Tutorial: A Case Study on Integrated Learning

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Abstract—**Today's world has graduated engineers in large number with good knowledge of fundamental engineering science but engineers lacks ability to apply that in practice with real time problems. One major reason for this may be that our students are exam oriented. Our emphasis must be on "what is learnt" rather than "what is taught" in class. Faculty should transform themselves from teacher to facilitator. Conventional transform focuses much on engineering science and technical courses without providing sufficient integration between these two. As observed, students study different courses as black box without interconnection between them. This paper presents a learning method that effectively integrates Circuit analysis with Signals and Systems Course. Integrated learning motivates the students to put together the knowledge of the different courses studied previously or in the same semester and apply them in real time problems through integrated tutorials. This learning method facilitates 100% involvement of students in group; help them changing their approach towards learning the course and enabling them to understand the importance and application of what they are learning catering to large class room. Findings shows that there was a significant positive difference in students academic achievement and attitude towards learning the subject through this pedagogical activity.**

Key words: Integrated tutorial, ABET

I. INTRODUCTION

Circuit Analysis (CA) and Signals and Systems (S&S) forms the basic foundation courses for Electrical, Electronic and Instrumentation students. S&S course focuses on mathematical representation of real time signals and its processing systems where as CA course focuses on the AC and DC currents, voltages, components like resistor, capacitor inductor. They all together combine and define the behavior of electrical circuits. These two courses were introduced in the III semester in the curriculum and as observed, students study these subjects without correlating them. As an initiative, the integrated tutorial has been proposed for these respective courses where applications of S&S properties were invoked in the solution of circuit network problems.

This paper presents a series of analog-circuit based activities that can help students visualize the complex mathematical concepts and gain a better appreciation for how the concepts are useful in real-world situations. Our engineers must be capable of using the theoretical and mathematical concepts from the courses to model a real world phenomenon. The majority of students find difficulty in doing so as they lack in visualizing the concepts been taught in class and correlate those theoretical concepts with real world problems or the physical phenomenon for modeling. An efficient way to make the students gain experience of real time problem solving is that they must be introduced to the real world applications that would make us create degree of credibility and relevance that is not possible with just chalk and talk method. The lack of the basics in the engineers will make them less competent in the present scenario were electronics, computational and embedded systems play a very important role in design, development and operation of engineering systems. The integrated tutorial as a pedagogical activity helped to improve the effectiveness of engineering education curriculum by addressing the lack of correlation between the courses.

In the past the courses that are S&S and CA were taught and tutorials of one credit were conducted every week for the students to solve extra problems on the course. This approach indeed helped the students to get an idea of various problems and how to deal with it, but again it was a normal chalk and talk method. This paper introduces an attempt where the integration of two courses is been done and solved some real time problems. These exercises have been used in an introductory integrated tutorial course since August 2013.

Organization of rest of the paper is as follows. Section II describes the methodology, Section III describes the implementation details, Section IV describes the Assessment, Section V describes the Effectiveness, Section VI describes the Experimental Outcomes and Discussions and Section VII describes the Conclusion.

II. METHODOLOGY

The two fundamental courses had tutorials on regular basis that is one tutorial for one subject in a week which constituted the syllabus and problems of the respective course. Another tutorial was introduced in the same week at the end after completion of both the course tutorials which was basically the integration of the concepts of CA and S&S courses. Transmission of knowledge present in the information by faculty does not guarantee an effective understanding of the student in a large class room which has been a greatest challenge. In order to address this challenge we divided the class room in exactly two sub divisions that is if the class strength is 80 then Group 1 have 40 students and group 2 have 40 students. Totally four faculties were assigned to carry out the tutorials. These two fundamental courses are the basic courses that students encounter in their degree,

where there is a heavy use of engineering mathematics, such as differential equations, integral calculus and complex numbers. By dividing the class room in subdivisions the faculty can deal with the difficulties faced by the students in an efficient manner and focus on much complex problems which involve electrical modeling of physical systems.

The details of this tutorial are presented in this section. The tutorial involves the following

- Recap session: In this session students have to quickly recall the concepts dealt in both the classes and analyse the concepts which constitutes 15 minutes of the tutorials.
- Group formation: In this the students in a group of two are given problems to solve and faculty have to assist them.
- Identification of physical component and analysis: Every week the students have to come up with a physical component and analyse the working of the physical component in a group.
- Problem solving: The students should provide the electrical equivalent circuit and solve the given problem by using the concepts of CA and study the behaviour of the system using S&S course.

