Engineering Course Curriculum Development with Application Specific Mathematics Course Content

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***Abstract*— A novel way in the teaching of mathematics course is presented. It focuses on using specific engineering examples and problems that are taught in other courses in the same semester of the curriculum, as application areas in the mathematics course. This technique does not only allow students to apply what they learn in engineering courses, but it gives them a point of reference in understanding fundamental mathematics principles. Using engineering and mathematics courses material archives and text books, numerous examples and application problems were reviewed and compiled for five consecutive standard mathematics engineering courses of the curriculum. From this study and analysis it was evident that several engineering application areas could be cited and referenced in the teaching of mathematics to engineering students. Consequently making the student learning experience a more rewarding that includes a set of examples and problems that can be solved in mathematics lectures and focused on engineering courses.**

Keywords*— engineering; mathematics; exercises; and problems;

I. INTRODUCTION

Many exercises and problems solved during engineering courses do not relate to the courses studied during the semester at that time. This makes it difficult for students to relate and pply what they learn in other courses in a comprehensive way. The formulae presented in this paper looks at courses covered in a given semester and provides exercises and problem solving that embodies applications specific to those courses. Efforts to develop a curriculum focused on engineering have been widely emphasized [1-3]. Also, it is important to prepare students with the skills required for engineering programs [4, 5]. It is necessary for students to understand how to apply concepts learnt in other courses to problems and designs in the courses they are studying [6-8]. Engineering courses involve a lot of mathematical and other problem solving; however, students find it hard to solve the problems they find in these courses. The basics behind these engineering mathematical and other problems are already covered in several other courses within the curriculum. However, students are unable to relate and apply what they were taught in other courses to solve the problems found in the engineering courses they are studying at a given time in the curriculum. On the other hand, the problems they solve in the other engineering courses are not directly presented as applications to real engineering problems in their current course. As a consequence, there is need to develop a formulation of utilizing examples and problems solved in other engineering courses, so that students will be able to apply what they learned across all engineering courses within a specific semester. The proposed method involves building a database of engineering examples and problems that are directly related to the mathematical and other problem solving that students are studying at the same semester or level within a curriculum. Not only does this ease the understanding of taught engineering principles and fundamentals, but it enables the students to pinpoint directly engineering applications to related mathematical and other problem solving.

For this technique to work properly, the examples and problems content for the various courses at each semester or level should be related. With this in mind, no course would have applications examples and problems from another at a higher semester or level. Students would then easily apply in the current courses what they learn in the other courses at that current or previous semester or level. By looking at a very generalized curriculum shown in Table 1, it is clear that courses taught in different semesters should have application examples and problem solving from the other engineering courses in that semester. Such examples and problem solving can be applied directly or modified to fit different engineering programs. Therefore, in each semester, mathematics, natural sciences, general studies, as well as engineering courses should be mapped and aligned. These details are further emphasized in the methodology section.

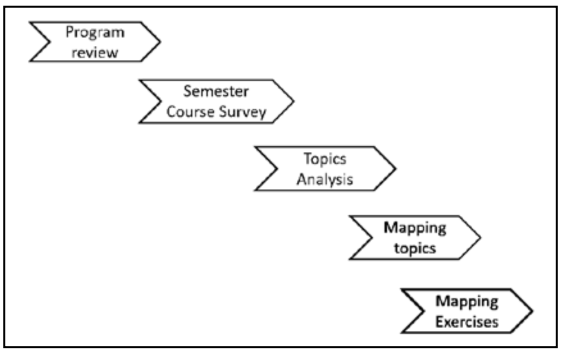

Fig. 1. Steps involved in the design

II. METHODOLOGY

Several engineering courses were evaluated to find out the examples, exercises, and problems that can be used in the other courses with reference. The methodology used in this work had many stages as shown in the Fig. 1. First of all the engineering program curriculum was reviewed. It showed the different engineering programs being covered in detail. Initially one of the engineering programs was chosen. From it, a list of the courses to be covered in this work was generated as emphasized in Fig. 2.

