Build a colorimeter: a final assignment for an electronic instrumentation course

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Abstract. As a final project for our electronic instrumentation practical course, students were challenged to build their own colorimeter to measure their own biochemical reaction, requiring them to apply all recently acquired theoretical knowledge and practical skills. They developed their electronic circuit on our recently developed Advanced Learning Platform for Analog Circuits and Automation, which allowed them to perform most measurements at home, though supervision was offered at the university. Their written reports show great understanding and application of all they have learned, with good grades. In feedback, students appreciate this assignment as the most enjoyable part of our course.

Introduction to our electronic instrumentation course

Nanobiology students in their 2nd year BSc engage in an electronic instrumentation course, which aims at acquiring theoretical knowledge of basic electronics and practical skills with advanced electronic equipment, as well as developing and understanding how the quality of their data is influenced by their instrumentation. A practical approach is taken with increasing level of complexity, as it resembles the eventual use and understanding of more complex instruments, built with understandable electronics. Students will encounter such instruments in a typical microscope or wet lab, for example automation of a microscope stage, mass spectrometry, spectrophotometry.

After covering passive and active electronics in both theoretical lessons and practical sessions, students engage in a final assignment in which all theory and practicals comes together. Students are challenged to build their own colorimeter, which can be as simple as LED light transmitted through a cuvette, which is detected by a photodiode, and data is stored for further analysis. Only the basic electronic circuit is given, as well as code to test whether this circuit is functioning properly.

Here, we present the assignment in which students were allowed, with some constraints, to plan and conduct their own experiment using the self-made colorimeter. We reflect on the produced reports and share some examples and feedback from the students.

Colorimeter

We were inspired by projects as [2] to use a colorimeter for our final assignment, in which all aspects of our course come together. We designed a platform for classroom education in which the basic measurement was to be done by simply connecting the right wires, placing a cuvette correctly and retrieve data (fig.1a). A three-color LED was used, with optional power control. The intensity received from a multi-color detector is converted to a frequency dependent signal, of which the pulse width could be modulated. Also, a heater and temperature read-out are integrated.

When converting our course to a hybrid format, with less time on campus, we invented our ALPACA (Advanced Learning Platform for Analog Circuits and Automation [1]). This electronic platform has some build-in features, like DAC for analog signal generation, and some amplifiers, but most of the electronic circuit plus cuvette holder must be fabricated by the students (fig. 1b).

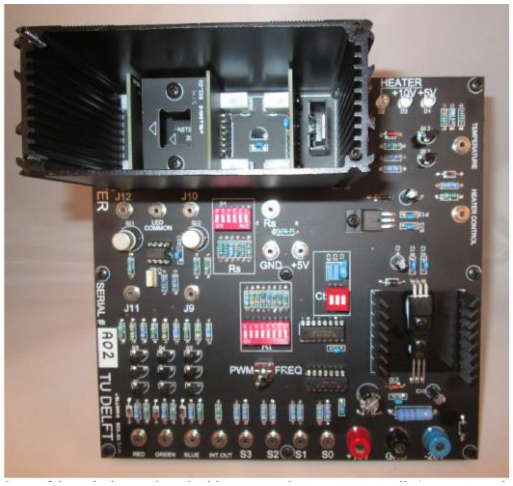
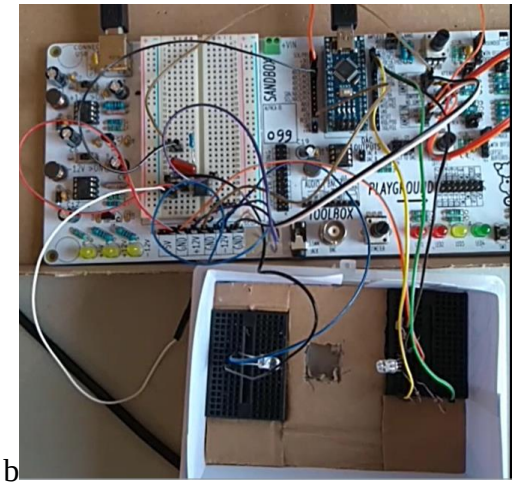
a  b 

Fig. 1. (a) the colorimeter board for use in the classroom, (b) a colorimeter built at home with the ALPACA [1].

Basic instructions on the LED and photodiode circuit, plus code for testing their functioning stand alone and combined, are given as starting point/ constraint for the students. From there on, students choose their implementation of electronics, code, and biochemical reaction. Some examples are given as inspiration and basic level of guidance, but students are free to implement their own ideas. Moving away from cookbook recipes, giving ownership to the students, contributes to students' strategies, attitudes, and engagement [3]. Needless to say, the level of complexity is determined by the students themselves.

Results

In classroom, we observed that students were more engaged in this final colorimeter assignment than in the previous, more structured, assignments. The report grade being 25% of their final grade is a good incentive; the number of passing grades increased from 84% before, to 95% after the report (out of 61 students in total). The number of students who tackled some of the more advanced topics in the colorimeter assignment was high; most students thought about (88%) and implemented (72%) a transistor or opamp, and most students (90%) worked on at least one optimalization (biochemical reaction, or additional electronics or coding). The level of understanding was high, which is reflected in an average score of 91% for basic execution and explanation. Familiar options, like red cabbage and pH reaction, were often chosen, but many students exceeded our expectations and truly produced a masterpiece with own ideas and successful implementation, like 3d printed cuvette holders, automated color detection, switches with 3 transistors, up to detecting the temperature and pH change of bicarbonate plus acid [4].

The level of content and grades are slightly better than previous years, and students appreciate our colorimeter assignment as best part of our course. One student even mentioned: "This has truly been the most fun part of nanobiology so far".

References

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