The software will be more useful if we know it well.
- It is a reliable program, therefore allocate some marks for its use and make it an integral part of the syllabus.
- Patterns are interesting. We can do problems of some particular type and find patterns in them.
- Graphing is easy and interesting. It is best for sketching graphs.

- It is good to be familiar the use of the software at this level.
- It should be used once a week.
- It is a helping device. It assists in understanding math.
- It translates math to computer language.
- Commands are easy to use.
- We can see some relevance of math in our life.
- Many problems can be solved in a short time.
- It is accurate and fast.
- Solving together with other students is fun.
- It is good to learn because it is used in the future.
- Time spent learning the software is not wasted.
- I learnt many things.
- Some relevance of math in our life can be seen from the shapes of functions generated in MATLAB.

Students also expressed the following:

- The program has good things but it also has weak points. It gives the answer but does not provide the steps.
- If there are no MATLAB-based exams then it is not helpful to learn.

Students were also asked about the best and the worst parts of their experiences of using the software. In addition, they were interviewed to hear their opinions.

Most positive aspects of the software:

- Its speed of solving.
- Sketching graphs.
- More fun and interesting to use.
- Short steps.
- Increases curiosity

Most negative or frustrating aspects of the software:

- Errors (syntactical, typo, use of brackets).
- In some cases, MATLAB's output was different from the textbook answer.
- It is not used in final exam.
- Sometimes not sure which command to use?
- No steps for solution.

The majority of students who took part in focused group discussions strongly liked the idea of using MATLAB as a pedagogical tool and this was further confirmed in the personal interviews conducted with them. Their overall experience was very positive and encouraging.

C. Observations

The Researcher-Instructor recorded observations of students learning tasks. In particular, the strategies adopted by students for learning calculus using MATLAB were observed. It was observed that for a given problem many students had the habit of asking too many questions to the Instructor. Initially, they did not show an interest in reading simple and easy to understand instructions. They rather wanted the instructor to tell them what to do in a given problem and which mathematical method to use. Several times students tried to do a problem, get stuck in the process, and then easily give up.

It was noticed that they were initially struggling to type the software commands given to them. This was observed despite their familiarity with the use of computer as they had already completed a course "Introduction to Computer and Programming". They found difficulties in trying to find relevance between the MATLAB commands to the mathematical tasks assigned on the worksheets. Some students preferred to do problems by hand rather than using MATLAB. However, they noticed that some mathematical problems can only be solved with the use of MATLAB. Students also found difficulties in describing orally the concepts of mathematical notions. This was partly due to the nature of traditional mathematical testing which is primarily paper-based. Responses to questions were given when oral questioning was done in groups of students. It was also noticed that students' participation increased and consequently they expressed their views more comfortably. Therefore, it can be said that the use of the software has been positive. Another aspect of the learning observed was the use of the appropriate mathematical methods students have used utilized in solving, simplifying, graphing, factorizing, differentiating and integrating functions.

Students' frustration was observed when MATLAB output, in some cases, was different from the textbook answer. The Instructor-Researcher had to show them that the simplification can lead to the more simplified answer usually found in the book. It was also shown to them that the mathematical functions such as $\int e^{x^2} dx.$ cannot be evaluated in MATLAB as it gives an error function.

D. Assessment of Students Performance

Students' transcripts of tests and exams analyses were performed to check their learning of mathematics. They demonstrated an understanding of the concepts where MATLAB activities complemented the traditional classes. Each MATLAB-based activity was followed by similar problems performed by students. All sessions were supervised by the Instructor-Researcher. Discussions with students were held in the post-MATLAB sessions to see if the learning objectives are being accomplished and the necessary changes required in the following sessions. An analysis of the final scores of students is given in Figure 13.

VI. RESULTS

Cronbach's Coefficient Alpha using SPSS was computed to check the internal reliability of the questionnaire items. It was found to be in the acceptable range of 0.7 to 1.0 which is shown in Table I:

TABLE I.
CRONBACH'S ALPHA COEFFICIENT ON INTERNAL RELIABILITY OF QUESTIONNAIRE ITEMS

Items	Cronbach's Alpha
Students' Attitudes towards math	0.88
Attitudes towards the use of MATLAB in teaching and learning of mathematics	0.98

Students' responses to post-study questionnaire items are summarized in Figure 11 and 12. About 74% of the students (45% strongly agreed, 28% agreed) have indicated that MATLAB has helped them in better understanding calculus. However, 12% of the students (4% disagreed, 8% strongly disagreed) disliked the use of MATLAB and the remaining expressed no opinion about their experiences. The questions are given as appendix I.

