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The use of Digital Technology in Mathematics Education for Engineering Students

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Abstract

Digital technology is essential in teaching and learning mathematics to understand the basic concept and the way of problem solving technique. The primary observation found that the mathematics lecturers are not fully utilizing digital technology in their classroom, while teaching engineering students. A survey was conducted to study the barriers preventing the integration and adoption of digital technology in teaching mathematics. Five major barriers were identified: insufficient lecturer training opportunities, inadequate technical support, and lack of knowledge about ways to integrate digital technology to enhance the curriculum, lack of time in the college or university schedule for involving Information and Communication Technology and unavailability of digital resources for the students to access the necessary mathematical materials. To overcome some of these barriers, this research proposes a prototype system for teaching and learning mathematics. The prototype system consists of three users; administrator, lecturer and students. It has many amenities such as lesson planner, assignments, collection of mathematical tools, resources storage, and mathematical guidelines, latest research and projects, forum and so on. The prototype system will be prepared for teaching and learning mathematics much more interesting, inventive, innovative, exploratory, and user friendly manner.

Keywords: Mathematics education; Digital tools; Lecturers; Engineering.

1. Introduction

Digital Technology is universal in society. There are new demands on educational systems in order to prepare students for further professions (Guo, 2015). The use of digital technology in the mathematics classroom has long been a topic for consideration by mathematics lecturers. Digital technology tools in mathematics include: portable, graphic calculator and computerized graphics, specialized software, programmable toys or floor robots, spreadsheets and databases. Access to technology via personal devices will increase, with the consequence that technology integration into mathematics education, within and outside the classroom, can be easily realized. Students will also have personal technology such as a tablet, a smart watch, a mobile phone or similar with which they are familiar to use mathematical focused applications. These tools are allowing pupils to collect data, and manipulate it using spreadsheets and databases for work in numeracy (Moseley, 2009). The use of digital tools in mathematics speeds up the graphing process, freeing people to analyze and reflect on the relationships between data (Hennessy, 2010). Mathematical specialists software such as Computer Algebra System (CAS), Dynamic Geometry System (DGS), Matrix Laboratory (Mat Lab), Statistical Package for the Social Sciences (SPSS) and so on. With the advent of such technology, the question arises as to what the impact on education and teaching practices should be in order to prepare the next generation of students for future careers (Clark-Wilson, 2015).

There are many implications of using digital technology in the teaching and learning of mathematics at college or university. As students often point out it is very exciting, enjoyable and productive to use digital tools in class. They are keen to use digital technology, so the environment becomes more conducive for learning. The engineering student's natural curiosity can be utilized to its fullest potential because they are keen to explore and discover. Digital technology can be a major factor in developing an exploratory approach to learning mathematics and in particular, investigating problems from multiple representational perspectives (Kumaresan, 2008).

With the traditional engineering mathematics curriculum, students do not often regard themselves as active participants in mathematical exploration. Digital technology offers a number of didactic advantages that can be exploited to promote a more active approach to learning. Students can become involved in the discovery and understanding process, no longer viewing mathematics as simply receiving and remembering algorithms and formulae (Li, 2010). The power of digital technology goes beyond routine computation. It has the potential to facilitate an active approach to learning, allowing students to become involved in discovery and constructing their own knowledge, thus developing conceptual understanding and a deeper approach to learning (Ruthven, 2009).

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The main objective of this research is to help mathematics lecturers in the integration of digital technology into their teaching. The study aimed at identifying the most significant digital tools and applications used by these lecturers. It also aimed at understanding how the web application was used by lecturers, analyzed their training needs and further assessed the level of digital technology usage in engineering programs. The barriers faced by lecturers during the integration of digital technology into mathematics lessons and their perception of the usefulness of a prototype system were also investigated.

1.1. Factors Inhibiting Digital technology use in Mathematics Classrooms

Many researches have shown several obstacles that lectures experience in the use of digital technology in their classrooms. The researcher Jones found a number of barriers for the integration of digital technology into lessons: These barriers were (a) lack of confidence among lecturer during integration (21.2% response), (b) lack of access to resources (20.8), (c) lack of time for the integration (16.4%), (d) lack of effective training (15.0%), (e) facing technical problems while the software is in use (13.3%), (f) lack of personal access during lesson preparation (4.9%) and (g) the age of the lecturers (1.8%) (Jones, 2014).

