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Teaching Electronics to First Year Non-Electrical Engineering Students

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Abstract

Teaching electronics is not only for electrical and electronics students but also for mechanical, aerospace, engineering design, computer science, civil and engineering mathematics programmes, which are likely to have electronics units as part of their curriculum. To teach electronics for these non-electronic programmes is very challenging in many aspects. First, the electronics unit has to satisfy the learning outcomes for each programme. Second, the student's motivation is normally very low since electronics is not the career the students would like to pursue. Third, the timetabling can be an issue when a large number of students are enrolled; for instance, at the University of Bristol, over 340 students are registered for the electronics unit. Due to this large number and the capacity of the electrical laboratory, students will have laboratory experiments timetabled in different weeks and some may have laboratory experiments before the lectures are

covered. Finally, a method of assessing this large number of students has to be put into place.

In this paper, the content of the unit including the laboratory experiments, the methods of course delivery and the assessment methods are justified. Also, since students learn differently and have a variety of motivations, a combination of teaching methods has to be found to satisfy more students and improve the learning outcomes.

Key words

Teaching electronics, motivating students, learning objectives

I. INTRODUCTION

Electronics has made tremendous advancements during the last few decades and our day-to-day life revolves around the use of electronic devices. The electronic subject has developed so much that it now is part of almost any technical field. The list of applications is ever expanding and ranges from Entertainment and Communication, Defense, Automotive, Space, Test and Measurement, and Medical. In all these applications, electronics plays mainly the role of the brain. Product complexity is always increasing and now we see integration of electronics with almost any device. Electronics on its own is composed of only a few components:

1. Passive

Resistors, capacitors and inductors.

2. Active:

Semiconductors (like diodes and transistors) and tube devices that are now obsolete.

Studying, designing or using these components leads to the variety of subjects listed below:

1. Analogue electronics
2. Digital electronics
3. Circuit design
4. Microelectronics
5. Integrated circuits
6. Optoelectronics
7. Semiconductor devices
8. Embedded systems

These subjects are taught to electronic and electrical engineers at both undergraduate and postgraduate levels and may last a few semesters or years depending on the programmes offered. There are also debates about what to teach in electronics and for how long [1]. In this paper, the author deals with teaching electronics to non-electrical students: Mechanical, Aerospace, Engineering Design, Civil and Engineering Mathematics students specifically. To do so, many issues have to be considered:

1. Unit content that satisfies all cohorts.
2. How to deal with the large number of students with different experiences and backgrounds.

3. How to plan the laboratory timetable.

4. How to assess a large number of students.

These issues are discussed in detail below.

II. UNIT CONTENT THAT SATISFIES ALL COHORTS.

Before designing the course material, a discussion with the relevant departments was conducted and, as a result, the following unit description and learning outcomes have been agreed with all departments:

a) Unit Description:

An introduction to the applications of analogue and digital electronic systems for non-electrical engineering students.

The aim is to develop students' high-level knowledge and skills to enable them to be effective specifiers and users of analogue and digital subsystems, electrical/electronic sensors and actuators. It also provides a basic understanding of electrical power. The unit consists of lectures, example classes, and laboratory experiments. Students will gain theoretical as well as hands-on experience of both analogue and digital aspects of electronics.

b) Intended Learning Outcomes:

- list the basic functions and elements of electrical and electronic systems.
- explain terms such as range, resolution, accuracy, precision, linearity and sensitivity.

- describe the role of sensors and the interface between typical sensors and electronic instruments.
- describe the characteristics of electric sources.
- describe the DC and AC electrical voltage and current.
- describe the characteristics of resistors, capacitors and inductors.
- explain the concept of weak signal amplification and the key specifications of signal amplifiers.
- have a knowledge of different types of amplifiers.
- carry out simple calculations relating to amplifiers.
- understand the main issues relating to power amplifiers.
- describe typical filter characteristics including amplitude and phase response.
- design simple networks using resistors and RC, RL, and RLC circuits.
- understand analogue to digital interface: anti-aliasing filters, sampling, and A/D converters.
- make use of Microcontrollers, Microprocessors and Digital Signal Processors.
- realize simple digital filters, carry out frequency analysis, and define transfer functions.
- understand the use of A/D and D/A converters.
- describe the role of actuators in electrical and electronic systems, and their interface with electronic systems.
- have a knowledge of mains power and power factor.
- describe the characteristics of the main types of motor.
- select a suitable motor for a given application.

To cover the above material, two sets of sessions covering analogue and digital electronics have been designed as shown in **Error! Reference source not found.**

Due to the sheer amount of material to teach and the large number of students enrolled in this course, it has been decided that teaching will be shared by two lecturers: one covering the analogue part and the other covering the digital part. It was also decided to teach analogue electronics first, which takes half a term and to teach the digital electronics during the second part of the term. The order is quite important as, for the analogue part, students do not need any knowledge of the digital part but the reverse is not true.

