Connecting staff expectations and student understanding of professional engineering skills in a multidisciplinary design challenge

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ABSTRACT

This paper discusses the evolution of an active learning assignment [1] for second year undergraduate biomedical engineers. An arc of assignments throughout the first two years of their study supports their understanding of the design cycle and aids in assimilation of material taught in lectures and more structured laboratory workshops [2]. The assignment – to create an item of 'smart' clothing for an athlete – was primarily designed to reinforce student learning in the areas of physiological monitoring through transducers, basic electronics and Arduino programming.

A misalignment was observed between teaching staff's preconceptions of students' skills and knowledge, and the experience that the students actually bring to the assignment which influences how they approach the work, echoing the concept of the hidden curriculum [3]. This led to the team aiming to improve support of students' skills in debugging, their awareness of laboratory health and safety and links between different strands of their education through pre-assignment material, changes in teaching vocabulary and small changes in assessment. The impact of the changes has been evaluated through teaching team discussions and analysis of short pieces of individual reflective writing done by every student as part of their assessment before and after the material's introduction.

Conference Key Areas: Engineering Education Research, Curriculum Development, Skills and Engineering Education

Keywords: Professional engineering; design; group project.

1 INTRODUCTION AND BACKGROUND

1.1 An active learning assignment

A key enabler for undergraduate students to make the transition from passive learner to competent practitioner can be to support the development of their problem solving and design skills through active learning [1]. This can be done through providing open-ended design projects structured to support the arc of the design cycle [4]. We have done this during our engineering undergraduates' first two years through a series of six week-long assignments that consolidate engineering knowledge taught prior to each assignment while encouraging students to apply their new knowledge to an open-ended design task [2].

For this assignment, Biomedical Engineering students work in groups of three to use wearable Arduino technology [5] and a free choice of electronic sensors and outputs to create a prototype item of clothing that will monitor an aspect of an athlete's condition, chosen by the students, and provide an alert if an unacceptable level of injury is likely to occur. The published Learning Objectives for the assignment cover the students' knowledge and understanding of physiology, biomechanics, digital and analogue electronics and microprocessor programming alongside the professional engineering skills required to meet a design brief such as time and budget management and working effectively in a group.

1.2 Research methodology

We have followed an action research approach in the evolution of this student assignment and look at differences between two separate cohorts of students taking the assignment in consecutive academic years – known as cohort A and cohort B. Cohort A consists of 11 students who were set the unaltered assignment; cohort B has 21 students who followed the modified assignment one academic year after cohort A.

While teaching cohort A, the teaching team discussed problems they perceived with the students' approach to their work, and this discussion led to the reflection and research used in the process of developing the assignment that was then undertaken by cohort B. Our initial hypothesis is that the students were unaware of their apparent shortcomings in the perceived problem areas noted by the staff. This was tested by considering a short piece of reflective writing on the assignment that each student carries out as part of the assessment. These pieces have been analysed to assess the students' own awareness of the perceived shortcomings.

Changes were made to the assignment between the two cohorts to address the perceived problem areas and the effectiveness of these changes has been assessed both by discussions with teaching staff on their observations of the class and their views on whether this disconnect between staff expectations and the students' performance had been addressed, and by looking at the reflective writing from cohort B.

2 ACTION RESEARCH ON AN ACTIVE LEARNING STUDENT ASSIGNMENT

Second year Biomedical Engineering undergraduates work in groups of three for five days to fulfil a design brief to make an item of ‘smart’ clothing for an athlete that can monitor an appropriate physiological parameter of their choice and give a warning should that parameter fall out of pre-set safety parameters. The clothing should be safe, reusable, customisable and fall within a set budget. The students receive an introductory end-user design requirement and question and answer session with an athlete (an ultra-runner) before starting the assignment, and have previously had teaching on the design cycle, technical drawing, physiological monitoring, transducers, Matlab programming and digital and analogue electronics. The students have had no formal teaching while at university in Arduino programming, but some may have prior experience outside of their studies. The intended learning objectives are given in figure 1.