The data were also collected through the post-study questionnaire regarding students' attitudes towards mathematics Figure 12. The experimental group of students expressed a strong positive attitude towards mathematics. To questions such as "I like math" and the other similar questions (see appendix II), students demonstrated an acceptable level of confidence to be successful in their math course. The negative statements 9, 10, 12 and 13 have been reversed for computing Cronbach's Alpha.

The positive effects of the use of the software were also confirmed by students' performance in traditional paper-based and MATLAB-based examinations. A comparison of students' performance in final exam between experimental and control groups is given in Figure 13.

Since the means and variances are high in both the groups, Experimental and Control groups, shown in the Table II, the difference between the two groups is further tested by two sample t-test for independent samples and found that there is a significant difference between the two groups. The calculated t value that is 2.34 which is significant at 5% level of significance and the corresponding probability 'p' value is 0.02.

Table II generated in MS-Excel gives the t-test value, means and p-values.

The analysis of the data, the retrospective students' views expressed in the interviews and focused group discussions have revealed that an overwhelming majority of students enjoyed the use of MATLAB in learning mathematics which in turn has a positive effect on their attitudes in learning mathematics.

Students' mathematical weaknesses and flaws in their reasoning were identified through different classroom quizzes, tests, exams and their in-class learning. This analysis revealed some of the underlying problems with regard to the students' difficulties in calculus concepts. Despite these challenges, the technology-aided learning has greatly enhanced the fulfillment of the course objectives.

VII. CONCLUSION

The various tools of data collection confirm the positive effects of the use of the computer software. It was observed that students learnt the course, their participation in the learning process enhanced, their final exam grades improved as evidenced by the comparison between experimental and control groups. As can be seen from the Figure 13, about 47% of the experimental group students achieved a final grade of C (C≥70 marks) or above compared to 32% of the control group. There was a marginal increase in the D and D+ grades of students between the groups. Only 21% of the experimental group students failed the course whereas 32% failed in the control group. The mean of the experimental group was about 63% which is 10% higher than the control group.

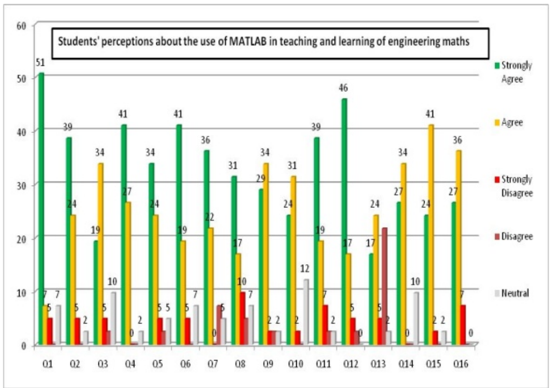

Figure 11. Summarizes the responses to each question of the questionnaire

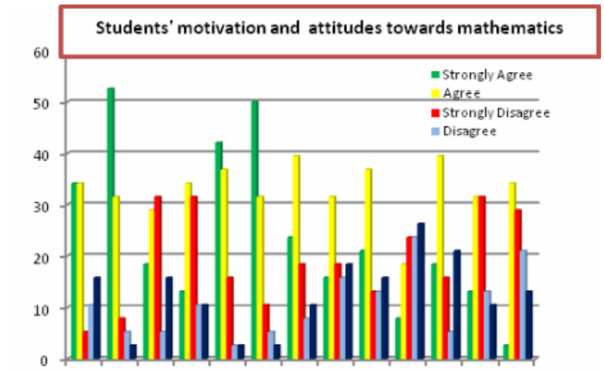

Figure 12. Summarizes the responses to each question of the questionnaire

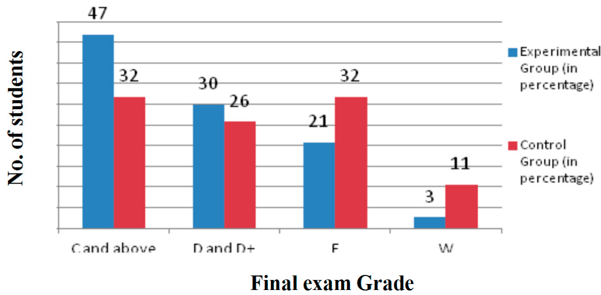

Figure 13. A comparison of students' performance in the experimental group and the control group in the final exam