Snoeyink and Ertmer have identified these or similar variations as widespread barriers: lack of computers, lack of quality software, lack of time, technical problems, lecturer attitudes towards computers, poor funding, lack of lecturer confidence, resistance to change, poor administrative support, lack of computer skill, poor fit with curriculum, scheduling difficulties, poor training opportunities, and lack of vision as to how to integrate information and communication technology in instruction (Snoeyink, 2012).

1.2. Software for Engineering Mathematics

The role of lecturers is very important in order to make the effective use of available mathematical tools. The following are the popular free and commercial mathematical software's (Mark, 2007), (Stein, 2009), (Kumaresan, 2008).

- ***Gap:*** is a software system for computational discrete algebra with particular emphasis on Computational Group Theory. It is mainly used in research and teaching for studying groups and their representations, rings, vector spaces, algebra, combinatorial structure and more.
- ***Macsym:*** is one of the oldest general purpose computer algebra systems which are still widely used. It was originally developed at MIT's project Mac.
- ***Magma:*** is a computer algebra system designed to solve problems in algebra, number theory, geometry and combinatory. It is named after the algebraic structure megma. It runs on UNIX like operating systems, as well as Windows.
- ***Mathcad:*** is computer software primarily intended for the verification, validation, documentation and re-use of engineering calculations. First introduced in 1986 for DOS, it was the first to introduce live editing of typeset mathematical notation, combined with its automatic computations.
- ***Matcom:*** the world's first Mat lab to C++ compiler reduces your simulation time and memory requirements. Matcom creates MEX files, DLL files for Delphi, Excel and Visual Basic and standalone C++ applications with royalty free distribution. Easy integration of Mat lab code and algorithms within existing C++ projects is now possible using matcom. Matcom translates Mat lab to C++. The compiler creates C++ code from Mat lab code which is compiled by the project manager into a standalone executable file.
- ***Matlab:*** is a multi-paradigm numerical computing environment. A proprietary programming language developed by Mathworks. Mat lab allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. Although Mat lab is intended primarily for numerical computing, an optional toolbox uses the Mupad symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.
- ***Maxima:*** is a computer algebra system based on a 1982 version of Macsyma. It is written in Common Lisp and runs on all POSIX platforms such as MacOS, UNIX, BSD and Linux as well as under Microsoft Windows and Android. It is free software released under the terms of the GNU General Public License.
- ***MicroMath:*** is a general mathematical modeling and data analysis application. It is specifically designed to fit model equations to experimental data. Other programs focus on technical graphics, symbolic manipulation, matrix operations or worksheets for engineering calculations. Scientist incorporates all these elements, but its primary function is fitting equations to experimental data. Scientist can fit almost any mathematical model from the simplest linear functions to complex systems of differential equations, nonlinear algebraic equations or models expressed as Laplace transforms. If you need to fit experimental data to mathematical models, you won't find a better tool than Scientist for windows libraries of mathematical models for Chemical Kinetics, Diffusion and Pharmacokinetics can be purchased separately.
- ***NMath:*** is a numerical package for the Microsoft .NET Framework. It is developed by CenterSpace Software. Version 1.0 was released in March, 2003 as NMath Core. The current version is called NMath 6.0 released in 2014.
- ***Pari-GP:*** is a computer algebra system with the main aim of facilitating number theory computations. Versions 2.1.0 and higher are distributed under the GNU General Public License. It runs on most common

operating systems. The system is a package that is capable of doing formal computations on recursive types at high speed, it is primarily aimed at number theorists. Its three main strengths are its speed, the possibility of directly using data types that are familiar to mathematicians and its extensive algebraic number theory module.