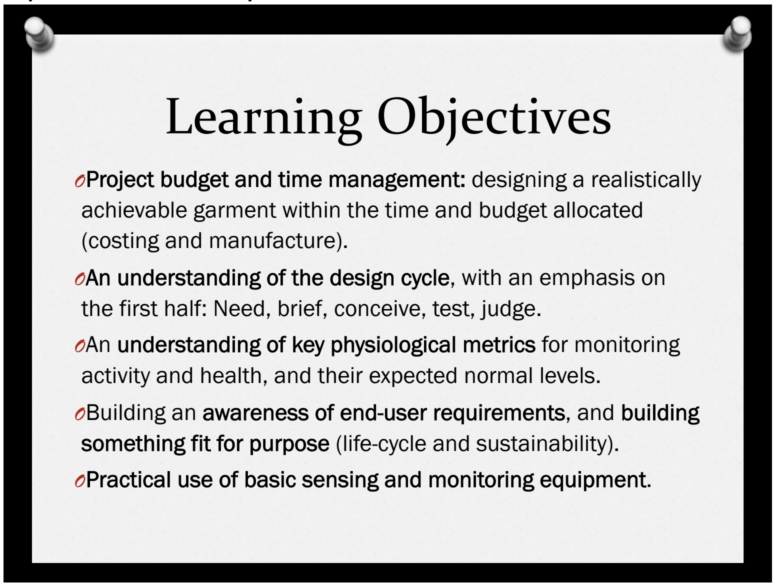

Figure 1. Learning Objectives given to the students before the start of the smart clothing assignment.

The assignment is the first very open-ended design and making project that the students encounter in their degree programme. Any type of clothing can be designed and built to monitor any parameter to give any signal so long as the students can justify how their choices meet the design brief. One student noted in their feedback:

“The [assignment] was by far the most fun I have had. The possibilities that we could have come up with were endless, only limited by time and budget” -Student B_6_2

Students are given access to the full range of facilities on offer in the undergraduate teaching laboratory and university maker-spaces. A wide assortment of electronics and sports clothing is available for instant purchase from the teaching team, but students also have the option of asking to purchase anything the laboratory does not have in supply. Adafruit Flora Arduinos have been stocked by the laboratory due to their robustness, wearable nature and the large amount of supporting code and maker projects available on the internet.

Between the two cohorts, the students have designed and built (with varying success) 2 pairs of pressure sensitive gait analysis trainers, 3 sweat concentration monitoring tops, 2 temperature sensing armbands, a temperature and humidity sensing top, a UV sensing cap, a core temperature and respiration rate monitoring sports bra and a GPS distance tracking wristband

Most groups chose to use coloured LEDs to indicate changes in the parameters they are monitoring.

Assessment for each cohort was based around the initial design, the end produce and short pieces of written work.

2.1 Cohort A pre-work and assessment

Cohort A received an introductory lecture for the assignment a few weeks prior to the week spent in the laboratory carrying out the assignment. This consisted of delivery of the brief, a presentation by a researcher working in the area of wearable assistive technology, and a discussion with a member of the teaching team who is a runner. The students were also shown two items of smart clothing developed by a previous student [6]. They received a list, and costs, of the electronic components readily available in the teaching laboratory and were told to research the available components and consider how they might meet the design brief. Links to information on Adafruit components and examples of wearable electronics were made available on the university VLE.

Cohort A's assessment is shown in Table 1:

Table 1. Assessment structure for Cohort A

Design Phase	*Decision matrix* using appropriate choices of criteria	5%
	List of physiological parameters the clothing aims to measure, and their expected ranges.	5%
	Design and estimated cost. A technical drawing full enough for someone else to be able to make your clothing	10%
Prototype Clothing	*Quality of prototype*, and closeness to meeting brief	30%
	Aesthetics – peer assessment	10%
Written report	*Full final costing* including broken components	10%
	Short reports on one area of: product life cycle, sustainability, scaling up manufacturing and costing	10%
	Individual reflection justifying any deviations from original design and plans. Reflections on how the week went and any changes that the student might choose to make if the process was repeated.	20%

2.2 Staff observations on Cohort A

Discussions with the teaching staff indicated that, on the whole, the class met the Learning Objectives shown in figure 1. However, staff felt there were shortcomings in areas where they had assumed students would be able to draw on prior experience of system troubleshooting and debugging, and be able to identify links between this assignment and previous classwork.

