Experiences of the implementation of a bring-your-own-device policy in electronics courses

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Conference Key Areas: Engineering Skills, Attractiveness of Engineering Education, Curriculum Development

Keywords: BYOD, Engineering skills, myDAQ, Study motivation

INTRODUCTION

University studies could be made much more effective in Finland by reinvention of a lot of the prevailing teaching methodology. Studying becomes more effective when the student independently reflects the subject matter in question [1-4]. There will be more time devoted on deep thinking, when the student finds the subject matter problems intriguing. Fortunately in university level engineering studies actual subject-related project topics are easily found. Every engineering area contains designing and building of something, and interesting project work topics can be found. Subject matter becomes more intriguing when the relevant problems are concrete and comprehensible, when students understand the meaning and use value of the project result. The increase in study motivation and study results are facilitated effectively by having a suitable portion of all learning activities as hands-on team work [5, 6], such as building and testing simple and basic electronic circuits. In addition, hands-on work enables students to approach the current topic from another perspective [7-9] that is likely to generate insight.

Engineers' key skills include experimentation and measurements. This also applies to engineering students. Hands-on work drives students to deeper learning and better understanding of engineering cases [9, 10]. However, the establishment of hands-on assignments to curriculum requires more lab and teacher resources than we have in Finnish universities at the moment. Therefore, completely new ways to increase the amount of hands-on work for students, and this way enhance learning and increase study motivation, needs to be developed.

Electronics students are very motivated and prone to do hands-on work from the very beginning of their university studies. When starting the studies in technology, students anticipate doing much hands-on work, such as construction and measurement of simple electronic devices. Unfortunately, in previous years, the hands-on work in basic courses of bachelor level studies has been limited to few lab-hours, mainly because of the large number of students and finite teacher and lab resources allocated for one course. The biggest emphasis during the first two years of university studies has been in theoretical topics. However, according to the student feedback, gathered by an electronic feedback system used in Tampere University of Technology (TUT), students want and need more hands-on work throughout university studies. This is extremely important for the students' study motivation.

A straightforward approach to increase students' hands-on work is to utilize more students' own time and infrastructure. In practice, this could mean doing hands-on work outside lessons and other teacher-involved learning events. The utilization of infrastructure under students' holding can provide savings for university in room and equipment costs. However, the room and equipment savings are not in focus of this study. In the case with Department of Electronics and Communications Engineering (DECE) at TUT, all the lab rooms and lab equipment have remained the same as they were before utilization of Bring Your Own Device (BYOD) policy in teaching. Hence, at least so far, savings related to rooms or lab equipment are not seen in DECE.

1 UTILIZATION OF BYOD IN ELECTRONICS TEACHING

Hands-on work in the field of electronics generally means building circuit prototypes and measuring their electrical performance. The very basic electronics measurement instruments include multimeter, oscilloscope, function generator, and power supply. Traditionally these instruments – being too big and heavy to carry around – have been situated in an electronics laboratory. However, nowadays there are choices for inexpensive data acquisition devices, which include all these basic measurement instruments in one case [11, 12]. Providing students access to such devices and employing BYOD policy in electronics courses, measurements and prototyping can be done anywhere and anytime. BYOD is a wide concept – including almost everything – where somebody brings something of his/her own to work or school, and utilizes it [13]. In this article BYOD refers to a measurement instrument for electrical measurements.

In order to increase the amount of hands-on work in the course of studies, and to maintain and even increase the students' interest and motivation in electronics, the DECE at TUT in Finland decided to include BYOD assignments in selected Bachelor level courses. Therefore, every student in BSc level Electrical Engineering (EE) and Information Technology (IT) study programs were provided with the chosen data acquisition device – National Instruments (NI) myDAQ. DECE provided myDAQs to students, students did not have to pay for them. The price for one device is about 210 euros [14], and this might be too much for many students. The first implementation of myDAQs was done during the academic year 2014–2015.