- ***Reduce:*** is a system for doing scalar, vector and matrix algebra by computer, which also supports arbitrary precision numerical approximation and interfaces to gnuplot to provide graphics. It can be used interactively for simple calculations, but also provides a full programming language with syntax similar to other modern programming languages.
- ***SageMath*****:** is a free, open-source mathematics software system licensed under the GPL. It builds on top of many existing open-source packages: NumPy, SciPy, matplotlib, Sympy, Maxima, GAP, FLINT, R and many more. Access their combined power through a common, python-based language or directly via interfaces or wrappers.
- ***Xfractint:*** It is very versatile and extensive fractal program with many great features and is constantly upgraded and improved by the Stone Soup team.
- ***Geomview:*** is an interactive 3D viewing program for UNIX. Geomview lets you view and manipulate three-dimensional objects, and can also be used as a display engine by other programs to animate objects. It supports OpenGL and uses a Motif X interface. Geomview is a free software application from the other subcategory, part of the Graphic Apps category. The app is currently available in English and it was last updated at 2007. The program can be installed on All POSIX.
- ***Kaleido:*** is dedicated to graphic designers that need to offer something new to their customers. Transform your agency in a multimedia solution provider. Kaleido is the first innovative authoring system for multi-touch interfaces. Based on a nested grid model, you may include content grids inside other grids. It allows you to build an infinite zoom browsing interface. Kaleido will take care about memory performances, loading contents only when needed. A nice, easy to use GUI will allow every user to build his own multi-touch interface.
- ***Kash / Kant:*** is a *computer algebra system* for mathematicians interested in *algebraic number theory*, performing sophisticated computations in *algebraic number fields*, in *global function fields*, and *in local fields*. Kash is the associated command line interface. They have been developed by the Algebra and Number Theory research group of the Institute of Mathematics in *Berlin*. Kant is free for non-commercial use.
- ***LiDIA:*** A library for computational number theory. It is a C++ library for number theory. The present version only contains tools for rational integers and some floating point arithmetic, however. Emphasis is put on easy usability, modularity (e.g., it can be used with different multi-precision packages) and speed. In this report the authors present several illustrative examples. In particular, they compare their running times with those of the software packages Pari, Maple and Mathematica.
- ***MCAS:*** is a large, well-supported software package designed for computations in algebra, number theory, algebraic geometry and algebraic combinatory. It provides a mathematically rigorous environment for defining and working with structures such as groups, rings, fields, modules, algebras, schemes, curves, graphs, designs, codes and many others. Magma also supports a number of databases designed to aid computational research in those areas of mathematics which are algebraic in nature.
- ***SIMATH:*** a computer algebra system for number theoretic applications. This paper surveys the functionalities of the computer algebra system. The SIMATH system is primarily intended to solve number-theoretic problems, with a special emphasis on elliptic curves and cryptography. SIMATH is a set of C libraries. It is open source and runs on a large variety of UNIX systems.
- ***PDEase2D:*** This software program uses the finite element method to obtain numerical solutions for a large class of partial differential equations. The program is integrated with Macsyma 2.3 which provides many easy-to-use Macsyma notebook and graphics capabilities. The program has a simple input language for the problem description. Moreover, there are 170 executable sample problems from various fields of physics, such as solid and fluid mechanics, heat transfer, diffusion, electromagnetism, chemistry and quantum mechanics, so that the user can often solve his specific problem by slightly modifying an existing sample code. The software is capable of solving static, dynamic, or eigenvalue problems in two spatial dimensions, with up to 32 nonlinear partial differential equations together with constraint equations. An automatic grid generator allows to mesh rather complex shapes and to estimate the errors.

2. Background of the Study

Previous empirical studies on the usage of digital technology in teaching mathematics focused on specific types of activities such as professional development programs, lecturer's collaboration or professional learning communities. In the field of mathematics (Bell, 2010; Blank, 2008) have identified successful programs that improved lecturer knowledge and instructional practice. However, only a small number of studies have examined the impact of student achievement. While regional experimental studies on programs such as building block professional development (Clements, 2016) and (Balfanz, 2006) were found to be effective in increasing student achievement in mathematics, recent large scale randomized control trials of professional development programs that are coherent, continues and collaborative consistently failed to produce positive results in improving lecturer knowledge, instruction and student achievement (Garet, 2015). Many empirical studies have also been conducted on the effects of lecturer collaboration or professional learning communities on the student's achievement. Lecturer collaboration (Moolenaar, 2012) grade level teams (Saunders, 2009) were found to be associated with higher student achievement in mathematics subjects.