- All groups in the cohort, regardless of previous measures of academic ability (examination results and staff reports), attempted to completely construct and hard-wire their designs before testing any individual components and had to be encouraged regularly by staff to build their systems' complexity step-by-step rather than taking a 'plug and play' approach. The staff spent a significant amount of time teaching repeatedly concepts of basic debugging of coding and electronic circuits to individual groups of students.

- The students failed to identify the sensors available to them as transducers, despite having previously worked in structured laboratory sessions to characterise a set of transducers. The teaching team had to remind all groups of this work that they had carried out in the previous weeks, and encourage them to look back at their notes to draw parallels between the two assignments.
- The class also exhibited limited attention to heath and safety considerations when working on these self-led projects compared to the usual levels of conscientiousness that they adhere to in heavily structured mass cohort laboratory work. They did not appreciate that the use of un-insulated conductive thread would increase the risk of short circuits, and forgot very basic laboratory safety concepts (figure 2).

Figure 2. Students forgot basic lab safety, such as not jumping on a narrow piece of wood while attached by a cable to a laptop.

2.3 Changes implemented between Cohort A and Cohort B after discussion of staff observations

Changes were made to the preparatory work and resources given to the cohorts and some of the assessment was modified. The teaching team were also encouraged to use vocabulary echoing that in other parts of the undergraduate programme of study to reinforce links across the syllabus.

2.3.1 Preparatory work and pre-assignment resources

The introductory lecture for Cohort B again took place a few weeks before the assignment. The students did not receive the additional lecture from a researcher, but spent more time discussing the prototypes made by previous students and also received more instruction on the importance of health and safety and building a complex system in steps for ease of debugging.

Additional material was prepared by the teaching team and made available to the students on the VLE. This included:

- A guide to Adafruit wearables
- A quick guide to C++ Android programming showing common functions for Arduino
- A troubleshooting flowchart, with brief accompanying notes to aid in successfully producing working electronics.

Cohort B were told that cohort A had lost time during the assignment due to problems with debugging and understanding basic coding concepts, and were encouraged to read this material before beginning the assignment. They were also explicitly told that they would be using transducers and should revise any previous learning in this area.

2.3.2 Assessment

Much of the assessment for cohort B remained as in table 1. However, 10% of the prototype marks were allocated to the production of a plot of ‘transducer characterisation’ and 10% to ‘health and safety’ in an aim to use the backwash effect [7] to modify student behaviour regarding health and safety. Cohort B were not allowed to hard-wire any components until the teaching team had seen evidence of a transducer characterisation that indicated that a group had knowledge of the correct circuit required to obtain data from the transducer(s) of their choice.

2.3.3 Staff-student interactions during the assignment

The teaching team were encouraged to use vocabulary throughout the assignment that mimics the rest of the students’ education – ‘technical drawing’ rather than ‘design’, ‘transducer’ instead of ‘sensor’, and ‘digital electronics’ rather than ‘Flora’ or ‘Arduino’. Staff also ensured that the student groups had worked through the troubleshooting flowchart before offering assistance in the laboratory. These protocols aimed to encourage students to make links between their learning, and to facilitate movement towards independent troubleshooting and debugging.

3 RESULTS

The individual reflection written by each student as part of their assessment was used to appraise their overall awareness of the three areas of weakness perceived by staff: system debugging and troubleshooting skills, making connections to the rest of their curriculum and awareness of health and safety.

3.1 Cohort A

Cohort A consisted of 11 students in total split into three groups of three and one group of two. Seven (64%) students used the terms relating to debugging, troubleshooting, and iterative processes in their reflections. Three (27%) students mentioned other parts of their curriculum – two referencing transducers and one the design cycle. Three (27%) students mentioned safety and comfort of the end-user.

