Strengthening student engagement by integrating the contents of a flipped course around a well-confined real life theme

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INTRODUCTION

This paper reports a teaching experiment where three means of strengthening student engagement were combined. Our means were *course backward design* [1]; the *flipped classroom* model [2]; and, *facilitating practical work in and out of the class room*. The framework of the experiment was an introductory level master degree course in “RF electronics”. The course extent was 5 credits (ECTS) and duration 7 weeks. Twenty students participated and passed the course.

Several challenges are typical in organizing an introductory course. Firstly, how to provide a sound and comprehensive overview without drowning the big picture in detail [3]. Secondly, how to cope with the fact that prior experience of students may vary to a great extent. Thirdly, in cases where students have to first learn to use certain practical tools, software programs, and measurement equipment before they can really comprehend deeper theoretical ideas: how to find time for acquiring the needed practical skills.

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1 OVERVIEW

To strengthen student engagement in the course was our main objective. Student engagement is a broad topic, for example, Trowler [4] provides an extensive literature review and versatile discussion of student engagement. Harper et al. [5] define student engagement as “participation in educationally effective practices, both inside and outside the classroom, which leads to a range of measurable outcomes”. This definition characterizes our objective well.

Over the years our university has organized introductory electronics courses in various formats. In the most *traditional format*, each topic is first introduced at a lecture; then exercised through homework, through exercise class activities, and/or perhaps through lab activities; and finally, tested in an exam. Occasionally courses have included lab demonstrations. Students would complete a brief preparatory assignment prior the demo session. They would also have to write a brief report after the demonstration. This format has included hardly any hands-on work. This format can be considered, to some degree, “teacher-centered”.

A more practice oriented format replaces part of the lectures and traditional exercises with weekly laboratory construction sessions. A particular challenge in this format has been that students have either not done properly preparatory tasks, or they have not comprehended them properly such that they could apply the subject matter in the laboratory sessions. Moreover, students may lack the routine to work fluently with the lab equipment. In such a case those students that would likely need most guidance and support, easily turn into bystanders, since time typically available for lab sessions does not allow them to proceed at their own pace.

The challenges mentioned above (and in the Introduction) lead us to consider the three means to design the course. Next sections provide an overview on the three means.

1.1 “Backward style” design

We assumed that a concrete theme would inspire the participating students right from the beginning of the course. A concrete theme would help participants envision the course contents and objectives as a bigger picture. Once they understand the objectives, they would be looking forward to the hands-on work, and they would look forward to accomplish something complete. The theme constituted a well-confined skeleton for deciding which contents should be included and which should be excluded. Only contents that directly related to the overall theme of the course were included in the syllabus. Moreover, having all students understand the *practical and understandable theme,* made it easier for teachers to motivate particular subject matters and preparatory assignments. Interestingly, the contents that *were* actually chosen turned out to be, to large extent, the same that have been the contents of more traditional courses before, however better related to each other.

The idea of a clear final target agrees well with principles of *backward design* [1]:

> *“One starts with the end—the desired results (goals or standards)—and then derives the curriculum from the evidence of learning (performances) called for by the standard and the teaching needed to equip students to perform.”*

1.2 Flipped classroom model

Roughly speaking, the flipped classroom model means that the traditional paradigm of “first-lectures-then-own-work” is flipped around. The theoretical framework of the flipped classroom model is rationalized and the related recent research has been reviewed by Bishop and Verleger [2]. In this model students arrive to the classroom sessions having already familiarized themselves with the current topic by completing preparatory activities. In the classroom they would work actively instead of passive listening.

Flipped classroom allows each student more freedom to work at one’s own pace. Students are in the position to take greater ownership of their learning. The flipped model allows teachers to devote as much in-class time as possible for spot-on personal instruction. Teachers can help students *when* they need and the *way* they need help. This type of instruction allows students and teachers to get to know each other better on personal level which affects the intellectual and emotional environment positively.

The pre-class activities included viewing video clips, reading online materials, or answering quizzes, and practical construction tasks. Many definitions of the flipped classroom model prioritize video clips as an essential pre-class activity [2]. We included the preparatory construction tasks also under the flipped model umbrella, since they were intended to prepare students for the next in-class, contrary to traditional homework. The different tasks of the course were aimed to form a weekly continuum that starts with an opening and ends with a wrap-up. The same weekly schedule was followed each week (see section 2.2). The weekly themes also form a natural way to assess learning and instructors can monitor continuously progress of each individual student.