In addition to myDAQs, students were provided with NI Multisim simulation software, breadboards, wire kits and selection of basic electronics components. Now, students are able to use the basic lab equipment with their own laptops and complete the given tasks at home as well as in normal classroom sessions etc. This arrangement truly facilitates students' learning process. Photos of student assignment utilizing myDAQ and students working with myDAQs are presented in *Fig. 1*.

MyDAQs have been utilized in different ways in courses during academic years 2014–2015 and 2015–2016. Implementing of myDAQs followed the students' curriculum in BSc level Electronics studies in TUT. A timeline of the courses utilizing myDAQs in academic years 2014–2015 and 2015–2016 is presented in *Fig. 2*.

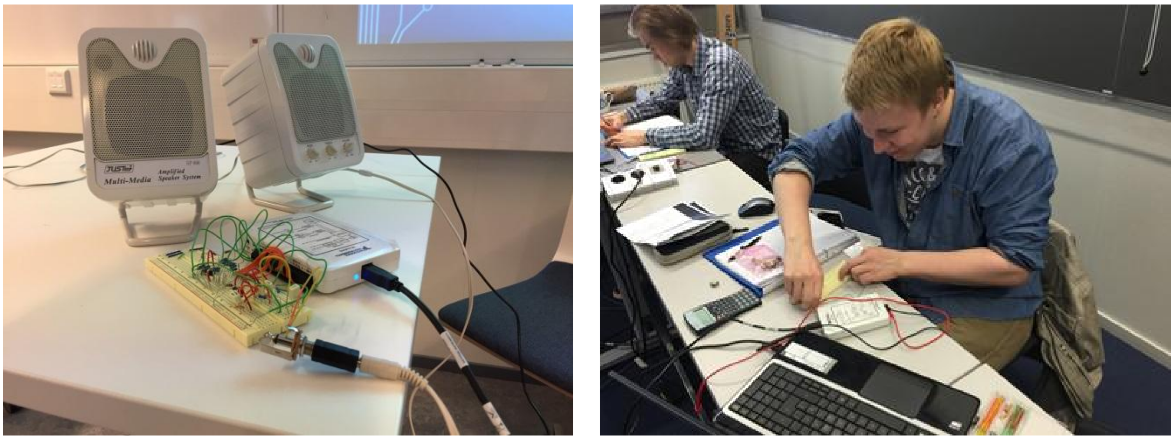

Fig. 1. Left photo: myDAQ utilized in a student assignment, right photo: students working with myDAQs in classroom.

Place in curriculum	Course
Second year fall semester	*Analog Electronics*
Second year spring semester	*Electronic Components*
Third year fall semester	*Transistor Amplifiers*
Third year spring semester	*Electronics and Communications Engineering Laboratory Course*

Fig. 2. A timeline of the courses utilizing myDAQs.

1.1 myDAQs in second year courses

In the first course, named *Analog Electronics*, where students get in touch for the first time with myDAQs, the students are familiarized with the device and the associated software. The importance of the measurement result evaluation is emphasised – first students solve the problem with pen and paper, then they build a simulation model and run some simulations, and after this they build the circuit and measure the performance with myDAQ. Finally, all results are compared, and the observed differences are analysed thoroughly. This is extremely important for the development of the electronics engineer's identity. During the courses after the first course, *Analog Electronics*, the students are expected to use myDAQs more independently.

In addition to *Analog Electronics* course myDAQs were also implemented in academic year 2014–2015 in *Electronic Components* course. This course is following *Analog Electronics* course, and it gives deeper insight into the basic components utilized in electronics. myDAQs were utilized in *Electronic Components* in the same way as in *Analog Electronics*. These two courses are situated in the students' second year curriculum, *Analog Electronics* in the fall semester and *Electronic Components* in the Spring semester.

1.2 myDAQs in third year courses

During the academic year 2015–2016 myDAQ was employed in the third year courses *Transistor Amplifiers* and *Electronics and Communications Engineering Laboratory Course* in addition to *Analog Electronics* and *Electronic Components* courses. The *Transistor Amplifiers* course is situated in the third year fall semester and *Electronics* *and Communications Engineering Laboratory Course* in the third year spring semester, as is seen in *Fig. 2*.

