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A New Integrated Style to Teaching Engineering Mathematics at Third Level Engineering Courses

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Abstract

Mathematics is the main pillar in the engineering foundation courses and the engineering profession where mathematical manipulation, modelling and simulation are used widely. However, experience in engineering courses has shown that students encounter some difficulties in mathematics, with a certain degree of disinterest and apathy. This is reflected in the mathematical continuous assessments, final exams, laboratory reports for other engineering subjects and in answering engineering numerical question-based mathematical formula.

This paper investigates a new development and the implication of two models of a CBL integrated with course lecture material. This is part of an overall integrated approach, achieved through an embedded Visual Basic mathematics programming into MS Excel. The results of this paper attempt to promote mathematics in engineering courses and provide substantial information to the educators in both mathematics and engineering at third level education.

Keywords: CBL, engineering mathematics, education.

1. Introduction

Recently there have been various attempts to improve the engineering education and teaching engineering mathematics. It has been shown that the engineering educational system at present is falling behind the manufacturing system with regard to quality within its industry (J.Perendergast, M.Saleh et.al , 2001). This suggests that urgent reform of the engineering tertiary educational system is needed, as this system is expected to provide the skilled engineering workforce for today's manufacturing technology (M,saleh, 2003). The general mathematics problem in undergraduate engineering courses was described already in (Howson. A.G, 1995 - James, D.G., 1995). At present, this general decline shows little sign of improving (Sutherland R. and Pozzi S., 1995)

P. Edwards et al.,2003, investigated a project to enhance students understanding of mathematics. This project has resulted in the translation of some *Visual Basic* programmes into Java applets delivered on the Internet Web site, *MathinSite.* A.Howrwitz et al.,2002, described a collaborative project between the Mathematics and Engineering Departments of universities. This collaboration effort involved enhancing the first year calculus course with applied engineering and science projects. The application project involved both teamwork and individual work, and required both programmable calculator and Matlab. Milton Fuller,2000, reviewed developments and trends in engineering mathematics education in Australian universities over the past number of years. He recommended that mathematics departments in Australia should set up working groups to tackle the emerging needs of engineering education.

A. Carlos et. al.,1996, have developed a sequence of programmes to assist the engineering students to explore in depth several features of the soliton's formation, propagation, and collision. The physical origin of the solitons is the Kerr effect, which relies on a nonlinear dielectric constant that can balance the group dispersion in the optical propagation medium. These numerical routines were implemented for use with MATHEMATICA ™ and the results give a very clear idea of this interesting and important practical phenomenon.

M. Saleh et.al.,1992, have developed a two dimensional linear and non linear finite element computer programme as an educational aid. This was to help the engineering students to understand the practical implication of the matrix manipulation and numerical analysis in engineering design.

This paper examines the integration between mathematics, computing and applied engineering to deepening the mathematical understanding at third level engineering courses. Graphical visualization and physical application of the mathematics of real engineering problems are used to motivate the engineering student and enhance the mathematical learning process.

2. Engineering Curricula and Mathematics

Engineering is a field of science where students develop their critical, lateral thinking and creative skills to enable them to apply the knowledge they gain effectively in an innovative fashion in real life. This is based on a combination theoretical, tutorial and experimental studies of the relevant subjects in the engineering curricula. The main objective of this teaching method, in engineering, must enable the students to construct engineering concepts. Therefore, the acquisition of engineering skills, during engineering courses, depends widely on the understanding and the flexibility of the teaching methodology. This is based on extracting the rational conclusion from a combination of theoretical, tutorial and relevant practical studies. The role of mathematics in the engineering profession is mainly to idealize a real-world situation through models that aid in the analysis of the engineering problems with minimum time and cost. Models in engineering can be theoretical or empirical models. The application of mathematical techniques and numerical methods-based computing are used widely in engineering to simulate and solve engineering models. On the other hand, mathematics is delivered in engineering courses as a series of sequential theoretical and tutorial based quiz sessions similar to the way it is delivered in any school of mathematics. Hence, mathematics is often seen among engineering students as a collection of abstract objects without direct practical reference. This discourages engineering students, as it is structured in direct contrast to other engineering subjects in the curricula, and lacks stimulation. However, the modern mathematical education of engineering students must recognise that (Norbert Grünwald and Dieter Schott, 2000):

- Understanding and handling the basics and foundations of mathematics is more important than knowing a lot the details.
- The use and interpretation of the results comes prior to being able to prove results.
- Controlling computations, calculations and estimations is more significant than being able to do computations by oneself.