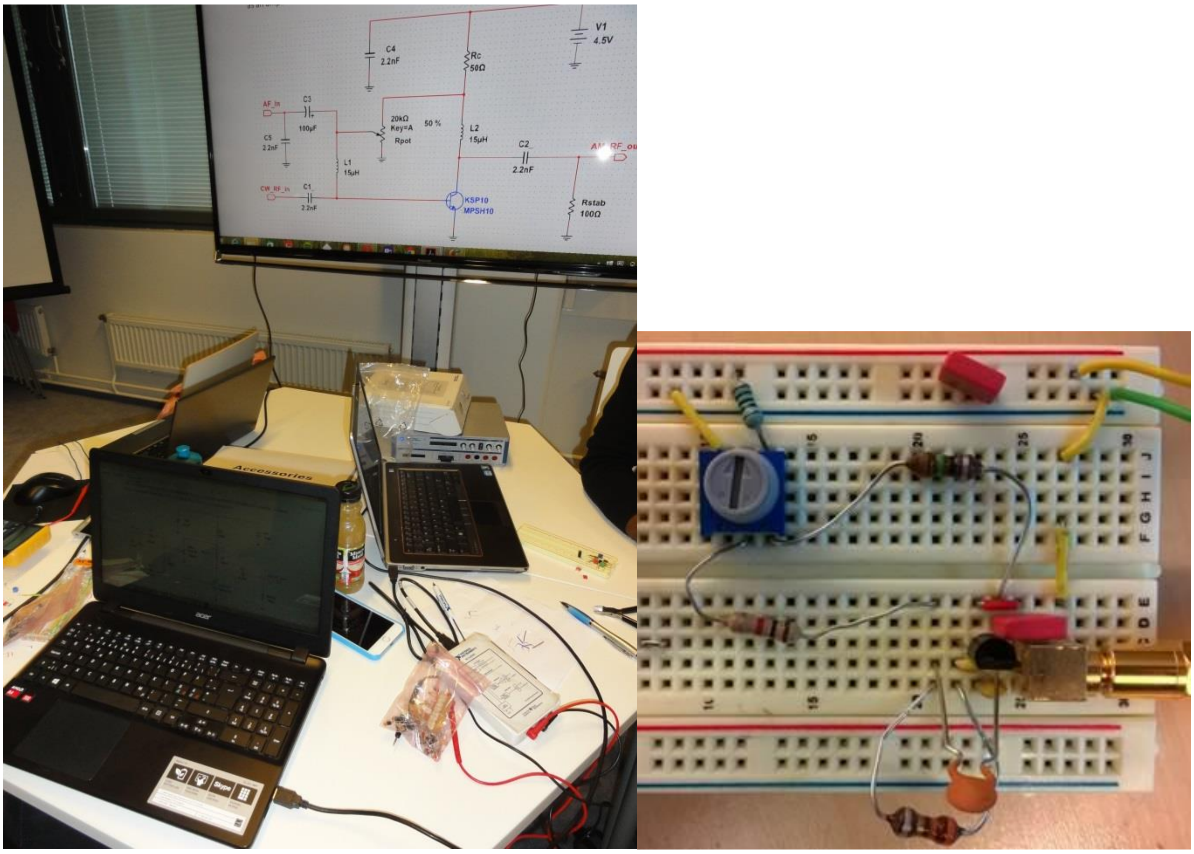

Fig. 1. Left: Work place for four students in the class room. MyDAQ is the PDA size white box. Right: an 18-MHz oscillator built on a solderless breadboard.

1.3 Portable ‘mini-lab’ for experimenting in-class and out-of-class

To allow students make practical experiments both in class and out-of-class, they were equipped with a set of hardware. Such portable 'mini labs' ('pocket labs', 'take home labs') have been used in different types of courses in engineering education as reported e.g. in [6],[7],[8],[9]. The set of hardware used in the course included (1) electronic components; namely transistors, resistors, capacitors, and inductors; (2) a solderless breadboard; and (3) a myDAQ [1]. myDAQ is an inexpensive, small-size USB-device from National Instruments (NI) that operates, for instance, as an oscilloscope, signal generator, and digital multimeter. myDAQ comes bundled with a simulation program (Multisim). *Fig. 1* shows an example of students’ work place in the class room and a circuit built on a solderless breadboard. We believe that having the possibility to work at one’s own pace and do one’s own “what-if experiments” is likely to inspire, arouse curiosity, make students think more, and in the end, lead to deeper learning. Students also had more time than in traditional labs to rehearse use of the ‘mini-lab’ to fluently do experiments.

2 COURSE ARRANGEMENTS

The following sections outline arrangements of the course. They describe the overall course theme, the weekly themes, and particulars.

