EFFECTIVE APPROACHES FOR TEACHING OF FUNDAMENTAL SUBJECTS IN ELECTRICAL ENGINEERING

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Abstract *- The fundamental subjects in electrical engineering, such as circuit theory, contain many abstract concepts, principles and ideas, which are usually needed in solving problems related to real life. These subjects may be hard for students to comprehend. Therefore, educators should help and motivate students to learn as well as to develop enthusiasm for these subjects. To achieve these objectives, educators need to use more effective methods of teaching which strengthen these concepts and help students to retain, retrieve and apply the concepts they have learned. An overview of some techniques that can be utilised to enhance memory retention to help students in retaining information to their maximum ability will be provided. Also the use of analogy as a teaching tool to promote better understanding of the behaviour of some electrical components, such as inductors, in electric circuits will be discussed.*

1. INTRODUCTION

In electrical engineering courses, core subjects which focus on fundamental concepts, are taught usually in the first and second years of the courses. These core subjects contain many abstract concepts and electrical components, such as inductors, which are often modeled and discussed in terms of mathematical equations. At this stage, almost all of the students need a means of qualitative models and analogies to facilitate a deeper understanding and long term retention of these abstract concepts.

The problem faced by lecturers when teaching these subjects is how to maximize their students' memory retention rates and how to help students to retrieve and apply the concepts they have learned. Jones [1] pointed out that the most useful approach to improved retention is to improve the systems of recoding rather than to try to increase the learner's retention span. Therefore, it is the lecturer's responsibility to help the students and to develop useful techniques for recoding material.

This paper will provide an overview of some techniques that can be utilised to enhance memory retention and will describe how these techniques can be applied by educators to help students to learn and retain information to their maximum ability. Also, the use of analogy as a teaching tool to help students to relate familiar concepts to those that are abstract, will be discussed as it pertains to forming a representational model of the behaviour of some electrical components. The paper will discuss the responses and feedback from students in relation to the use and effectiveness of these teaching methods.

2. TECHNIQUES FOR MEMORY ENHANCEMENT

These techniques depend on the individual educator, situation, subject and material to be learned.

2.1 Meaning and Retention

Research has shown that "Not only is meaningful material more rapidly learned than meaningless material but also it is remembered for longer periods of time" [2]. Meaningfulness consists of students' grasping relationships among facts, generalisations, rules and principles for which they see some use [2]. Therefore educators should concentrate on teaching related and connected facts and not facts in isolation. Facts need to be put into some context for the students - for example, connecting facts to some previously learned material is one way to put facts into context. In this situation a teaching strategy that links different units together would provide some reference for students.

Students need the material to be applicable to them and the teachers should be able to help students to see the applicability of the material for situations in which they may find themselves in. The quality of material presented is another aspect of the meaningfulness factor. Lecturers should present their material in a simple and straightforward way with a logical order, so that the students can see the relationships among facts and put them into context.

2.2 Purposefulness

Purpose and meaning are closely related factors. Students need to be aware of the purpose of the material they learn and need to know where the new information will get them in real life. Teachers can address this in many ways. Explicit statements such as "at the end of this lecture you will be able to use multimeters to measure voltage, current and resistance in electric circuits". Clear objectives of each lecture can be included in course outlines and unit introductions. Similar

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descriptors can be added to assignments and practical sessions to let the students know the purpose of each of them and what they are going to achieve after completing them. Research has shown that material, which can be learned insightfully, particularly on the level of generalised insight [2], will have a stronger chance of becoming more permanent. This might be achieved if teachers could help their students find meaning and purpose for the material they learn.

2.3 Overlearning

It has been found that overlearning does contribute to retention and has been listed by most books in educational psychology as one of the means of improving retention especially when the information to be learned is initially meaningless. Bigge [2] defined overlearning as "the percentage of additional practice spent after initial mastery". Overlearning may be achieved through revision examples during lecture time after each new topic with tutorial or practice problems and tests, which are directly related to the new topic. These exercises, problems and tests serve to reinforce the information.

This technique is best utilised in instances where simple association is being learned that will later be the basis for further knowledge [1]. Fig.1 shows the effect of overlearning on retention [1]. The figure indicates that the 50 percent overlearning group produced higher levels of retention than did students who stopped practice as soon as they attained mastery.

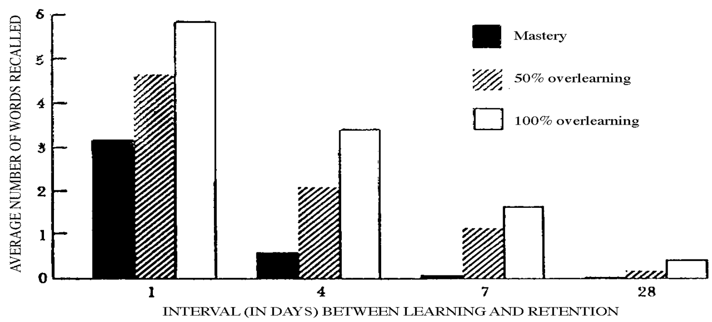

Fig. 1. Effects of overlearning on Retention [1]

