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# Developing undergraduate teaching materials in collaboration with pre-university students

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## ABSTRACT

In this project we have involved four high-achieving pre-university summer placement students in the development of undergraduate teaching materials, namely tutorial videos for first year undergraduate Electrical and Electronic Engineering lab, and computer simulations of didactic semiconductor structures for an Electrical Science first year compulsory taught module. Here we describe our approach and preliminary results.

## INTRODUCTION

Significant experience has been accumulating at the Advanced Technology Institute with the running of successful summer research placements [1]. Final year (A-level) high school students have been spending between four and six weeks at the Institute working on current research problems, and usually generating publishable new results [2]. Students accumulate large amounts of focused technical information at and above an undergraduate level, as well as research practice behaviors, in a very short period of time.

In the present study, we changed the aim of the placements from producing new research findings to creating engaging teaching materials, mainly for first year undergraduate Electronics courses [3, 4]. We approached the projects as a form of peer instruction, recognizing the value of the placement students' *inexperienced* input in the design and creation of learning resources for beginners.

Simulator-based resources were developed for the undergraduate classes on advanced semiconductor devices. In parallel, training videos for the first-year undergraduate laboratory were designed, scripted and produced, following extensive research of available online videos.

## CONTEXT

Previous experience shows that students interested in pursuing STEM at university, come into the summer placement with a strong background of physics and mathematics, and perhaps chemistry, but very few notions of material science, semiconductors or electronic engineering. Their subtle difference in background is representative of the spread of prior knowledge in a typical first year undergraduate cohort in our department. With this in mind, we leveraged our summer placement's students relative inexperience with a set of technical notions in the creation of teaching materials.

Using principles outlined by Mazur [5] this method borrows from and goes beyond peer instruction [6], which has been shown to be a valuable learning method [7]. Taking advantage of a series of opportunities offered by this particular group we asked the placement students to act as co-creators of materials and their production [8]. It utilised their existing knowledge of STEM concepts to build supporting knowledge, which have increasingly been recognised as important but often troublesome within first year university learning [9]. Through a naïve starting position, placement students were able to understand the difficulties faced while learning new material. Being of a similar age and background to first year undergraduates who will be using the materials, placement students were able to suggest technologies, patterns and channels which facilitate learning for their generation. Through observation [10] we recognised that placement student's own research of the new concepts sheds light on both the most likely and the most effective resources which undergraduate students might use.

Figure 1. The tutorial videos were scripted, set up, filmed and edited in the EEE UG Teaching Labs.

## LEARNING RESOURCE DESIGN AND PRODUCTION

Four students worked in pairs on two distinct projects, over approximately four weeks. None of the students was familiar with the technical topic of their project before starting.

### Undergraduate laboratory training video project

The first project involved the production of twelve tutorial videos for the first-year undergraduate Electronics laboratory (Fig. 1). These materials are intended as supplementary learning resources to be accessed by undergraduates when needed from the Surrey virtual learning environment.

In the past, it has sometimes been a challenge for academics and postgraduate demonstrators to attend in a timely manner to all students in the group (40-50), and one reason for this may be the fact that students tend to make similar mistakes, or encounter problems in the same place during a practical, and one-to-one discussion in this instance is not an efficient use of time. Video resources, such as those developed in this project, should be valuable in streamlining the interaction between students and academics or demonstrators during the lab session, allowing the discussion to concentrate on elements of deeper understanding. Feedback can be equally simplified, e.g. if a student has difficulties with a particular concept, the relevant video can be recommended for self-guided, basic training.

The topics for the videos were chosen based on their essential nature to novice electrical engineers, and for their alignment to the first-year practical curriculum at Surrey: Introduction to the Undergraduate Lab (and Health and Safety Messages); Preparation (prior to the lab session); Lab books and log keeping (during the lab session); Toolkits; Breadboards; Debugging and fault-finding; Soldering; Stripboard; Power supplies; Digital multimeters; Oscilloscopes; OpAmps.

Placement students were responsible for the research, scripting, staging, recording and editing of the videos. Academics set out the learning outcomes and specific technical aspects to be covered, and performed constant quality control and monitoring.

In the initial stage, a comprehensive review of existing public videos from YouTube and similar platforms was undertaken, in order to familiarize the placement students with the notions involved, and to decide on which aspects needed to be emphasized in each video. The placement students then had the opportunity to experiment with the actual equipment in the lab.