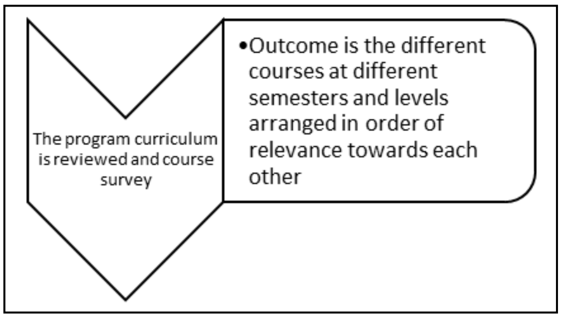

Fig. 2. Program curriculum review stage

The course outlines of these courses were also downloaded from the course catalogue and printed for reference. Each of the courses was then sought under the common electronic archive files for all courses, to find out its content specific to examples, exercises, and problem solving as emphasized in Fig. 2.

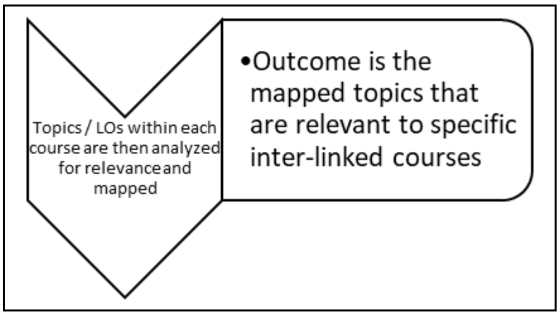

Fig. 3. Program curriculum review stage

In these archives, specific reference was made to assignments, exams, student sample work, although instructor resources were also reviewed. The procedure was repeated for the all targeted courses and in all cases the examples, exercises, and problems were taken out so that they could be used in the other courses. Electronic text books, and reference text books for each course were also used as sources of exercises and other problem solving content.

A detailed sample list of examples, exercises and other problem solving was compiled that could be used for the relevant courses and instructors as a guide. The work was divided into two categories or phases, with phase I focused on semester one courses taught at level one, while the phase II dealt with the semester two courses taught at the level two as shown in Table 2.

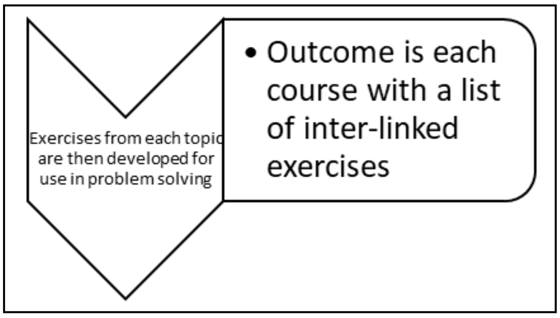

Fig. 4. Program curriculum review stage

The courses in phase I were reviewed through the electronic text books for specific application examples, exercises, and problems problem solving. Since most of the courses are in level one or semester one where students have already covered related courses, the use of these examples, exercises, and other problem solving in their course contents is limited. Nevertheless, the examples, exercises, and other problem solving were reviewed and collected for reference. The data from these courses could also be used in the phase II of this work where examples, exercises, and problem solving from lower semester courses are employed used in higher semester courses that are within the same hierarchy and are prerequisites for them.

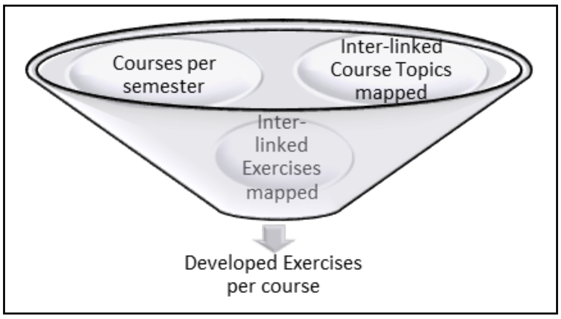

Fig. 5. Algorithm/Formulae in summary

III. RESULTS AND DISCUSSION

A visualization of the course mapping algorithm/formulae is shown in Fig. 5 with all stages and the final expected outcome. An engineering curriculum was reviewed. One of the engineering programs was chosen, and its courses listed. Each course was checked under the electronic archive files with emphasis on instructor resources and assignments/exams. Instructor resources were a good resource for demonstration of problem solving application areas while assignments, exams were good to demonstrate the examples, exercises and other problem solving. An overview of courses for level one (semesters one and two) is shown in Table 1.