2.4 Spaced Review versus Cramming

Retention is higher when study periods are spaced methodically over the course of an entire semester than when a student waits a day or two before the final examination and then tries to study the subject matter of a course all at once [2]. When students cram, there will be no guarantee that they correctly remember the material, which they learned some time ago. Previous studies showed that the rate of forgetting follows the typical forgetting curve shown in Fig. 2. The rate of forgetting is much more rapid relatively soon after the initial learning and for this reason spaced review should happen before the students have a chance of forgetting a large chunk of the material that they have learned. For the best effect this should immediately follow initial learning. It should be noted that review does not refer to repetition but rather to practice. Spaced review can take the form of assignments, short diagnostic tests, quizzes, etc., and should be integrated into other units of work and, at best, related to the unit that the students are currently studying.

2.5 Other Techniques

2.5.1 Mnemonics

Probably the most promising way to work on improving students' memory is by improving their encoding strategies. One way to do this is to use mnemonics. Mnemonics provide connections with new knowledge and already learned material. It is a very useful technique that can be used by students when they need to learn material that is not meaningful. One type of mnemonic that is commonly used is imaginability, which relates to the formation of visual images [3]. The students should be encouraged to build a visual image that they recall when they want to retrieve the learned information.

2.5.2 Familiarity

Teaching students material that they have some knowledge of will reinforce what they know and prepare the way for the new knowledge. Teachers should try to link new material with something that the students already know. This will help students to form links with previous knowledge and also make the material more meaningful to them.

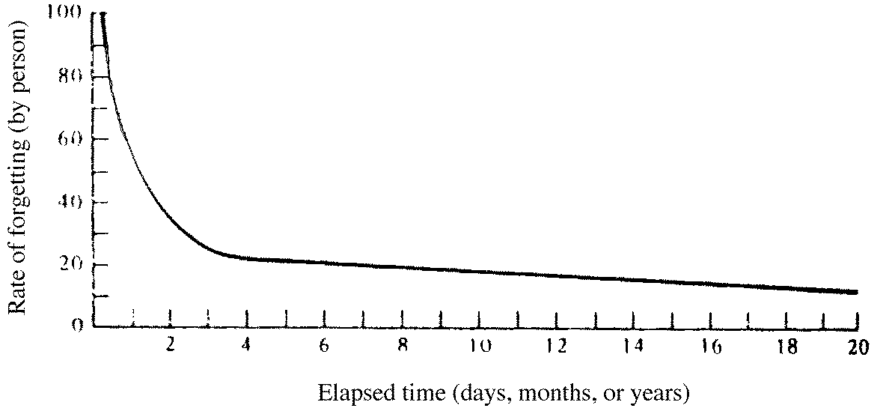

Fig. 2 A typical forgetting curve

2.5.3 Structurability

Structurability relates to the structure of the material to be learned. The lecturer should be aware that the material to be presented should be systematically organised. This will reduce students' confusion and will make sure that the material is well organised into the student's cognitive structure. For instance, summaries and introductions at each lecture are important for students. At the beginning of each unit of work, lecturers should spend some time to detail the objectives of the unit, how students will progress through it and what the methods of assessment are.

2.5.4 Stimulus Patterns

Teachers should be aware of stimulus patterns. "We must either teach students under conditions that are highly similar to those under which we later expect them to perform, or we must arrange for them to learn under varied conditions of stimulation" [1]. For instance, practical subjects should include some practical sessions that allow the students to have hands-on practice. It is one thing to know what to do technically, and another to actually do it.

3. USING ANALOGIES TO AID UNDERSTANDING

Analogies have the ability to provide a powerful tool for students to learn about abstract concepts. Studies suggest that through the use of analogies, students can obtain a conceptual understanding of complex scientific concepts and increase their long-term retention [4,5]. Using analogies provides the ability for students to solve problems using a new or alternative approach, helps point out behavioural and functional similarities to real world systems, encourages visualization of the abstract, and initiates interests which can motivate [5].

3.1 Basic Hydraulic System

Although some analogies to teach electrical engineering concepts exist, much of the information provided in textbooks and lectures are based on mathematical equations and theoretical principles or laws. However, an analogy encompassing a basic hydraulic system to explain the behaviour of resistors in circuits is sometimes used. Each of the components in a basic resistive circuit has a respective counterpart in the analogy. The comparisons between object mapping, property mapping, and relations among them are shown in Table.1 [6]. After testing the analogy on college and high school students, the results indicated that the analogy was useful for explaining circuits with single and multiple resistors and voltage sources in series and in parallel.