III. IMPLEMENTATION

As a facilitator, faculty member have to foster the students reasoning from front end explanation to the back end and scaffolding. There is a possibility of students gaining knowledge to tackle realistic problems and increase his or her control over learning.

The following plan is been developed to carry out the integrated tutorials:

- Start with an essential question.
- Monitor the students and the progress of their approach.
- Assess the outcome.
- Evaluate the experience.

Discussion of some of the examples as case study:

Case study 1: Realisation of the R-L circuit:

At the beginning the students are given with the R-L circuit which has to be solved using the KVL and KCL concepts dealt in CA course to find the transfer function of the system. After getting the impulse response of the system, this system is later interacted with any input to get the response. Using the impulse response of the system the stability, linearity, causality and time invariance properties of the system are

checked and behaviour of the system is analysed using the concepts been covered in S&S course. An example is shown below which is an R-L circuit is:

Given a system below, find the interaction of the system with the step signal as an input. Check whether the system is stable, causal and memory less.
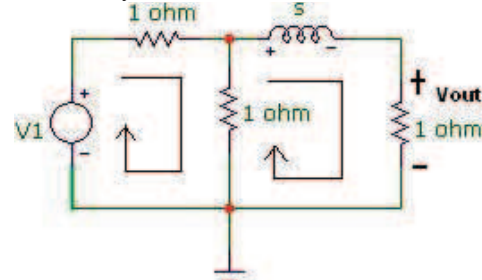

Fig.1. R-L Circuit

Loop 1 equation: $-V_i+i_1+1(i_1-i_2) =0$, Solving the above equation we get

$2i_1-i_2=V_i$---**1st Equation**

Loop 2 equation: $1(i_2-i_1) +Si_2+1i_2=0$, Solving the above equation we get

$-i_1+ (2+s) i_2=0$-------------------------------------**2nd Equation**

$$\begin{bmatrix} 2 & -1 \\ -1 & (2+s) \end{bmatrix} \begin{bmatrix} i1 \\ i2 \end{bmatrix} = \begin{bmatrix} Vi \\ 0 \end{bmatrix}$$ ------------------------**3rd Equation**

Using Cramer's rule, find the value of loop current i_2 in order to get the equation for Vout

$$\Delta = \begin{bmatrix} 2 & -1 \\ -1 & (2+s) \end{bmatrix} = (2s+3)$$

$$i_2 = \begin{bmatrix} 2 & Vi \\ -1 & 0 \end{bmatrix} / \Delta; \quad i_2 = V_i/ (2s+3)$$

Applying Ohm's law

Vout = $i_2*1 \Omega$ Vout=$V_i/(2s+3)$

Now the impulse response is :

$H(s) = \dfrac{Vout}{Vi}$, $H(s) = \dfrac{1}{(2s+3)}$

Its inverse Laplace transform is required impulse function of the system provided

$h(t)= \dfrac{1}{2} e^{-\frac{3t}{2}} u(t)$-------------------------------- Using the concepts covered in CA.

Using the properties to check for the behavior of the system the students analyze that the system is stable, memory less and casual.

- Condition for stability: $\int_{-\infty} h(t).dt < \infty$
- Condition for causality: h(t)=0 for t<0
- Condition for memory less : $h(t)=\delta(t)$

By using these conditions, we apply to the impulse response of the system obtained by analysing the circuit and the behaviour of the system is studied.

Case Study 2: Problem statement: Analyse the system behaviour and interpret the results in the DC motor torque when the input is a step input.The students have studied about the DC motor in their first year as a part of their academy. By giving this as the physical component, the students have to first compute the electrical equivalent of the component and find its impulse response by computing the transfer function of the system.
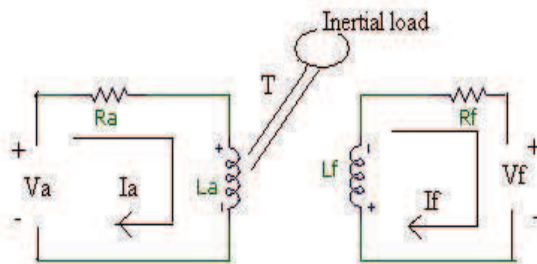

Fig.2. Electrical equivalent circuit the DC motor

As seen in the above Fig.2 the DC motor consists of an inductor and resistor, the resistances and inductances of the field and armature sides of the motor are represented by Rf, Lf, Ra and La. The voltages applied to the field and armature sides of the motor are represented by Vf and Va. If only field controlled current is considered then we find that the system is of single order. In a field current controlled motor the armature current i_a is held constant and the field current is controlled through the field voltage V_f.