TABLE I. LEVEL ONE COURSES

Year 1 – Semester 1	Year 1 – Semester 2
GEN-0001 General Course 1	GEN-0002 General Course 2
ENG-0001 Engineering Course 1	ENG-0003 Engineering Course 3
ENG-0002 Engineering Course 2	ENG-0004 Engineering Course 4
Nat-0001 Natural Science Course 1	Nat-0002 Natural Science Course 2
MAT-0001 Mathematics Course 1	MAT-0002 Mathematics Course 2

In semester one, the mathematics 1 course exposes students to linear and quadratic equations, exponential logarithmic and trigonometric functions, as well as complex numbers. On the other hand, during the same semester students are taking engineering 1 course which exposes them to measuring and determining voltages and currents, and then tabulate the results as well as finding the mean, median and standard deviations. They may go as far as writing or solving simple resistor, voltage and current linear equations. Therefore if in the mathematics 1 course, examples, exercises, and problem solving related to the topics they cover or have covered in the measurements course, then students could easily apply what they learn and understand in mathematics 1 better. A batch of related examples and problems were compiled. The same can be related to interlink there is between mathematics 1, Natural Sciences 1, and engineering 1. Such interlink resulted in the mapping shown in Table 2.

TABLE II. SEMESTER ONE MAPPING

Year 1 – Semester 1	Mapped Relevant Course
GEN-0001 General Course 1	
ENG-0001 Engineering Course 1	ENG-0002; Nat-0001; MAT-0001
ENG-0002 Engineering Course 2	ENG-0001; Nat-0001; MAT-0002
Nat-0001 Natural Science Course 1	MAT-0001
MAT-0001 Mathematics Course 1	Nat-0001

From this mapping, it is evident that engineering course 1 can benefit from mathematics 1 as well as natural science course 1 in the development of the examples, exercises and other problem solving that is done in class during semester 1, level 1.

In semester two, the mathematics 2 teaches the students about limits and derivatives of different functions like trigonometric, hyperbolic, exponential and logarithmic functions. At the same time they have started another engineering 2 course which covers the relationship between voltages, resistances, currents and power, manipulation of ac signals, as well as circuit laws and theorems like Kirchhoff's, Thevenin and Norton, all of which result in linear and differential equations of various functions in the form of trigonometric, exponential and logarithmic. Examples and problems related to these were compiled. A similar analysis can be applied to the mapping of mathematics 2, Natural Sciences 2, and engineering 2. Additionally, it could also explain the existing mapping between semester one courses with semester two courses between the same hierarchy. For instance general course 1, mathematics 1, Natural Sciences 1, and engineering 1 with general course 2, mathematics 2, Natural Sciences 2, and engineering 2 respectively, as shown in Table 3.

TABLE III. SEMESTER TWO MAPPING

Year 1 – Semester 2	Mapped Relevant Course
GEN-0002 General Course 2	
ENG-0003 Engineering Course 3	ENG-0004; Nat-0001; MAT-0002
ENG-0004 Engineering Course 4	ENG-0003; Nat-0002; MAT-0002
Nat-0002 Natural Science Course 2	Nat-0001; MAT-0002
MAT-0002 Mathematics Course 2	MAT-0001; Nat-0002

In semester three, the mathematics 3 covers integration and anti-derivatives of logarithmic, numerical, trigonometric, partial, and other functions in different coordinate planes. At the same time, two engineering courses are being taught: engineering 3 and engineering 4, whose applications could be helpful in understanding the mathematics course. Engineering 3 is about transient and steady state responses of circuits made of resistors, capacitors, inductors, and also equivalent circuits like thevenin, Norton, and filter circuits whereas engineering 4 takes students through diodes, transistors and their characteristics and applications. Examples and problems related to these have been selected and compiled.

In semester four the mathematics 4 course covers linear algebra and differential equations with details on matrices, vectors, eigen values, first and second order differential equations, as well as laplace transforms. The engineering courses in this same semester are engineering 5, engineering 6, and engineering 7. In engineering 5 they cover amplifier circuits, filters, and oscillators while in engineering 6 they cover a communication system from transmitters and modulation to receivers and demodulation, as well as the transmission channel, whereas in engineering 7 they cover three phase electrical circuits like transformers and ac generators, motors and related circuits. These topics are prime application areas that students can be referred to when teaching mathematics, and related examples and were compiled.