3. Methodology

A research methodology is a systematic plan for conducting research. Sociologists draw on a variety of both qualitative and quantitative research methods, including experiments, survey research, participant observation and secondary data. The research approach applied in this research has two major phases which are quantitative and prototype method. The quantitative method aims to classify features, count them and create statistical models, questionnaire survey, data analysis and validation. The prototype method includes the process of design the ideas for developing real time system in the future.

3.1. Quantitative Method

Quantitative research method is a method dealing with numbers and anything that is measurable in a systematic way of investigation of phenomena and their relationship. It is used to answer questions on relationships within measurable variables with an intention to explain, predict and control phenomena. In the field of information and communication technology, quantitative methods often deal with result computation and system analysis using a scientific approach. The objective of the quantitative method is to develop and employ models based on mathematical approach, hypotheses and theories pertaining to the nature of an ICT phenomenon. The process of measurement is the focus of quantitative method due to its connectivity relationships. This method is also known as an iterative process where the evidence is evaluated, and hypotheses and theories are refined with some technical advances, leveraging on a statistical approach (Leedy, 1993).

The survey is used for the techniques of investigation by a direct observation of a phenomenon or a systematic gathering of data from population by applying personal contact and interviews when adequate information about certain problem is not available in records, files and other sources. The survey is an important tool to gather evidences relating to certain social problems. The term social survey indicates the study of social phenomena through a survey of a small sampled population and also to broad segments of the population. It is concerned with the present and attempts to determine the status of the phenomenon under investigation.

A total of 150 educators participated in this research. Mathematics lecturers were used in the study. The participating lecturers were selected from 10 colleges, 4 university colleges, and 7 universities ranging from government, private and international. The average age of these lecturers was approximately 39 ranging between 25 and 58 years. There were 62 and only 18 females. The average teaching experience was approximately 12 years, ranging from as low as 2 years to 35 years. A questionnaire was used to collect data for this study. The first section of the questionnaire was used to collect demographic data. Following this was perceived barriers in the use of digital technology. The questionnaire was distributed through online. The data gathered and arranged use of SPSS 20.0. The descriptive statistics methods were used for data analysis.

3.2. Prototype Method

Prototyping is a development methodology in which a model is quickly constructed to test or illustrate design features and ideas in order to gather user feedback. Subsequently the models are created by refining earlier versions, with the aim of convergence on the desired end product. Prototyping has been widely used for at least 30-35 years. Prototyping consists of a series of phases in which a model is discussed and refined by the stakeholders and then implemented by the developers (Leng, 2015). A prototyping methodology is a software development process which allows developers to create portions of the solution to demonstrate functionality and make needed refinements before developing the final solution.

Software prototyping is somewhat similar. It produces a throw-away solution this is designed for the sole purpose of verifying user functionality and for demonstrating capability. It is an excellent way for the development team to confirm understanding of the requirements and ensure that the proposed solution is consistent with business expectations. This methodology works very well with online transaction processing system, which usually interacts. It also works well with web-based development and can very quickly help confirm page navigation and other user interaction requirements. A prototype methodology is a software development process which allows developers to create portions of the solution to demonstrate functionality and make needed refinement before developing the final solution. This technique can save considerable development time by reducing rework as users see the product for the first time.

The authors have followed the various step while constructing prototyping which are (a) decide on the goal of the project and its major components or categories, (b) choose one or two features to begin with usually in the main categories or home page, (c) create a preliminary design on paper, (d) discuss the design with stakeholders with the aim of improving it, (e) repeat steps 3 and 4 generate a simple design that all can agree on (f) implement the design on the computer, (g) repeat the consultation process until the features are good enough to continue and (h) add another feature and repeat the prototyping process of consultation and refinement.