TABLE II.
STATISTICAL ANALYSIS OF STUDENTS' PERFROMANCE IN FINAL EXAMINATION

t-Test: Two-Sample Assuming Unequal Variances		
	Experimental Group Score	***Control Group Score***
Mean	62.91	53.12
Variance	489.18	731.37
Observations	77.00	66.00
Hypothesized Mean Difference	0.00	
df	126.00	
t Stat	2.34	
P(T<=t) one-tail	0.01	
t Critical one-tail	1.66	
P(T<=t) two-tail	0.02	
t Critical two-tail	1.98	

Visualization of graphs and 3-D volumes of solids of revolution were one of the areas which benefitted students the most throughout their course followed by pattern recognition in evaluating integrals of mathematical functions. Students learning of MATLAB and submitting their assignments in small groups of 2 to 3 has helped them in their learning of mathematics; motivated them towards learning; increased interaction among students as well as with their instructor, and somehow alleviated students inadequate competence in English. MATLAB-aided learning as a supplement to traditional classroom instruction promoted active learning which has helped students to develop a stronger conceptual understanding of the course. It was noticed that the use of the software has benefitted both weak and strong students in many areas of the course. Students' performance in the course has improved significantly unlike the past record of teaching a number of students groups of similar background over a number of years. However, it must be noted that some confounding factors such as students' abilities of this particular experimental group and/or the instructional delivery of the course might affect the outcome variable which is the mathematics achievement.

Students' conceptual understanding of the course concepts enhanced through the multiple representation (graphical, algebraic, and numerical) of the course and the connection between the concepts such as the derivative of a function to its integral by taking a number of examples with ease and speed.

Software like MATLAB provides ample opportunities for conceptualization and problem solving in mathematics. And because of its relevance to math and engineering disciplines, it should be integrated as a compulsory component of the curriculum. However, several factors have to be taken into consideration such as the careful design of the course; when to use technology, what concepts to teach using MATLAB; and how to use it appropriately keeping in view of the characteristics of students.

ACKNOWLEDGMENT

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APPENDICES

Appendix I

Q	QUESTIONS REGARDING STUDENTS' ATTITUDES TOWARDS THE USE OF MATLAB FOR CALCULUS
1.	I enjoyed doing calculus with MATLAB.
2.	I enjoyed doing integration problems with MATLAB.
3.	I can learn any computer program needed for my course.
4.	I learnt many things about graphing using MATLAB.
5.	MATLAB is good for understanding solids of revolution.
6.	Sketching graphs is easy in MATLAB.
7.	Sketching graphs is fun in MATLAB.
8.	MATLAB is easy to use.
9.	It was interesting to learn power rule of integration using MATLAB.
10.	MATLAB made it easy for practicing integration problems.
11.	I like MATLAB because it is important for engineering.
12.	I like to learn calculus with MATLAB in a group.
13.	Doing calculus with MATLAB alone is not easy.
14.	I can enjoy using MATLAB if I use it more and more.
15.	MATLAB made it easy to see patterns in calculus.
16.	Using MATLAB I learnt that there are patterns in calculus.

Appendix II

Q	QUESTIONS REGARDING STUDENTS ATTITUDES TOWARDS MATH
1.	I like math.
2.	Math is important for studies.
3.	I can handle difficulties in math.
4.	I am confident in math.
5.	I like to learn new ways of solving problems in math.
6.	I am sure I can succeed in math courses.
7.	I have no problems in understanding math questions.
8.	I understand vocabulary in math.
9.	I don't like solving problems which has many steps.
10.	I don't like to understand math.
11.	I like to attend lectures where is math is discussed.
12.	Math is important only because I have to pass the course.
13.	Math has no connection with engineering courses.

Appendix III

Teaching and Learning of calculus using MATLAB

Objectives of the lesson:

- To define the definite integral of a function as a single variable and its properties;
- To visualize definite integral as a process of infinite summation (Riemann sums);
- To demonstrate numerically the value of integral as overestimate and underestimate;

Learning Activities:

1. Type rsums (sqrt(x),0,1) and press enter.
2. A new window with the graph will appear on the screen.
3. Move the slider to increase the no. of rectangles.
4. Enter the value in the given table that appears at the top of the window.
5. Observe the change in the integral values.
6. Observe the link between Riemann sums and the definite integral.

$$\int_0^3 \ln x dx$$

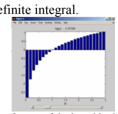

Illustration of Riemann sums interactive feature of the logarithmic function

Using the commands given below, compute the area of the functions:

Compute the area	MATLAB command	Area under the curve with		
		10 rectangles	100 rectangles	128 recta
$f(x)=\sqrt{x};[a,b]=[0,1]$	rsums (sqrt(x),0,1)			
$f(x)=\sin(x);[a,b]=[0,\pi]$	rsums(sin(x),0,pi)			

What happens when you increase the number of rectangles? Explain in your own words either in English or in Arabic. Please email the MATLAB output.