In semester five the last mathematics 5 course is related to Hyperbolic functions, Taylor and Fourier series, vectors, partial derivatives, limits, as well as line integrals. The engineering courses in the same semester are engineering 8, engineering 9, and engineering 10. engineering 8 covers Continuous and discrete signals, Fourier, Laplace, and z transforms, while engineering 9 involves digital modulation, transmission, error detection, and coding techniques, satellite and fiber optic communication systems whereas engineering 10 covers processes variables for open and closed loop control systems and their characteristics, as well as pid systems. Examples and problems related were compiled.

An extension to this work would be to apply the same technique to engineering courses themselves using their prerequisite courses. With this approach, courses like engineering 12, engineering 13, and engineering 14, would benefit from previously taught courses like engineering 11, but this would be part of future work.

A. *Sample Example or Problem*

Considering a task given to students while studying mathematics 1 course where they connect the circuit that is familiar to what they learn in engineering 1. The circuit is shown in Figure 2 and is made up of three resistors and a supply voltage V1, with R1 in series while R2 and R3 are in parallel. Assuming that the currents through the resistors R1, R2, and R3 are I1, I2, and I3 respectively, then when students apply Kirchhoff law [9] which they learn in engineering 1, they can form equations (1-3).

$$I_1 + I_2 + I_3 = 0 \tag{1}$$

$$R_1 I_1 - R_2 I_2 = -V_1 \tag{2}$$

$$R_2 I_2 - R_3 I_3 = 0 \tag{3}$$

As students solve the above linear equations, they are applying the things they find them familiar since they cover them in engineering 1. A more complex problem can also be formulated as shown in Figure 3 where a resistor R1 and inductor L1 are connected in series with a current I passing through them. Since students would have learnt the total impedance Z, of the circuit in engineering 1, they would easily formulate equation (4), and solve the total voltage of the circuit as shown in equation 5 thereby understanding clearly the application and relevance of the trigonometric, exponential and logarithmic functions to what they are learning.

$$\mathrm{Z} = \mathrm{R} + L_1 \tag{4}$$

$$\left|\mathrm{V}_{RL_1}\right| = \mathrm{I} * |Z| = \mathrm{I}\sqrt{(\mathrm{R}^2 + {L_1}^2)} \tag{5}$$

Similar sample examples and problems can be generated that cover all courses at various semesters and levels thus transferring what they is studied in engineering as examples and problems in mathematics.

IV. Conclusions and Future Work

Sample examples and problems borrowed from engineering were generated that could be used in teaching and learning of mathematics courses to enable students understand and apply what they learn in engineering and while at the same time seeing the relevancy of the courses. The key criteria however was to consider that mathematics and engineering courses that are taught in the same semester or level were mapped together so that examples and problems from the engineering courses at that level or semester where the ones used in the mathematics courses at that level or semester. To generate sample examples and problems, text books, course outlines, as well as electronic archives of the courses, were used. It was found that specific topics in mathematics courses matched those in engineering courses at the same level or semester, and examples or problems could be easily integrated and used during teaching and learning.

Other courses that are not related to mathematics would also benefit from this novel technique where students apply what they learn on one side as they do another course. This is the focus of further work.

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Table 1: Lists of targeted mathematics courses with respective sourcing engineering courses

Targeted Mathematics course	**Sourcing Engineering course**
MTH-0001-Mathematics 1	ENG-0001 Engineering 1
MTH-0002- Mathematics 2	ENG-0002 Engineering 2

MTH-0003- Mathematics 3	ENG-0003 Engineering 3
	ENG-0004 Engineering 4
MTH-0004- Mathematics 4	ENG-0005 Engineering 5
	ENG-0006 Engineering 6
	ENG-0007 Engineering 7
MTH-0005- Mathematics 5	ENG-0008 Engineering 8
	ENG-0009 Engineering 9
	ENG-0010 Engineering 10