4. Results and Findings

4.1. Quantitative Analysis

The important barriers in integrating digital technology in lessons were investigated in the research. Respondents were asked to indicate their levels of agreement on perceived barriers to digital technology integration on a five point Likert scale (1 = strongly disagree, 5 = strongly agree). The typical Likert scale is a 5 or 7 point ordinal scale used by respondents to rate the degree to which they agree or disagree with a statement. The score values were interpreted as one is the lowest possible score, which represents a negative attitude, while five is the highest possible score, which represent a very strong positive attitude (Likert, 1932). Table-1 shows the mean values of the barriers as perceived by the lecturers.

Table-1. Summary of Barriers to Digital Technology Integration

Barriers to Digital Technology Integration	% Response as		
	Not a barrier	Minor	Major
Not enough or limited access to computer hardware	52.20	43.62	04.23
Availability of computer software	42.82	50.76	06.55
Lack of time in the school schedule for projects involving digital technology	25.55	40.33	34.21
Lack of adequate technical support for digital technology projects	37.16	39.98	23.04
Lack of knowledge about ways to integrate digital technology to enhance curriculum	30.89	50.30	18.97
Digital technology integration is not a school priority	68.03	28.94	03.16
Difficult finding substitutes in order for lecturers attend training	36.26	61.17	02.74
Students do not have access to the necessary technology at home	62.02	26.02	12.02
Lecturers do not have access to the necessary technology at home	81.50	16.09	02.57
Integrating and using different digital technology in a single lesson	35.02	43.24	21.83

From the survey, some major barriers hindering the implementation of digital technology in mathematics teaching were found to be the lack of time in college and universities schedules for projects involving digital integration, the lack of adequate technical support for digital technology projects, inadequate lecturer training opportunities for digital projects, the lack of knowledge about ways to integrate digital technology to enhance the curriculum and to integrate and use different digital tools in a single class session. It is also recommended that the contents of the subject be reduced so as to integrate digital technology lecturers consider that inadequate time is a factor against teaching and learning effectiveness.

Table-2. Digital Technology uses in the Class

Application Response (%)	Using presentation tools	Using Courseware	Using graphical visualizing tools	Online demos	Others	None
	56.5	6.9	15.0	12.7	3.0	5.9

6.9% of the respondents used courseware in the class, 56.5% used ICT as presentation tools, 15.0% used ICT as a graphical visualising tool, 12.7% used ICT as an online demonstration tool, and 3.0% used it for other purposes in class. About 29.7% of the respondents did not use ICT in the classroom. Table 2 shows the percentage distribution of ICT uses in the class.

Table-3. Use of internet by Teacher

Activity (%)	Browsing	e-mail	IRC	Discussion forums	Chat rooms	Others	None
	51.5	32.0	6.2	5.5	1.2	1.0	2.6

The Internet was used for various purposes. 51.5% respondents used it for browsing, 6.9% used the e-mail facility, 32.0% used chat rooms, 6.2% used IRC, and 5.5% used it in discussion forums and 1.2% for other purposes. 1.1% respondents did not use the Internet. Table 3 depicts the details.

Table-4. Levels of Use in Digital Tools

Descriptions	Frequency	Percent
Digital tools is fully integrated into my instructional programme	005.0	009.3
I have integrated digital tool into specific instructional units	025.0	025.7
I use digital tools infrequently with students	032.0	035.0
I have not used digital tools at all	038.0	030.0
Total	100.0	100.0

The level of use of digital tools in instruction was still low with 38.0% respondents stating they had not used digital tools at all and 32.0% of them stating that they used digital tools infrequently. On the other hand, 25.0 % of them responded that they had integrated digital tools into specific areas of instructional units and 5.0% stated that they had fully integrated it into their instructional programmes. Table 4 depicts the levels of digital tools use in teaching.