2.1 Course theme: “Simple but fully functional 18-MHz radio transmitter”

A complete radio communication system is composed of a radio transmitter and a radio receiver. Same concepts are applied in construction of a transmitter and a receiver; however, it is much easier to construct a simple but working transmitter than a simple but working receiver. There are digital and analogue radio systems. An analogue system was chosen because it can be very simple and those are usually taught and learnt first. For the modulation scheme, amplitude modulation (AM) and frequency modulations (FM) are the simplest options. AM was chosen because it is more fundamental and usually taught and learnt first. What comes to the carrier frequency, 18 MHz was chosen because that can be listened to with a standard short-wave receiver. 18 MHz is low enough for solderless breadboard experimentation, nevertheless, high enough for some of the engineering challenges, typical in RF electronics, starting to show up. 18 MHz is also high enough for the antenna to be still reasonably small.

The transmitter consists of circuit blocks shown in *Fig. 2*. The structures and operation of theses circuit blocks constituted the contents of the course.

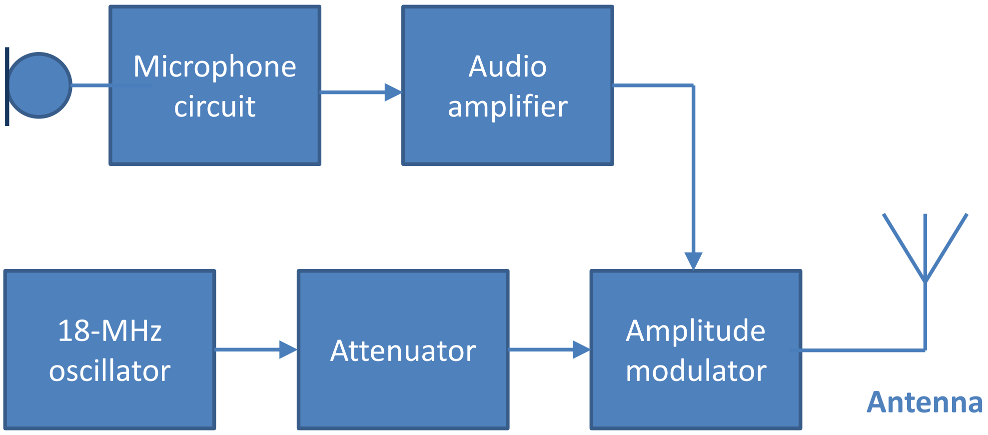

Fig. 2. Block diagram of the 18-MHz transmitter.

The upper frequency limit of myDAQ is 20 kHz. Therefore students were not able to test directly their 18-MHz circuits out-of-class. For that reason the operating frequency was scaled down to 10 kHz for the out-of-class assignments. Then at in-class sessions, students built 18-MHz versions of these same circuits and those were tested using another (yet similar) equipment [11] provided by teachers. Nevertheless, scaling frequencies up and down helps student see what is essential in a circuit to operate properly.

It should be pointed out here that besides improving students' basic theoretical comprehension about the "first principles in RF electronics", the practical tasks improved a number of essential practical skills:

1. Finding useful information from datasheets of electronic components.
2. Running time and frequency domain simulations.
3. Prototyping with a solderless breadboard and familiarizing oneself with real RF components.
4. Setting up measurements.

2.2 Weekly schedule and weekly themes

As explained earlier the course followed same schedule each week (*Table 1*).

Table 1. Weekly schedule.

Pre-tasks	**Monday in-class**	**Construction tasks**	**Wednesday in-class**	**Minute reports**	**Friday in-class**
Out-of-class: Online materials Opening a theme	Guided group work	Out-of-class: Independent group work	Applied group work	Out-of-class: Self-assessment Feedback	Wrap-up lecture Closing the theme

For a typical Monday session, students familiarized themselves to a topic by, for example, viewing a short video or reading online texts and then answering a quiz. In the Monday 2-hour session, they solved simple hands-on tasks. To get prepared for the Wednesday 3-hour session, they were, typically, given another hands-on assignment as continuation of the Monday in-class tasks. To complete the hands-on tasks, occasionally students had to solve calculations with pen and paper.

After the "applied group work" on Wednesday, students returned brief online reports ("minute reports") where they asked or commented unclear points and assessed their own learning. Some of these questions were answered publicly online. Others were covered in the Friday 2-hour in-class either personally or within a short wrap-up lecture that closed the week.

The weekly themes (*Table 2*) were derived from the building blocks of the 18-MHz RF transmitter. Each week, one or more building-blocks or design concepts were introduced; those which finally constituted the complete transmitter. The weekly themes ranged from basic to more challenging ones; some underlying key design principles repeatedly popped up throughout the course.

Table 2. Weekly themes of the course.