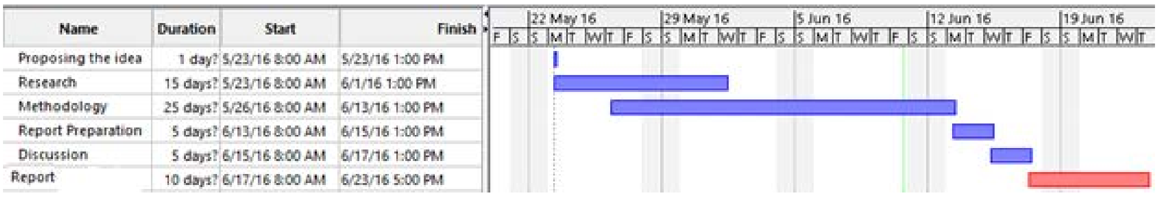
Table 2: Division of work

Phase I	Phase II
ENG-0008 Engineering 8	ENG-0001 Engineering 1
ENG-0009 Engineering 9	ENG-0002 Engineering 2
ENG-0010 Engineering 10	ENG-0003 Engineering 3
ENG-0011 Engineering 11	ENG-0004 Engineering 4
ENG-0012 Engineering 12	ENG-0005 Engineering 5
ENG-0013 Engineering 13	ENG-0006 Engineering 6
ENG-0014 Engineering 14	ENG-0007 Engineering 7

Table 3: Course content from electronic archives and electronic text books

Course	**Ecafs and Etext resource coverage**
ENG-0011 Engineering 11	- Complex equations (imaginary and real) - Logarithms (log & ln) - Exponentials - Matrices - Cosines/sines/tangents/sec - Integrals and differentials - MATLAB programming
ENG-0012 Engineering 12	- Logarithms (log & ln) - Exponentials – powers and series Cosines/sines/tangents/sec - Multiplexers and Demultiplexers from EEC2013 - Digital Circuits - ASCII and Gray code from EEC2013 - Digital Circuits
ENG-0013 Engineering 13	- Complex equations (imaginary and real) - Exponentials – complex exponentials - Matrices and Vectors - Cosines/sines/tangents/sec - trigonometry - Integrals and differentials - Summations, Series/Power Series, Limits - MATLAB programming
ENG-0014 Engineering 14	- Complex equations (imaginary and real) - Exponentials – complex exponentials - Matrices and Vectors - Logarithms (log & ln) - Cosines/sines/tangents/sec - trigonometry - Integrals and differentials – small changes or

	deltas (partial differentiation) - Summations, Series, Limits – (Taylor series) - Laplace transforms - MATLAB programming
MTH-0001-Mathematics 1	- Basic Linear equations of V, I, R - Complex equations - Representing data - plotting - Probabilities - Probability distributions - Regressions/Correlations
MTH-0002- Mathematics 2	- Linear equations, absolute Values - Logarithms (log & ln) - Exponentials - Cosines/sines/tangents/sec
MTH-0003- Mathematics 3	- Cosines/sines/tangents/sec (trigonometry) - Integrals and differentials - Limits
MTH-0004- Mathematics 4	- Natural Logarithms (ln) - Integrals and differentials - Differential Equations - Laplace Transforms - limits
MTH-0005- Mathematics 5	- Hyperbolic Functions – sinh/cosh… - Integrals and differentials of hyperbolics - Series – Taylor & Fourier - Matrices and Vectors – and their plotting - Partial differentiation (small changes or deltas)



Name	Duration	Start	Finish
Proposing the idea	1 day?	5/23/16 8:00 AM	5/23/16 1:00 PM
Research	15 days?	5/23/16 8:00 AM	6/1/16 1:00 PM
Methodology	25 days?	5/26/16 8:00 AM	6/13/16 1:00 PM
Report Preparation	5 days?	6/13/16 8:00 AM	6/15/16 1:00 PM
Discussion	5 days?	6/15/16 8:00 AM	6/17/16 1:00 PM
Report	10 days?	6/17/16 8:00 AM	6/23/16 5:00 PM

Figure 1: Rough scheduling of tasks during this work

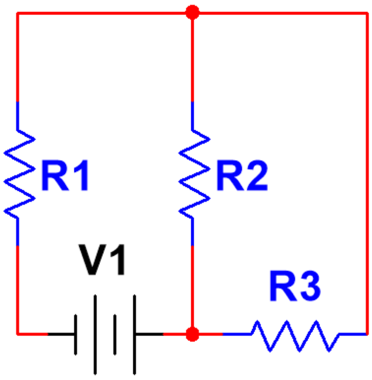


Figure 2: Sample circuit for a mathematics task with engineering application.

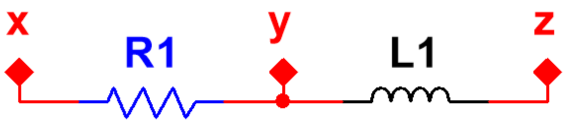


Figure 3: Sample circuit for a mathematics task with engineering application.