II. HOW TO DEAL WITH THE LARGE NUMBER OF STUDENTS WITH DIFFERENT EXPERIENCE AND BACKGROUNDS

There are two main issues to manage in answering this question:

TABLE 1 COURSE CONTENT

Analogue Electronics Sessions	<ol style="list-style-type: none"> 1. Applications of Electronics. 2. Analogue Signals - description and characteristics. 3. Signals and Systems. 4. Electrical sources. 5. Amplifiers. 6. Filters. 7. The Operational Amplifier.
Digital Electronics Sessions	<ol style="list-style-type: none"> 8. Introduction. 9. Binary arithmetic. 10. Boolean algebra and combinatorial Logic. 11. Pulse with modulation, PWM 12. Sampling. 13. Analog to Digital Converters, ADCs and

	Digital to Analog converters, DACs 14. Digital filtering. 15. Microprocessors.
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a) *Logistic Issue*

The logistic issue becomes real when the number of students goes over 100 as most universities are not equipped to accommodate all students in one session. However, the answer is simple, the class must be divided and lectures repeated if the lecture room capacity is not sufficient. This will put more pressure on lecturers as they have to increase their teaching duties. If the lecturing room capacity is sufficient, there still will be laboratory space to consider for running experiments. For instance, at Bristol, the capacity of some lecture rooms can reach 400 but not for the laboratory space. In this case, the laboratory experiments are divided into sessions, each dedicated to a department and one session is dedicated to two departments which have a low number of students. This will ease the timetabling since each department runs its own programme. Dividing laboratory sessions solves one problem but also creates another one. Divided laboratory sessions will inevitably run at different times which can spread into weeks. Therefore, some cohorts will have some topics in the laboratory that will not have been covered in the lectures, especially for the digital electronics laboratories which are run last, see **Error! Reference source not found.** One positive element of this laboratory scheduling is that it benefits students who need to reschedule their laboratory sessions due to extenuating circumstances. This number of students is not negligible considering the total number.

So that students who have laboratory sessions before the lectures are not disadvantaged, an introduction is given during the laboratory sessions and also the number of laboratory demonstrators is increased in order to provide more support.

b) Different expectations and experiences

Not only do students who are registered in this course have different expectations and come with different experiences, these students can also be either not motivated or not interested and sometimes both. Both extrinsic and intrinsic motivations should be used. One should explain to students clearly the relevance of electronics to their particular field and the excitement that they can get from learning this subject (extrinsic motivation), by giving them some examples and also encouraging them to discuss their own experience and ideas. In addition to this, students can also be reminded to learn the subject thoroughly in order to achieve good results (intrinsic motivation). It is also evident that a good enthusiastic teacher who likes his subject by itself is motivating and leads to good results. This is something that we all have experienced from schools to universities that we have attended.

Figure 1. Laboratory timetable

EENG16200: Applications of Electronics - Aero, Civil, Mech, Eng Maths & Engineering Design

		Start	1	2	3	4	5	6	7	8	9	10	11	12
Monday	AM													
	PM (1-3pm)	Aero			Analogue Cohort 1		Analogue Cohort 2		Digital Cohort 1		Digital Cohort 2		Digital Cohort 2	
	Engl				Analogue Electronics			Digital		Digital				
Tuesday	AM													
	PM (1-3pm)	Civ			Analogue	Analogue	Digital				Digital			
Wednesday	AM													
	PM													
Thursday	AM													
	PM													
Friday	AM (10-12pm)	Mech			Analogue Cohort 1	Analogue Cohort 2	Analogue Cohort 1	Analogue Cohort 2		Digital Cohort 1	Digital Cohort 2	Digital Cohort 1	Digital Cohort 2	
	Eng Maths				Analogue			Digital						

Once the students are aware of the subject and its importance, the next step is to keep students engaged. This can be achieved by the following steps:

1. Provide students with good and comprehensive teaching material. Mistakes in the teaching notes can sometimes make students lose confidence in the lecturer.
2. Before any lecture, remind students of the subjects that were covered in the previous lecture and ask them if they have any questions.
3. Before starting to teach a topic, emphasize the learning objectives so that students get the big picture before embarking on the details.
4. The teaching material contains new knowledge that students obviously do not have or been exposed to previously; in addition to this, it has to be delivered for a specific period of time. This can be achieved successfully by probing students with a few questions. An experienced teacher knows which part of the lecture is challenging and therefore asks questions at the appropriate time. Asking questions alone is not very useful. The answer that students provide can give a good indication of what the student does and does not understand.

5. Determine what prerequisite knowledge students need and encourage students to ask questions, for instance by saying “A good student is a student who ask questions and there is no stupid question”.
6. Relate what you teach to practical examples. For instance, if you are teaching logic gates, ask students what they can be used for in their fields and provide them with your own examples. If relevant, also point them to the examples in the laboratory experiments.
7. At the end of a lecture, provide a summary and set the scene for the next lecture.
8. Encourage and provide guidance to students to prepare for lectures well in advance (flipped teaching). However, this must be enforced to be effective especially for laboratory experiments where the majority of students come unprepared. Students could be told that they will be asked to explain the experiment and may be assessed at the beginning of the laboratory.
9. Encourage students to form small groups that can meet regularly to discuss issues that they may have.
10. Set an online forum where students can ask questions or provide answers. However, this forum has to be monitored by the lecturer or by teaching support staff.
11. Enhance the lectures by asking tutors to provide you with feedback from their tutees.
12. In addition to lectures, example classes and laboratory sessions, a weekly voluntary drop-in session can be organized and run by postgraduate

demonstrators. The postgraduates can provide feedback on the main issues students face.