3. Practical Considerations

The proposed teaching method is mainly to sustain the academic balance between engineering and mathematics. The current approach to date has been to write software that is capable of creating problems which typically involve random numbers, and detailing associated solutions. The engineering mathematic modules should be developed in collaboration with engineers and mathematicians, containing a set of mathematical problems/mini projects underlying engineering applications. Students should be introduced to the basic concepts of these problems. A mathematic laboratory should be available to students at different levels during the engineering course of study. These laboratories should be equipped with the relevant tools/materials to deliver the mathematical theoretical concepts or to suppor the relevant acquisition of experimental data. Students should be encouraged to solve the assigned problems/mini projects through group work. Based on the experimental and theoretical investigation of each mini project, each student has a different related problem to solve through the CBL system. This is intended to reduce the possibility of direct "cogging" by students, and enhances the sense of personal "ownership" of their particular problem. Students who get stuck can simply look at the answer provided, and unlike a book or a problem database that has limited numbers of questions, the system can then create a brand new problem and try again. They can also experiment by creating different types of problems (sometimes specifiable within the application) and looking at the solutions to see how the solution varies with the problem details.

4. Foundation Mathematics

In some respects this is a difficult subject area to tackle. Key areas of weakness for students tend to be in algebraic manipulation and transposition of formulae. To date we have not tackled this with CBL but some of our ideas are presented below. It is the inescapable symbolic nature of this area of mathematics that makes it more difficult. Many other specific areas, such as those treated later, do not need to focus on the symbolic nature of the solution techniques and so are more tractable in CBL terms using applications programming in Visual Basic or Microsoft Excel. To tackle algebraic manipulation and transposition of formulae would either involve:

- A fairly restricted problem set, or
- A fairly (very?) advanced software application, or
- Software written using an existing symbolic manipulation packages, such as MuPad, Macsyma, Maple, etc.

One idea here, whichever environment is chosen, is to present the student with varying levels of difficulty with each level introducing additional aspects of manipulation. This approach allows the student to build up confidence at each level, and in essence gives them more control to pace the learning to suit themselves.

So level 1 might contain problems that only require basic laws of algebra: Associativity, commutativity and distribution of multiplication over addition.

A sample question might be:

Simplify $2(x+y)-2x$

Then at level 2 introduce more complex manipulations and equations, for example:

Solve $2(x+y)=2x-y$ for *x*.

Then at level 3 introduce quotients of terms. Then at level 4 include powers, logs, e^x . Next at level 5 introduce trigonometric functions. Finally at level 6 combine them all.

One key difficulty, with a symbolic manipulation programme, is to implement the mathematical equivalence of the expected answer and the answer provided by the student. Most computer algebra systems (CAS) can test for the equivalence of two expressions. Writing a computer programme to determine whether both the student's answer is equivalent to the expected answer, and determining that they did in fact use the expected rules is probably a significant and difficult challenge. A way around this is to provide a "symbolic editor" which allows the user to manipulate the expressions using only an allowed and restricted set of operations. This would help determine that they took the correct steps. On the downside it removes the manipulations from the "real world" somewhat, and is a complex application to create.

4. Case Studies

5.1. Harmonic and phase analysis:

This is to demonstrate the understanding of the mathematical concept of the harmonic and phase analysis in AC circuits and dynamic systems. Figure 1 shows the MS Excel application of the Sine function and Figure 2 shows the Cosine function. Simply, the value for the amplitude, frequency and phase can be altered in the target values, and accordingly the current value of the Sin/Cos is graphically changed. This current value can be visualised from the screen and compared with a standard waveform every time the target value is altered.