The motor torque increases linearly with field current i_f then we write $T_m = k_{mf} \cdot i_f$

By taking Laplace transform we get the transfer function from the input current to the resulting torque.

$$\frac{T_m()}{i_f(s)} = k_{mf} \text{-------------------------------------}1^{st}\textbf{ Equation}$$

Solving the given circuit with the concepts of circuit theory i.e. KVL

$V_f = V_r + V_L$

$V_f = Ri_f + L(\frac{dif(t)}{dt})$

The transfer function from the input voltage to the resulting current is found by taking Laplace transforms of both sides of this equation.

$$\frac{()}{Vf(s)} = \frac{(\frac{1}{Lf})}{s+(\frac{Rf}{Lf})} \text{---------------------------------}2^{nd}\textbf{ Equation}$$

The 2nd equation is a 1st order system. The transfer function from the input voltage to the resulting motor torque is found by combining equations 1 and 2

$$\frac{Tm}{Vf(s)}(s) = \frac{\frac{Kmf}{Lf}}{s+\frac{Rf}{Lf}}$$

$$h(t) = \frac{Kmf}{Lf} e^{-(Rf/Lf)} \cdot u(t)$$

For a step input that is $u(t)$ interaction will be

$y(t) = u(t) * \frac{Kmf}{Lf} e^{-(Rf/Lf)} u(t)$. Hence when solved using convolution integral the step signal as an input produces the motor torque to increase exponentially.

IV. ASSESSMENT

Each student was assessed based on his/her individual contribution and in the group. The assessment criteria for evaluating the performance of the students are as shown in Table I.

TABLE I. ASSESSMENT CRITERIA

S.No.	Assessment criteria	Weightage
1	Physical component chosen.	5%
2	Analysis of the component and ability to arrive at the electrical equivalent circuit of the component.	30%
3	Choosing an approach to solve the given problem and arrive at its impulse response using concepts dealt in circuit analysis	25%
4	Providing the behavior of the system and the output for various inputs using the concepts dealt in signals and system course.	25%
5	Simulation of the given physical model and provide the input specified and verify the simulated result with the theoretical results.	15%

V. EFFECTIVENESS

The effectiveness of the activity has been assessed through the student's performance before and after conduction of the integrated tutorials. Comparison of the semester end results of the academic year 2012-13 to the academic year 2013-14 for CA course is been done and feedback is collected by the students. With this activity, students were able to have thorough analysis of the concept being learnt in the class. Feedback Questionnaires for this activity is listed in Table II.

TABLE II. QUESTIONNAIRES FOR STUDENT FEEDBACK

Q.No.	Particulars
1.	In future where will these integrated tutorials help you in better understanding in other courses and project?
2.	Did this activity enhance the purpose and justification towards learning the concepts in different courses?
3.	After this integrated tutorial how do you rate the understanding level of the course?
4.	Did technique inspire you for collaborative learning?
5.	Any other comments or feedback.

Question 1 relates to whether the students will use this learning technique in future for interactive learning in other courses and project. In response students suggested that this tutorial helps them in providing better analysis of different concepts and make them capable of problem solving at III semester level which they will be using in there higher semesters for mini, course and capstone projects. Question 2 reflects on why the students are learning the particular concepts, where it is used and how the concept is applied, and in response 91% students agreed that this learning method helped them to apply the concepts studied in solving real time problems. For question 3&4, an achievement of 88% is observed to justify better understanding of the concept and 90% in enhancement in collaborative learning as shown in Fig.3.In the below figure X –axis corresponds to the number of questions and Y-axis to the response of the students in percentage.
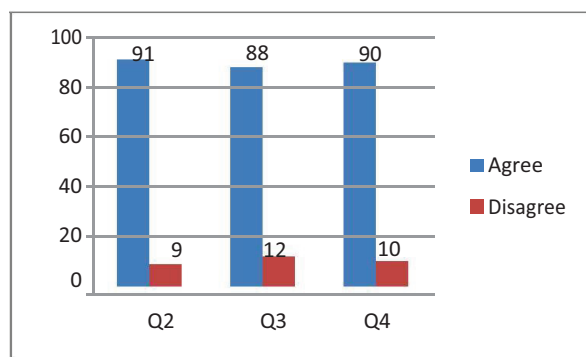