13. A well-structured laboratory plays an important role in motivating students, see Section III.

14. Due to issues of timetabling a course across the faculty, lectures sometimes are scheduled to run continuously for two hours. However, knowing that students can only concentrate for short periods of time (~15min/hour) and also knowing that their attention declines as the lecture proceeds [2], short and regular breaks seem to keep students focused. For a two-hour lecture, it has been found that shorter breaks for students to contemplate or exchange knowledge and a 15 minute break halfway seems to work well.

III. LABORATORY EXPERIMENTS

Not only are laboratory experiments very important as they prepare students to bridge the gap between theory and practice but they also provide the opportunity for both students and lecturers to closely interact. Laboratory learning objectives and instructions should be well considered and made very clear. However, these are often ignored [2]. Some fundamental objectives of engineering instructions for laboratories can be found in [2].

Postgraduate support in laboratories is vital for a sizable laboratory. However, without training this can have an adverse effect. Postgraduates should be briefed and trained [4] and some backup should always be planned as some postgraduate students may be attending meetings or conferences.

III. METHOD OF ASSESSMENTS

On our course, there are a total of three assessments covering both analogue and digital sessions, including: two laboratory assessments that are conducted in the laboratory, with feedback given at the end of each laboratory session. The final assessment which combines both analogue and digital electronics, is a written, 40 questions multiple choice exam. This is very convenient when a large number of scripts have to be marked during a busy exam period. In fact, all the marking is done automatically and a statistical report is provided. This report can be very useful for improving the lectures.

IV. STUDENT ATTENDANCE AND MONITORING

It is well established that regular attendance leads to good achievement **Error! Reference source not found.** and strong emphasis on this is made at the beginning of the course. Attendance at lectures and example classes is not compulsory but laboratory experiments are. About 80% of students attend the lectures and the rest claim to be satisfied by the videos of the lectures recorded and provided by Blackboard and Mediasite. However, when tested during the laboratory sessions, students who do not attend do not seem to grasp knowledge as students who attended lectures and seem to have less confidence. Students who attend are very motivated and engaged. Since laboratory sessions are compulsory, they are well attended (100%). Example classes vary, sometimes they are well attended and sometimes not. This mainly depends on the student workload around the time of the example classes. Saying that, example classes are better attended during the last quarter of the term as students start preparing for exams.

Taking statistics over the last three years which involved around 900 students, it has been found that:

(1) During the first lecture students were asked if they enjoy studying electronics and if they have any background in electronics. 95% said they don't enjoy doing electronics and only 2% said they have done electronics in their A levels.

(2) After a few weeks of lectures and towards the end of the laboratory sessions, students were asked if they enjoy studying electronics. 70% said now they understand the importance of electronics and that the hands-on laboratories made many concepts covered in lectures much easier.

(3) Students from all departments normally have at least AAA grades, good academics skills and knowledge level and find the mathematics behind the lectures very easy to follow but find it difficult to grasp the concept behind electronics and could not relate this to physical phenomenon, despite the number of examples provided during the lectures. Some even found it difficult to remember electronic symbols as they are only used for this unit.

(4) From data obtained in the last three years, it has been found that there is no correlation between the student's degree subject and the achievement in this unit. This can be justified since all students at this stage of their education have the same qualifications.

V. CONCLUSION

Teaching electronics to first year non-electrical engineering students is no different from teaching electrical engineering students. However, initially students' motivation is low but by explaining the relevance of electronics to their specific subjects and providing enough support, students can achieve outstanding results. An approachable, enthusiastic lecturer who knows his subject well can, not only motivate students, but also can raise the profile of all students regardless of their background or academic abilities. All students from different departments have the same education background and therefore no differentiation is necessary.

Students can still achieve lower grades or fail, despite the good overall academic skills and knowledge they have and good lecturers' teaching skills. This is mainly to do with the students' motivation and attitude to learning. Somehow these students should be identified from the start and measures taken to provide them with support. Further research work is required to achieve this.

Finally, laboratory experiments are very important and therefore for a small number of students combining lectures and laboratory (workshop type lectures) can be very effective.

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Conflict of interest

None declared.

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Naim Dahnoun received his PhD in Biomedical Engineering at Leicester University in 1990 and worked at the Leicester Royal Infirmary as a researcher on blood flow measurements for femoral bypass grafts and then as Lecturer in Digital Signal Processing at Leicester University. In 1993, he started new research in optical communication at UMIST University in Manchester on Wideband Optical Communication Links before joining the Electrical Engineering Department at the University of Bristol in 1994 where he is now holding the position of a Reader in Learning and Teaching of DSP. In 2003, in recognition of the important role played by

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