3.2 Cohort B

Cohort B consisted of 21 students split into seven groups of three. 13 (61%) students used terms relating to debugging, troubleshooting and iterative processes in their reflections. Nine (43%) referred to other parts of their curriculum – seven referencing transducers and two the design cycle. Nine (43%) students mentioned health and safety, although only one mentioned it in the general context of their groups work, with eight discussing health and safety purely from an end user context.

3.3 Staff perspective

Three members of the teaching team were asked to report verbally on their personal comparison of the two cohorts. Overall, it was stated that cohort B required ‘less help’ in debugging their systems and were more engaged in troubleshooting processes. However, it was also noted that the cohort did not appear to make copious use of the troubleshooting pre-assignment resources during the week-long assignment. Cohort B was reported to show a slight increase in their awareness with other parts of the curriculum. Staff reported no change in the proportion of groups, in their estimation, who lacked awareness of laboratory health and safety requirements.

4 DISCUSSION

Overall, this work has involved small cohorts of students: 11 and 21 in the two groups. This means that the statistics on the data are poor. An additional student adds 9% onto any quantitative values for cohort A and 5% onto those for cohort B.

We have made changes to the assignment reported in this work. However, it is possible that other university teaching staff have also made changes to the students' wider programme between delivery to the two cohorts that could also contribute to the changes in the students' skills and understanding reported in this paper.

4.1 System debugging and troubleshooting skills

Assessment of the students' written reflections shows no increase in phrases relating to system debugging and troubleshooting between the two cohorts. 64% of cohort A and 61% of cohort B use terms relating to this area. Staff reported that cohort B required less help in this area, but this has not been quantified.

It was noted by the teaching team that the students did not appear to regularly refer to the troubleshooting material provided by the teaching team during the week. It is possible that they read and understood the material prior to beginning the assignment. It is also possible that the act of introducing clear summative assessment for the transducer characterisation and not allowing hard-wiring of components before showing evidence for this assessment created additional structuring to the assignment that supported the students to de-bug before full construction of their prototypes.

4.2 Making connections to the wider curriculum

Cohort B showed an improved awareness of the links between this assignment and their wider curriculum. The ratio of those relating the assignment to the design cycle and those relating it to their transducers learning was ~1:2 for both cohorts. No student mentioned both the design cycle and transducers.

4.3 Awareness of health and safety

There was an increase in the awareness of health and safety requirements for the end-user seen in cohort B. However, staff noted no improvement between the two cohorts' general awareness of laboratory health and safety guidelines.

5 SUMMARY

This paper considers the efficacy of changes made to protocols and material related to a second year undergraduate assignment between the 2015/16 and 2016/17 academic years.

The assignment took place during the 2016/17 academic year with this new material and protocol in place. Staff noted that this class appeared to be more engaged with awareness of connections across their wider curriculum and debugging. No change was seen in awareness of laboratory health and safety. Reflective writing by the students showed no increase in discussion of debugging between the two cohorts, but an increase in discussions regarding links to the design cycle and classes on transducers, and a greater awareness of health and safety for end-users of their prototypes.

Action research will be continued for this assignment and further changes will be made for the 2017/18 academic year:

- The lecturers on the transducers course will be included in the preparation of this assignment with an aim to increasing integration between different parts of the overall programme.
- The teaching team will continue to highlight laboratory health and safety – pre-assignment quizzes in this area are being considered.
- We will continue to monitor the response of cohorts to troubleshooting and debugging, with an aim to facilitating a movement towards independent and confident use of these skills. One student stated:
  "I have primordially learned on the importance of having a vision by starting very simple. Breaking down the idea on multiple layers and starting with the foundation. Once that is working, you can add layers of complexity one by one.." – Student B_7_2

We aim to reach a point where the majority of students show awareness in this area.

We believe that, in a wider context, the work supports the concept of the backwash effect - the use of an assessment scheme that explicitly allocated marks for an awareness of a given area (in this case health and safety) led to an improvement in students' self-reported awareness of the area. The work also shows that integrating the vocabulary used by teaching teams across students' entire education can reinforce the process of making links between separate areas of learning.

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