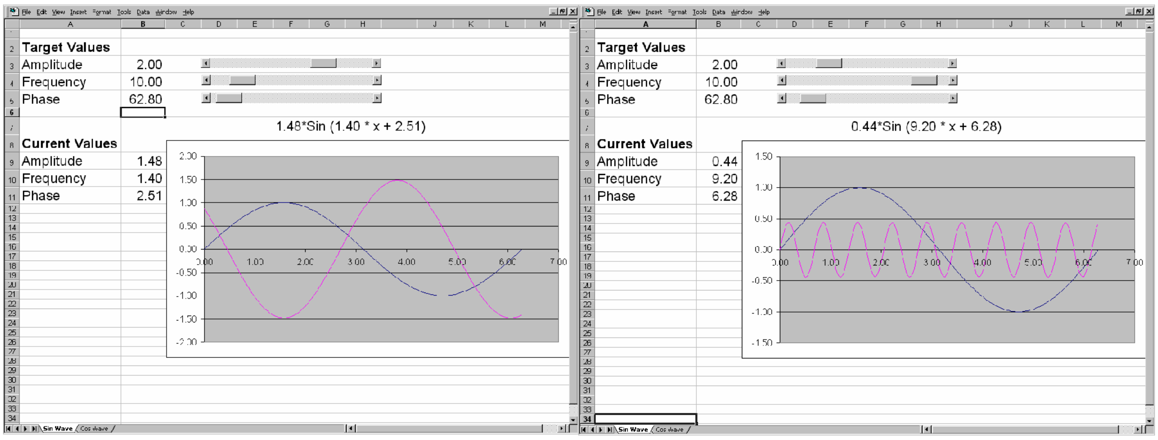

Figure 1: CBL Sine function

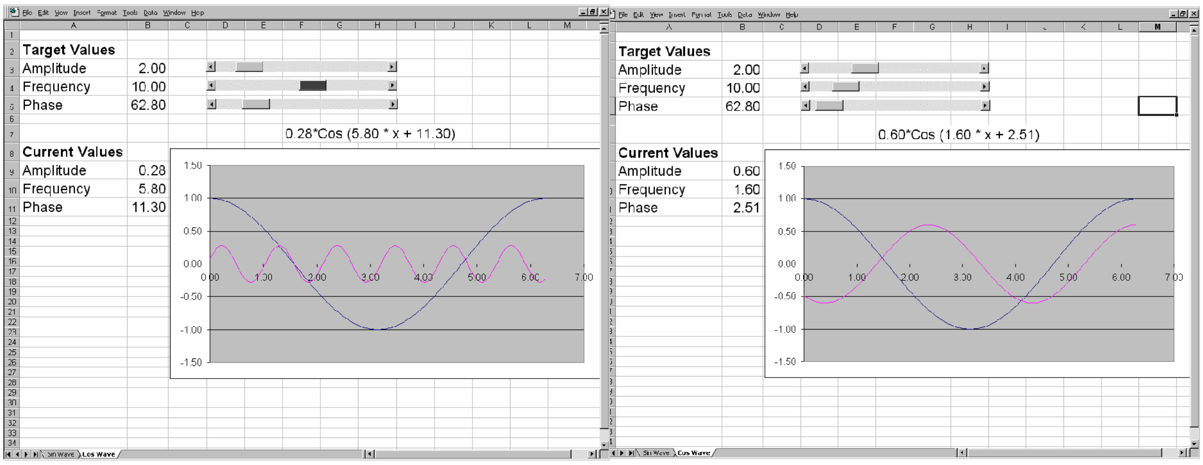

Figure 2: CBL Cosine function

5.2. Analysis of Variance (ANOVA):

This is a sample application which could be used to give students practice in single factor ANOVA. It is not intended as a standalone learning module. It is intended to be used as an integrated course tool (i.e quality assurance, measurement system, etc.) to give students practice with real data, and a tool that they can interact with, and carry out personal investigations into ANOVA and the F distribution. Students should have prerequisite knowledge of:

- random sampling;
- frequency distributions, frequency polygons;
- probability distributions - Normal & F;
- hypothesis testing, and ANOVA.

Learning Objectives:

- To give students practical and interactive experimental experience with ANOVA from multiple samples;
- To show students how the F-distribution is generated from MSA/MSW where H0 is true/false. The CBL of this analysis is shown in Figure 3.

5. Discussion

Remembering mathematical ideas and techniques can be a problem. Students will depend heavily upon semantic memory, for example, under examination conditions where careful and accurate recall is required. Semantic memory relates to the meanings of things, such as words or concepts. In contrast, episodic memory is the remembering of events, things that happened, places visited, based upon sequences of events. Calling on episodic memory requires event reconstruction (...and then I did this...), which, unfortunately on the one hand, can be susceptible to an individual's perceptions and interpretations but on the other hand, can complement semantic memory (Peter Edwards et.al,2003). Since the proposed integrated learning method depends heavily on the interactive visualisations. This visualisation approach can aid memory stimulation and retention. Also, the graphical visualisation of this approach, through a sequence of events, give students a deeper insight into the mathematical problem they are investigating as every time a graph is accomplished on the screen it will add some meaning to the students. This encourages students to sketch the visual graphs from the screen. The integration and the application of this approach in real engineering problems help the students to construct the engineering mathematical concept through the reflective abstraction. The teamwork in this approach allows students to abstract the engineering principles, and hence to explore the engineering profession. Consequently, studying and solving problems as a group would enable students to gain very good communicative skills.