Detailed scripts including voiceover, props and setup were drafted, then the videos were filmed in the teaching lab. Audio voiceovers were recorded, and video editing was performed using the resources in the Media Engineering undergraduate teaching labs.

**Semiconductor device modelling and simulation project**

The second project used numerical modelling software from Silvaco [11] to design and produce training materials for first year undergraduate Semiconductor Physics lectures (Figure 2). This software suite is one of the standards in semiconductor research and is widely used in our department for our electronic device modelling.

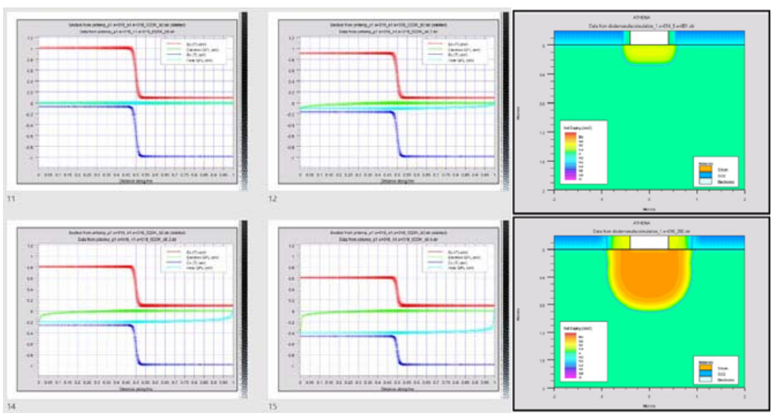

Figure 2. Examples of simulator-based resources. Left – computed energy bands illustrating the effects of bias on abrupt p-n junctions; right – series of simulated cross-sections of implanted p-n junctions demonstrating the effect of implant dose and energy.

In Semiconductor Physics lectures, students are taught about the fabrication process of semiconductor devices, as well as their operation, via current-voltage characteristics, cross-sectional diagrams, energy band diagrams, etc. During the placement, simplified didactical structures were modeled and simulated, and their behavior was plotted against a variety of parameter values. In order to generate these resources, placement students had to become familiar with semiconductor physics notions as well as the Silvaco software environment. As with the other projects, the learning outcomes and desired output were set by academics, and frequent discussions provided feedback and advice.

## DISCUSSION

### Undergraduate student engagement

Scheduling changes have meant that both of the modules for which these resources have been produced, and in which RAS will be teaching will now take place in Semester Two. Moreover, for a meaningful analysis, at least two cohorts of students would be required. As a result, the findings discussed here are preliminary. Further investigation, comparing module evaluation questionnaire (MEQ) scores, student grades and satisfaction with baseline historic averages, will follow.

First year undergraduates starting in Semester One have had the opportunity to engage with the lab training videos, however, this was not actively highlighted to them from the start of semester.

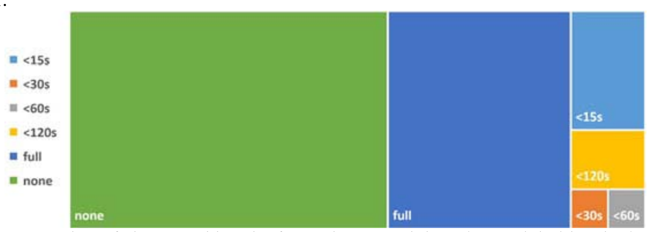


Figure 3. Proportion of class watching the four-minute “Stripboard” tutorial video, by length of time spent by each user.

Figure 3 presents the proportion of students who have viewed a certain duration of the “Stripboard” video, one of the twelve available, cumulatively, over the first five weeks of semester. The data, generated by Panopto [12], which is a lecture capture system linked to the virtual learning environment, shows that a large proportion of the class have not played the video at all. Initially, this was blamed on the fact that a large proportion of the class does not encounter the stripboard practical in the period studied, however, similar trends have been seen in other videos. Panopto also revealed that a few students replayed small sections of the video repeatedly. This is to be expected, as students focus on the portion of interest, and is one of the assets of this type of resource. The videos will be highlighted as a learning resource to students in the next academic cycle and further data will be gathered.