Fig. 3. Feedback Summary of Integrated tutorials by students

The effectiveness of the integrated tutorials proposal has been reflected in the performance of students. The performance of students in the academic year 2012-13 for CA is compared with the performance of the students in the academic year 2013-14 and is observed that the percentage of the large class room is increased as shown in Fig.4 In the below figure X –axis corresponds to the consecutive academic year and Y-axis corresponds to the passing percentage of the students
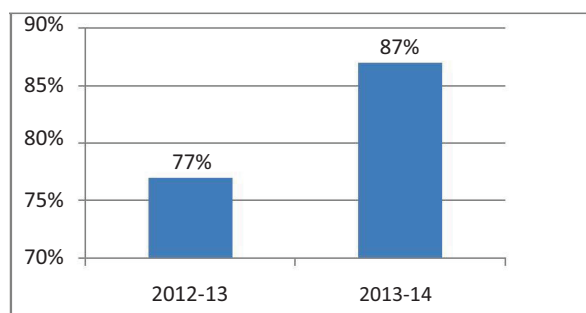

Fig. 4. Comparison of results

VI. EXPERIMENTAL OUTCOMES AND DISCUSSIONS

Integrated tutorials as a learning technique is mapped to the learning outcomes a to k of Accreditation Board for Engineering and Technology (ABET)[5] criteria as shown in Table III.

TABLE III. ACTIVITY OUTCOMES MAPPING TO ABET PROGRAM

Steps	Performance indicators attaining the Program outcomes	Program outcomes a-k criteria's addressed
Team work	To collaboratively select the best solution with justification	d
Concept analysis	Students can apply their knowledge of engineering to develop a solution for a given problem and have a better Understanding of the concept.	a
Extended learning	Students should be able to use this learning technique in any course	i
Soft skills	Students have to simulate the given physical model and provide the input specified and prove there results are correct.	k

The attainment of Program outcomes through performance indicators is shown in the Fig. 5 In the below figure X –axis corresponds to the Program outcomes (PO), performance indicators and Y-axis corresponds to the attainment of each PO out of 10.
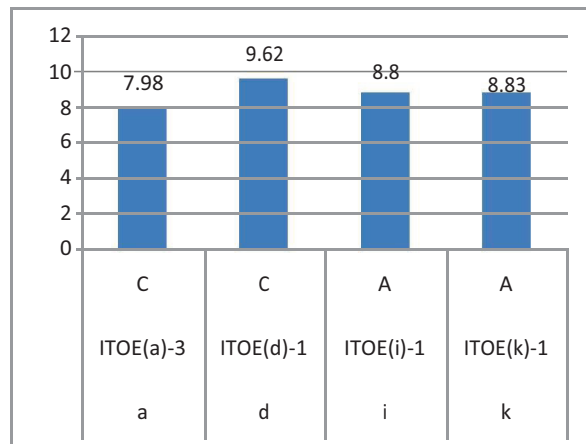

Fig .5. Program Outcomes Attainment through Performance Indicators

By the above graph we can infer that by adopting this learning centric method we are able to achieve the outcomes a, d, i, k. A number of improvement points have been identified through this measurement.

- In collaborative learning method students have to intensively practice brainstorming and generate ideas thoroughly as a team for a given problem.

- In this study the students have to apply the knowledge of basic electrical and electronic sciences.

VII. CONCLUSION

This paper reflects the student's exposure to the collaborative learning technique that is, introduction of integrated tutorials and it was observed that the students learn and interpret the concepts to solve real time problems. As this is a collaborative learning technique the students were motivated to learn the course. The most prominent positive outcome of the experiment is that over 90% of the students have clearly indicated that this has given them a very good opportunity to evaluate, work on and improve their conceptual learning method.

This interactive learning approach adopted has great impact in significantly improving the overall teaching learning process, encouraging the faculty and the students to extend the same to the relevant courses in the curricula program. By implementing this integrated tutorial we were able to attain the ABET[5] criteria a,d,i,k whereas before this subject was only able to attain a & k.

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