4.2. Prototype System Development

The system prototyping is an approach to developing, testing, and improving ideas at an early stage before large-scale resources are committed to implementation. It is a way of project and team working which allows you to experiment, evaluate, learn, refine and adapt. The prototype system is the activity of creating prototypes of software application. It is an incomplete version of the software program being developed and also an activity that can occur in software development and is comparable to prototyping as known from other field such as software engineering, mechanical engineering, or manufacturing (Leng, 2015). The benefits of prototype systems are: (a) misunderstanding between software users and developers are exposed, (b) missing services may be detected and confusing services may be identified, (c) a working system is available early in the process, (d) the prototype may serve as a basis for deriving a system specification and (e) the system can support user training and system testing.

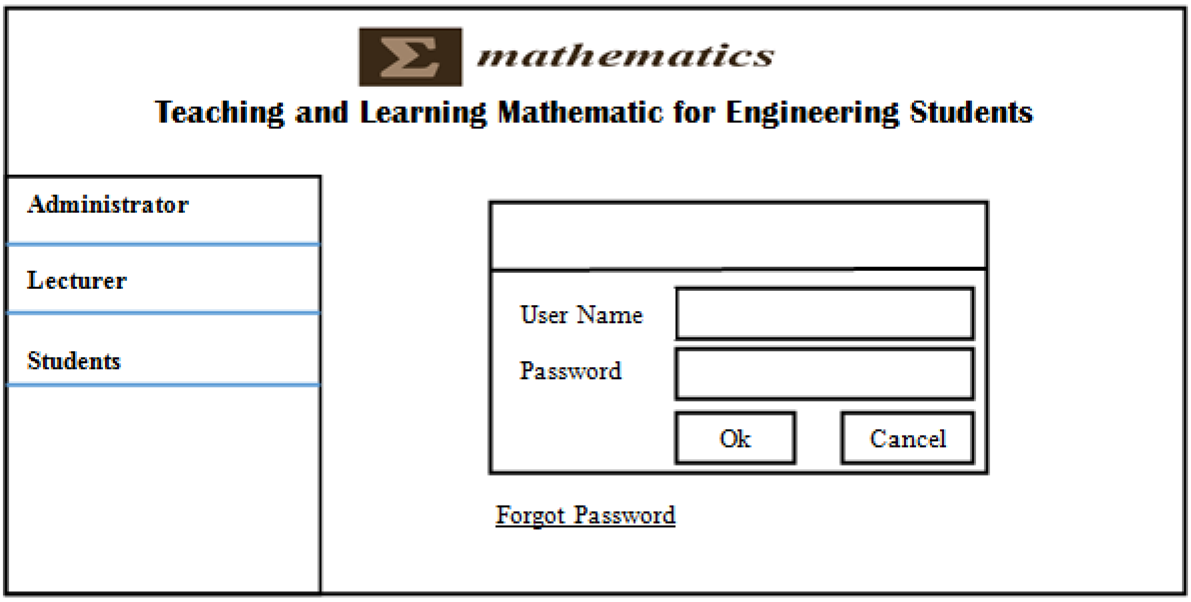
The proposed prototype system for teaching and learning mathematics consists of three users, namely Administrator, Lecturer, and Student. Each user has a unique username and password. Once the user has entered their username and password the system will open the individual page under their name. The user name can be alphanumeric and minimum length should be 6 to 20 characters. The password must use a minimum password length of 12 to 14 characters and include lowercase and uppercase alphabetic characters, numbers, and symbols. The prototype system consists of three users; administrator, lecturer and students. It has many amenities such as collection of mathematical tools, resources material storage, and mathematical guidelines, latest research and projects, lesson planner and so on.

Table-4. Perceptions towards the proposed prototype system

	% response as very useful and helpful	**% response as useful and helpful**	**% response as not so useful and helpful**	**% response as not at all**
A proposed solution to develop a mathematics prototype system for teaching mathematics	80.5	18.0	1.5	0.0