The learning events of *Transistor Amplifiers* course include 12 weekly exercises – each of which typically consisting of 3-4 assignments. As a result of the previous course implementations, one existing exercise assignment already included measurements utilizing the Dreamcatcher ME3000 analog electronics board [15]. Also, 3 assignments included experiments with NI Multisim and NI ELVIS II [16]. During the previous implementations, students needed to go to the lab and see if the associated workbench was free in order to complete these tasks. Now these four assignments were customized for myDAQ so that the experimental part could be done outside the lab at the most convenient time. Furthermore, one additional assignment was extended so that simulation, assembly and measurement of the analysed transistor circuit utilizing NI Multisim, breadboard and myDAQ was also included. However, the majority of the exercise assignments in this course were still traditional circuit analysis tasks solved by pen and paper only and the partial use of myDAQ was a development step towards practical assignments included in each weekly exercise in the future implementations. In addition – once provided with myDAQs – students were enabled to independently make experiments at will on any circuit appearing in the exercises.

In the first bachelor level electronics laboratory course, *Electronics and Communications Engineering Laboratory Course,* myDAQs have been used to increase students' readiness for actual laboratory measurements. For example, in the preliminary reporting before the laboratory measurements the students design, construct and measure a simple circuit with myDAQ and thus familiarize themselves with the subject of the laboratory assignment. The corresponding circuit is then investigated in the laboratory. The aim of this is to increase students' readiness for the laboratory measurements and to increase comprehension of the subject matter.

Prototyping is another way myDAQs have been utilized in the *Electronics and Communications Engineering Laboratory Course*. On the basis of given specifications the students design and simulate an audio amplifier circuit. After the circuit has been designed and simulated the students build a prototype of the circuit with a breadboard and test the prototype with myDAQ. Only after this the final printed circuit board (PCB) is designed and fabricated, components are soldered and the audio amplifier is tested. The objective of the prototyping phase is to reduce the number of faults in the actual PCB. The faults in the ready-made PCB or in a ready device are very time consuming to repair, a lot of teacher and student time is spent on finding and repairing the faults. As simulation is only a model of the real circuit it does not reveal all necessary design solutions. For example, with an audio amplifier the simulation does not require emitter resistors to protect transistors of the current amplifier part from overheating. myDAQ measurements, however, indicate that these resistors are needed for the actual circuit to function properly. The prototyping phase thus naturally saves a lot of students' and teachers' time, because it eliminates most of the faults that was previously found in the ready-made PCB. In addition, based on the teachers' experience, prototyping deepens the students' understanding from real life electronics engineering cases. This kind of experience is intrinsic to hands-on work, it cannot be achieved via neither analytical work nor simulations.

2 STUDENT FEEDBACK AND TEACHER EXPERIENCES

The DECE facilitated the adoption of myDAQs by allowing teachers to include preparation time in their work plans. However, in practice it was observed that the required amount of preparation work for a teacher can be enormous – the actual number of hours could be twice or triple the amount reserved in the work plan. On the other hand, this huge workload for a teacher is present only when implementing the BYOD assignments for a course for the first time. In the following years the amount of preparation work is quite similar to that of the course implementations without BYOD.

The course feedback from students after the implementation of myDAQs has been very positive – myDAQs were found to be great. TUT has an electronic feedback system in which the students have to give feedback upon completing a course. Since DECE has determined a basic set of multiple-choice questions to the electronic feedback system, which are the same every year and for every course, the comparison of feedback between different years and courses is possible. Results for three multiple-choice questions for two courses, *Electronic Components* and *Transistor Amplifiers*, in two consecutive implementation years are represented in *Table 1*. These results are from the electronic feedback system of TUT and unfortunately e. g. variance of these results is not available at this moment in the feedback system. Since the only difference between the implementations of the course *Electronic Components* was the utilization of myDAQs, one can conclude that myDAQs have affected the increased mean values of the answers.