**Placement student feedback**

The placement students unanimously commented positively on their experiences at the end of their time at Surrey. The repetitive nature of some of the tasks was highlighted as the only downside. One was very hesitant at the beginning, as he could not identify the skills that he could use as a contribution, particularly in the communication/video area. All four students reported that the placements were overall enjoyable and gave them a good understanding, through observation, of the duties of an academic. They also highlighted that they are significantly more confident in attempting large new pieces of work, which at the beginning seem daunting and discouraging. All students said that the placement did not change their decision regarding the subject they wish to pursue at University, but one student suggested applying to Surrey was now an option, after enjoying the campus and seeing the facilities. Students undertaking the semiconductor simulation projects commented that they are now more aware of the complexity and underlying physics of technology that they use every day. Those developing the training videos remarked that, following the work, they are now aware of the limitations of freely available training materials, especially at this level; that they now would be more confident attempting to build simple electronics circuits after building on their formerly superficial understanding; and that the production process allowed them to practice synthesis and organisation of information, brevity in communication, and time management.

**Academic perspective**

The resources created add another dimension to the teaching in the department, and present another route for undergraduate students to engage with learning materials. From a teaching efficiency perspective, these materials reduce the load on teaching basic tasks and concepts, are always available to students, and free up time for discussion and clarification of more complex knowledge. They are not intended, however, as a substitute for lectures, class activities or one-to-one interactions. Monitoring of student performance and engagement will be ongoing, and a more substantial study will be presented in due course.

For placement students, these projects are an excellent way of increasing their self-confidence. Engaging with the activity creates a sense of ownership and achievement, despite the virtually absent prior knowledge of the field. It is expected that students will be more confident in the face of new challenges, armed with the positive experience of these projects. Time and resource management skills were also developed, and as students' understanding of the theoretical concepts developed, they were able to formulate viable plans for achieving the goals set. Introspection played a major role in internalizing the learning: at the end of the placement, discussions with research staff and academics, a public presentation and a poster served as a means of capturing their progress and experience, not least for their own benefit, and a tool for communication training.

From the early literature review it became clear that the resources already available online contain valuable information, but they are usually either incomplete for the formal training of an engineer, poorly structured, or contain inaccurate information. A list of the videos reviewed can be found in [13]. It was decided to produce a complete set of training materials for reference, and to use links to the more accurate web resources as "further reading".

While the computer-generated curves and plots are not meant to replace hand drawn schematics (there is, of course, a correct sequence of drawing these), the possibility to compare behavior when a parameter value is changed is the main driver for using computer-generated graphics. Not only do these represent an accurate, versatile teaching tool, but they also introduce students to the principles of numerical modelling for electronics. The data have been exported as images, and also exist in the raw form, ready to be consulted with the dedicated software. This way, an image sequence can be included in the notes to make a particular point, but a live demonstration can be made in class by connecting remotely to the simulation server. The resources have been used for the first time in March - May 2017 in lectures on p-n junctions, and advanced bipolar and MOS transistor concepts, with a student feedback session expected in late May 2017. Lectures contain a mix of historical references, application context, mathematical derivation, schematic drawings on the board and comparative (overlay or slideshow) use of simulated data to study the effect of parameter variation (bias, doping, geometry). Early indications are that students enjoy visualizing the advanced device behavior which the simulation allows, and feel closer to the forefront of development through the use of the same tools researchers use in their work, perhaps inspiring them to undertake final year research projects or postgraduate studies in related topics.

Developing learning materials with novices appears to be a good route to targeting the explanations, idea sequences and even visuals that would appeal to a similar undergraduate population. Placement students were able to use their everyday experience to suggest channels and media which their peers might use for information. They were observed performing tasks (e.g. using equipment or soldering) as novices, their actions were discussed, misconceptions were challenged, and their behavior taken into account in producing the scripts for the videos.

## CONCLUSIONS

The research placement is a valuable resource to academics wishing to try small, self-contained projects over a short period. In this instance, we attempted to use this resource in the creation of teaching aids for first-year undergraduates, relying on the naïve nature of the placement students' understanding in the design of these materials. The reduced technical ability which the students have at the start is a valuable asset for understanding the perspective of new undergraduates, and tailoring the presentation of teaching materials to better address their misconceptions or difficulties.

While deployment of these teaching materials has not been fully completed, early feedback is positive, student engagement is adequate, and the built-in longevity of the resources is expected to contribute measurably to the efficiency of teaching in the department.

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