Table 1: Mapping between Water Flow and Electricity [6]

Base - Hydraulic System	***Target – Circuit***
Object Mapping:	
pipe	Wire
pump	Battery
narrow pipe	Resistor
Property Mapping:	
PRESSURE of water	VOLTAGE
NARROWNESS of pipe	RESISTANCE
FLOW RATE of water	CURRENT (FLOW RATE of electricity)
Relations Imported:	
CONNECT	CONNECT
(pipe, pump, narrow pipe)	(wire, battery, resistor)
INCREASE WITH	INCREASE WITH
(flow rate, pressure)	(current, voltage)
DECREASE WITH	DECREASE WITH
(flow rate, narrowness)	(current, resistance)

3.2 Modified Hydraulic System

Since, at the present time, there is no widely used analogy to help students to conceptually understand the inductor, an analogy has been developed to assist students to find an alternative means of explaining and learning the behaviours within a resistor-inductor (RL) circuit [7]. The inductor analogy, as described in Table 2, is a modification of the hydraulic system using similar mapping to that of the resistive circuit.

Providing students with the analogy of the resistor and the basic hydraulic system will help them to form relationships between the modified hydraulic system and the inductor analogy if the need arises. Hence, the modifications to the basic hydraulic system are specific only to the inductors leaving all other components the same as before. Associated with the behavioural functions of the inductor is the induced voltage (back EMF), magnetic field, and time constant. The inductor analogy approaches each concept using the modified hydraulic system.

3.2.1 Induced Voltage

When there is a change in the flow of current, a voltage is induced across the inductor that opposes the change in current flow. Considering the analogy, suppose that a bi-directional motorised pump is connected to a narrow pipe and an elastic pipe. Assuming that the pipes are filled with water (as is a conductor is filled with electrons) at the time the pump is turned on, there is a high pressure through the elastic pipe. This pressure opposes the flow of water in the elastic pipe and initially limits the water flow. As the water flow increases and approaches a steady state, the pressure decreases. Finally, when there is a constant flow of water, the pressure is zero.

3.2.2 Magnetic Field

The magnetic field through the inductor is dependent on the amount of current flow. In the modified hydraulic system, the size of the expansion (or bulge) in the elastic pipe is analogous to the size of the magnetic field. When the pump is first turned on, the pressure, as a result of the current flow through the elastic pipe, causes the elastic pipe to bulge. As the water flow increases, the bulge will increase. Once water reaches a steady flow, the bulge in the elastic pipe cannot increase or decrease. When the pressure from the hydraulic pump begins to decrease, the pressure in the elastic pipe also decreases. However, the remaining pressure in the bulge keeps the flow of water without sudden decrease.

3.2.3 Time Constants

In a resistor-inductor (RL) circuit, there is a time constant associated with the increase of current through an inductor. The time constant is related to the amount of inductance (L) divided by the amount of resistance (R). The modified hydraulic system works similarly. The amount of time it takes for the water to increase to a steady flow depends on the elasticity of the elastic pipe and the amount of resistance the narrow pipe provides. For example, holding the amount of elasticity of the elastic pipe constant (or the inductance), connected to a slightly narrowed pipe (low resistance), the amount of water flow through the circuit is high and the amount of time it will take for the water to reach steady flow is decreased. Conversely, if the size of the narrow pipe is held constant and the elastic pipe has a higher elasticity, then it takes a longer time for the flow of water to be constant.

Table 2: Mapping between Water Flow and RL Circuits

Base - Modified Hydraulic System	Target – Circuit
Object Mapping:	
Pipe	Wire
Bi-directional Pump	AC voltage source
Narrow Pipe	Resistor
Elastic Pipe	Inductor
Property Mapping:	
PRESSURE of water	VOLTAGE
NARROWNESS of pipe	RESISTANCE
FLOW RATE of water	CURRENT
ELASTICITY of pipe	INDUCTANCE
BULGE in elastic pipe	MAGNETIC FIELD
PRESSURE in elastic pipe	BACK EMF
TIME CONSTANT	TIME CONSTANT
Relation Imported:	
CONNECT	CONNECT
(pipe, pump, narrow pipe, elastic pipe)	(wire, AC voltage source, resistor, inductor)
INCREASE WITH	INCREASE WITH
(flow rate, pressure, bulge)	(current, voltage, magnetic field)
DECREASE WITH	DECREASE WITH
(flow rate, narrowness, elasticity, time constant)	(current, resistance, inductance, time constant)

4. FEEDBACK FROM STUDENTS

It has been our practice to ask the students to survey the subject we teach. A special questionnaire was designed and distributed to 35 students taking first year's electrical engineering subject. The aim of the questionnaire was to obtain students' evaluation for the unit. Analysis of the results of the evaluation of the subject structure, organisation, assessment procedures and teaching techniques showed that 73% of the students selected strongly agree to all the essential aspects covered in the questionnaire. Results also suggested that the analogy can be an effective tool for helping students obtain comprehensive understanding of the inductor.
In addition, the comments of the students have proved usefulness in further improving our teaching to make student learning more effective.

5. CONCLUSION

In conclusion, lecturers who are involved in teaching core subjects in engineering should be aware that students often experience problems in learning these subjects. There are a number of techniques, which can be used to maximise student retention rates and to enable them to reach their maximum potential knowledge. The utilisation of these techniques can make teaching more effective. In addition, the methods described in this paper have proved their success in encouraging the interest and motivation of students.

6. REFERENCES

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