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Assessment		
Individual test	Group test	Oral test

Observations and comments:

REFERENCES

[1] B. Morgan, "Mind the Gap: Mathematics and the transition from A-levels to physics and engineering degrees," EdComs, Institute of Physics, London, UK, July 2011.

[2] T. Zacharaides, P. Pamfilos, C. Chirtou, R. Maleev, and K. Jones, "Teaching introductory calculus: Approaching key ideas with dynamic software," Paper presented at CETL-MSOR Conference on Excellence in the Teaching and Learning, Stats and Op, University of Brimingham, 2007.

[3] S. Papert, "Mindstorms: children, computers and powerful ideas," Basic Books, New York, 1993.

[4] L. Tokpah, "The effects of computer algebra systems on student's achievement in mathematics". Doctoral dissertation, KenState University College, 2008.

[5] J. Liang, S. Y. William, "A MATLAB-Aided Method for teaching calculus-based business mathematics," American Journal of Business Education, Volume 2, Number 9; ProQuest, Dec. 2009.

[6] M. L. Brake, "MATLAB as a Tool to Increase the Math Self-Confidence and the Math Ability of First-Year Engineering Technology Students," The Scholarship of Teaching and Learning at EMU: Vol. 1, Article 5, 2007.

[7] X. Shi, "Some thoughts on the way in which calculus is taught and learned," The China Papers, July 2004.

[8] P. K. Dunn, C. Harman, "Calculus Demonstrations using MATLAB," International Journal of Mathematical Education in Science and Technology, 33 (4). pp. 584-596. ISSN 0020-739X, 2002.

[9] P. Cretchley, C. Harman, N. Ellerton, G. Forgarty, "MATLAB in Early Undergraduate Mathematics: An Investigation into the Effects of Scientific Software on Learning," University of Southern Queensland, 2000.

[10] L. Colgan, "MATLAB in first-year engineering mathematics," International Journal of Mathematical Education in Science and Technology, 31(1), 15-25, 2000. http://dx.doi.org/10.1080/002073900287345

[11] K. A. Qing, "Principles and standards for school mathematics," National Council of Teachers of Mathematics, Edmonds, University of Calgary, 2000.

[12] M. Schneiderman, "What does SBR mean for educational technology?" T.H.E. Journal, 31(11), 30-36, 2004.

[13] L.S. Vygotsky, "Mind and society: The development of higher mental processes," Cambridge, MA: Harvard University Press, 1978.

[14] B. A. Keller, C.A. Russell, "Effects of the T1-92 on calculus students solving symbolic problems," The International Journal of Computer Algebra in Mathematics Education, 4(1), 77-98, 1997.

[15] N.M. Webb, "Task-related verbal interaction and mathematics learning in small groups," Journal for research in mathematics education (Reston,VA), vol. 22, p. 366–89, 1991.

[16] S.K. Lewis, "The relationship of full time laptop computer access to student achievement and student attitudes in middle school," Dissertation. Retrieved Dec 07, 2005, from ProQuest database, 2004.

[17] R. Weida, "Computer laboratory implementation issues at a small liberal arts college," Electronic Proceedings of the 9th ICTCM, 1996.

[18] D. Lumley, "Improving Student Motivation. Electronic Learning," 11(3), 14, ProQuest database, Dec 07, 2005

[19] J. D. Bransford, A.L. Brown, R. R. Cocking, "How People Learn: Brain, Mind, Experience, and School." Washington, DC: National Academy Press, 1999.

[20] L. Milevicich, "Las ideas previas sobre el calculo integral en los alumnos de primer año de la Universidad," Acta Latinoamericana de Matemática Educativa, 21, 329-338. México, Colegio Mexicano de Matemática Educativa A.C. y Comité Latinoamericano de Matemática Educativa A.C., 2008.

[21] M. Axtell, "A two-semester precalculus/calculus sequence: A case study," Mathematics and Computer Education, 40 (2), 130-137, 2006.

[22] J. W. Creswell, V.L. Plano Clark, M.L. Gutmann, and W.E. Hanson. "Advanced mixed methods research designs. In Handbook of mixed methods in social and behavioral research," eds. A. Tashakkori and C. Teddlie, 209–240. Thousand Oaks, CA: Sage Publications. 2003.

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