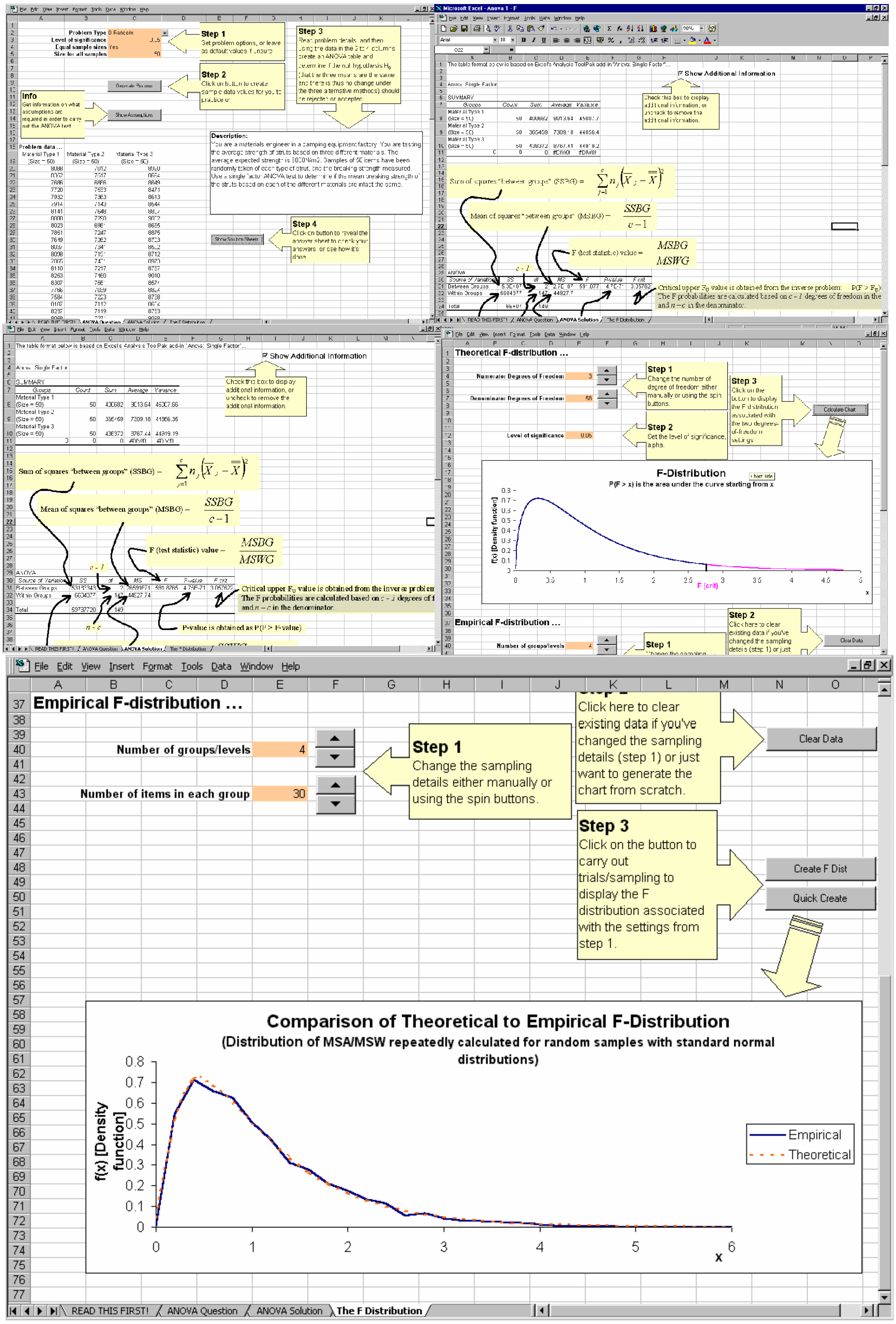

Figure 3: CBL of ANOVA

This is to ensure an effective environment for the exchange and development of ideas (Belbin, R.M ,1996). Also, this environment develops the lateral and critical thinking which allows the students to use what is so called the How? and Why? effectively in engineering mathematical modules. The nature of the challenge in this method would stimulate the students and give them a sense of ownership and thus, motive and commit them to further study. The role of the lecturer in this method is to provide a strategic practice in which he or she should be working with the students, suggesting different methods and solutions.

6. Conclusion

Overall, the proposed integrated CBL approach has been discussed. It has been argued that this graphical visualisation approach is an effective method to learning engineering mathematics at third level engineering courses. However, it should be noted that the CBL approach does not replace the lecture entirely. It is a tool to help the student's own learning process and students need to formulate the problems in mathematical language and thinking.

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