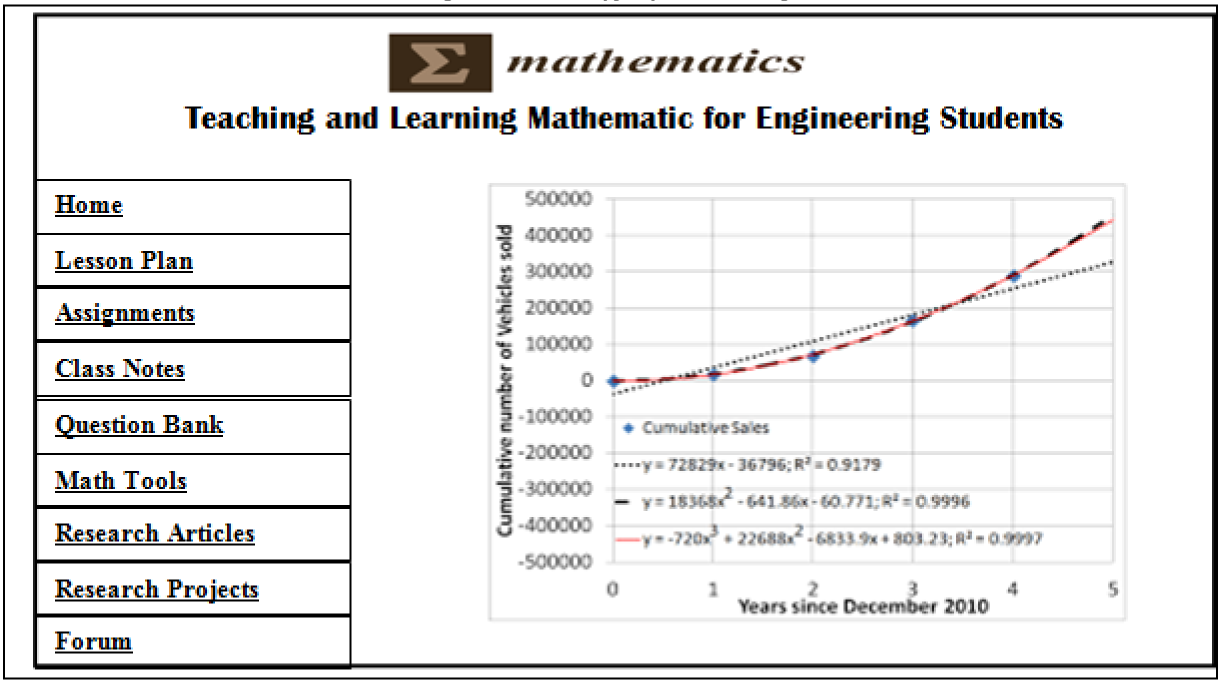
There is a very strong positive response to the proposed solution to develop a mathematical prototype system for teaching mathematics; wherein a collection of resources and a lesson planner are incorporated to relive the lecturer from routine tasks. 80.5% of the respondents considered it to be very useful and helpful and 18.0% viewed it as useful and helpful. Only 1.5% of the respondents considered that the prototype system would not be very useful and helpful. Table-3 gives the percentages of the response.

Figure-1. The Login Page



The prototype system main page contains lesson plan, assignments, class notes, question bank, mathematics tools, current research articles, research projects and forums. A lesson plan is a lecturer's detailed description of the course of instruction. A daily lesson plan is developed by a lecturer to guide class learning. Details will vary depending on the preference of the lecturer, the subject being covered, and the needs of the students. An assignment is a task or piece of work that lecturers are given to do, especially as part of the study. The forum is also a vibrant community of educators that share their ideas and opinions with one another. The ability to interact with peer across the class, it also creates an opportunity to build professional relationships.

Figure-2. The Prototype System Main Page



5. Conclusion

The use of digital technology in teaching mathematics can make the teaching process more effective as well as enhance the students' capabilities in understanding basic concepts. Nevertheless, implementing its use in teaching is not without problem as numerous barriers may arise. The authors believe that mathematics teaching for engineering university in the college or university can be made much more interesting, inventive, innovative, and exploratory using the proposed prototype system. The most common types of barriers have been identified in this research. The proposed prototype system has scored 80.50 percent from the respondent stated that it is considered to be very useful and helpful. The authors conclude that the system is to overcome some of those barriers as well as enhance the engineering students' capabilities in understanding mathematics concepts.

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