In the case of the course *Transistor Amplifiers*, the change of the ratings cannot be fully concluded to be the consequence of employing myDAQs, since there was also another difference between the implementations. During the implementations prior to myDAQ, passing an examination was required in order to complete the course and the examination grade could then be elevated by one number, provided that certain amount of activation assignments included in each week exercise were successfully solved. During the implementation with myDAQ, however, an alternative way to complete the course was introduced – the course could be passed with the grade 1 without taking the examination, provided that adequate solution for every activation assignment was submitted. Students who passed the course this way still had an opportunity to elevate the grade by taking the examination. Since 27 % of the active students (students who at least tried to complete the course) were able to utilize this alternative way, the feedback also includes the effect of this change. Altogether, the implementation with myDAQ and an alternative way of completing the course was rated higher.

Unfortunately also many other things changed in *Analog Electronics* course at the same time with the implementation of myDAQs. Hence, numerical comparison between two consecutively years in the case of *Analog Electronics* does not clarify the impact of myDAQs in that course.

In addition to answering multiple-choice questions, students can write open feedback to the feedback system. This written feedback is very qualitative, unfortunately thorough statistical analysis cannot be done based on it. However, the written feedback is often very informative and useful for the teacher in further course development. In this case, the written feedback from the students confirmed that the myDAQs were enhancing their learning. Examples of the written feedback can be seen in *Table 2* for the *Electronic Components* and *Analog Electronics* courses. There are both, pros and cons, gathered from the first implementation round with myDAQs for these courses.

Table 1. Results of student feedback for two courses with and without BYODs.

Feedback topic	Electronic Components		Transistor Amplifiers	
	Mean without BYOD	Mean with BYOD	Mean without BYOD	Mean with BYOD
Overall rating of course and its implementation (scale 1 to 5)	3.60	4.17	3.58	3.87
Please evaluate the appropriateness of the course in relation to the intended learning outcomes (scale 1 to 5)	4.00	4.14	3.64	4.14
The course increased my interest in the subject matter (scale 1 to 4)	3.00	3.52	2.87	3.24

Table 2. Written course feedback related to myDAQs.

	Pros	Cons
Analog Electronics	· A very good device! · Great and interesting! · Great to do hands-on work · Great to be able to do measurements anywhere and anytime · Advances learning · Combines theory and practice · The use of myDAQs helps a lot with real lab devices · Easy to use · Versatile and very safe device · A good user interface (UI) · Small and easily portable · Motivation to study increases	· The assignments take surprisingly lot of time · Some problems with software installation · Needs practicing, takes a while to learn how to use · A bit slow · Ability to be used also with other operating systems needed (Mac especially) · Needs a laptop
Electronic Components	· A very good device! · Excellent device! · Easy to do own projects at home · Helps a lot in learning · Helps in conceptualizing of electronics · Understanding increases · myDAQ and Multisim are a very positive experience · Interest in electronics increased a lot · Combines theory and practice	· A bit hard to get started, more training needed in the beginning · Problems with software · Gets stuck, needs to reboot · Heavy software, needs a lot of memory · Too short usb cable · Too small restrictions (current and voltage)

Written feedback for the course *Transistor Amplifiers* did not include any direct comments on myDAQs, but the activation assignments in general were considered useful and motivating. The possibility of passing the course by solving assignments and improving the grade by examination was considered less stressful way to complete the course. The average grade for students who solved the activation assignments also supported this feedback – 3.8 / 5 (with myDAQ and alternative way) vs. 2.4 / 5 (without). Since by the time of the implementation, students had not yet gained much experience with myDAQ, first practical assignments were considered time-consuming. From a teacher's point of view, the changes made for the exercise practices and assignments of the *Transistor Amplifiers* course were successful. Based on the teacher's long experience teaching this course, active students were more motivated to study during the whole semester instead of reading the course material just before the examination.

3 PRACTICAL ASPECTS OF IMPLEMENTING BYOD

Inventing and creating a BYOD assignment can be challenging and time-consuming for a teacher. However, it is a very important process as it defines how useful and intriguing the assignment will be for students. Carefully prepared assignment guarantees that the students are focusing on the right things and achieving learning targets without spending too much time with irrelevant details such as software or incompatibility problems. First of all, teacher has to take a grip on the selected BYOD device and associated software in order to understand its possibilities and avoid possible pitfalls. As an example related to the courses covered in this paper, some modifications were needed for certain assignments due to the limited bandwidth, power supply resources and voltage measurement range of the myDAQ. In addition, for the future implementations of the *Transistor Amplifiers* course, new activation assignments are needed in order to increase the amount of students' hands-on working, because reasonable experiments using breadboard and myDAQ cannot be directly included in some of the existing assignments, which are now done using pen and paper.

By understanding thoroughly the software, the teacher is able to tell to the students the optimal way of installing the necessary software to their own computers. This is especially important when the software consists of several separate modules and file sizes are large. Good knowledge about the software also gives to the teacher the ability to solve the problems that the students may encounter during installation or while using the software. The teacher should also be aware of software licenses. Even if the university would provide the needed software license for all the students, it is good to know if the license expires and it has to be renewed at some point. Unexpectedly expiring software licenses may cause severe delays, if it happens when a course is already running.

While preparing new BYOD assignments, it is good to acknowledge that there is vast amount of ready-made demonstrations in the internet made by the device provider or its user community [17]. Those are a good starting point, but our experience has shown that many times it is not possible to find exactly what you are looking for. A ready-made demonstration can serve as a starting point, but it has to be tailored for the specific course at hand. It is also good to acknowledge that the demonstrations may have compatibility issues between different software versions, and what is more, nobody guarantees that their content is perfectly accurate scientifically.

Even nowadays it is not fully guaranteed that all the students have their own computer. Other challenge is that the selected BYOD device and its software may not be compatible with all operating systems, such as Windows, Linux, Mac OS, and Android. This is seen also in the student feedback in *Table 2*. One good solution to this problem is to take advantage of computer classrooms available at the University campus. Once the teacher makes sure that the classroom computers have all the necessary software installed, students can use their BYOD devices there, if they do not have a computer or it is incompatible.

For the students' equality, the best case is that the university or department, like DECE in our case, provides BYOD devices for all the students. For many students the price of the device would be a significant financial expense. They can also be uncertain about its usefulness, if they are not sure that they can utilize the device on more than one course. Also from the department's point of view, it is important that the same BYOD device would be utilized in many courses. This way the benefits from the investment can be maximized. In addition, when students get familiar with the device and software on one course, they will get much more out of it on the next course. If the department makes sure that all the students have the same kind of a device, it also eases teacher's workload in a sense that teacher does not have to deal with the traditional problem of BYOD where students have various different kinds of devices and software from multiple vendors. This kind of diversity would be likely to increase the time required for preparing a BYOD assignment and also the time spent on solving irrelevant technical details. This challenge should be acknowledged when dealing with advanced versatile technical instruments such as data acquisition devices. Typically it does not create challenges if all the students in the class use their own kind of pocket calculator, but data acquisition devices with complex software are a whole another story.

We have not yet implemented, but considered organizing myDAQ mini-exams where students would need to design, construct, and test a circuit and then demonstrate its operation. Such an assessment method would better conform to the course arrangements than traditional exams.

4 SUMMARY

Implementing BYOD devices, in the case of this study NI myDAQs, in university level electronics engineering studies improves the study experience of students. However, the implementation of a BYOD device for a course for the very first time is a huge workload for the teacher, this should be definitely taken into account in teacher's work plan. When using BYOD in the way it is used in this study the amount of hands-on experience for students can be considerably increased. Hands-on working is very important for engineering occupation and to an engineer's identity. As a conclusion it can be said that the pros definitely overwhelm the cons in systematically integrating the use of BYOD devices into university level engineering education.

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