Topic	**Key Concepts**
Basic circuit elements and related analysis.	Behaviour and modelling of basic components at high frequencies.
Frequency selective circuits.	AC circuits, phasor representation, reactance, resonance, frequency response.
Nonlinearity in circuit components.	Difference between linear and nonlinear operation and models. Diode, transistor.
Transistor amplifiers.	Difference between (one-transistor) low frequency and high frequency amplifier designs.
More on active circuits, oscillator, amplitude modulator	Turning an amplifier into an oscillator. Using a variable-gain amplifier as an amplitude modulator.
Basics of antennas and electromagnetic waves.	Free space EM-wave propagation. Key antenna parameters.
Completing/assembling the transmitter, final measurements, and field tests	Transmission range.

2.3 Practicalities

To facilitate peer learning, students were assigned to work in pairs or teams of four (two pairs working together). The first set of pairs was formed randomly. The pairs were reformed twice during the course by instructors. The online tasks were individual, out-of-class construction tasks were done in pairs, at in-class sessions students worked also in teams of four.

To complete the course students had to gather 120 points (maximum was 166 points). Students earned points from completed Moodle-tasks and other preparatory and in-class tasks as detailed in *Table 3*. In a typical week maximum of 24 points were available. Multiple-choice and open questionnaires were used online. The former were graded automatically. The in-class and out-of-class construction tasks were assessed through instructor-student discussions. Students were expected to be able to explain the operation of the circuit, to use the tools available demonstrating its properties, and in some cases to be able to perform additional tasks.

Tasks	Points awarded
Pre-tasks, minute reports	2
Monday in-class, Friday in-class	4
Construction tasks, Wednesday in-class	6

Two instructors and a teaching assistant were involved in the course. However, running this course was not a full time job for neither of the instructors. Preparation of the assignments took time, as always when running a course for the first time. In the Wednesday in-class sessions students' need for assistance was the greatest. The total of three instructors for 20 students was enough to have them running fluently, in other sessions less resources were needed.

3 ASSESSMENT OF THE EXPERIMENT

This pedagogical experiment was assessed from three perspectives: student feedback, teachers' observations, and student retention number.

3.1 Student feedback

Anonymous student feedback was collected through the standard intranet application of our university. The students were generally very pleased with the course arrangements. Most students praised the hands-on work, the group work, the discussions among participants, and the level of student-teacher interaction. To a standard question in the questionnaire ("Overall rating of the course and its implementation") they gave very high rating 4.72 (out of five, with 18 responses given).

During and after the in-class sessions students gave very positive remarks both about the tasks and the arrangements. Some were very pleased about having the opportunity to work in many different groups and mixing Finnish and foreign degree students and exchange students.

One example of free text responses appreciated the course atmosphere:

> *"The learning atmosphere was of outstanding quality and the group tasks (e.g. attenuator/amplifier) were a great way to work in a team."*

Another was happy with pre-tasks:

> *"The strategy to do pre-tasks before the class helped me a lot to have better understanding of the practical work done in the class."*

3.2 Teachers' observations

Based on the teachers' observations and discussions with students, the students were seemingly more active, curious, and enthusiastic than in a more traditional course. The teachers felt that the clear final objective also inspired and engaged students to work more in depth on the pre-class assignments, which is often considered a challenge in course flipping. The final week when the radio transmitter was completed, tested outdoors, and found to be working, students had spontaneous and lively discussions about the subject matters. This clearly confirmed that most students had become aware of the most important ideas brought about in this course. To a larger degree, the course objective had been reached: "After completing the course students are able to construct a simple radio transmitter on a solderless breadboard and explain how it operates."

Some of the students had very limited prior experience with hands-on work, but, through the peer-work and the instantaneous guidance, they were able to get started and proceed towards the completion of the course.

To further evaluate the qualities of this flipped-course implementation, we made self-observations such that we identified *effective educational practices* [12], set forth by National Survey of Student Engagement (NSSE). We considered three of the five items applicable. The two other items (Enriching educational experiences, Supportive campus environment) as described in [12] are not readily applicable to this work. The analysis is based on the descriptions, not on use of the questionnaire itself.

i. ***Level of academic challenge***
   Observation: The level of academic challenge and allowed studying time adjusts in this arrangement according to individual needs. Certain basics and key concepts are repeatedly applied assuring they are finally grasped. Students have possibilities to do their own "what-if experiments" according to their interests.

ii. ***Active and collaborative learning***
Observation: While working on the hands-on assignments, students teamed up in pairs or teams of four. Unreserved course atmosphere makes student-to-student and student-to-instructor interaction easy and frequent. Having circuits finally working ensures learning, empowers and triggers more interaction. Teams worked effectively both in-class and out-of-class. The many-sided co-operation clearly created stronger bonds among students.

iii. ***Student–faculty interaction***
Observation: Faculty members devoted much of their time to helping students succeed in their hands-on work and problem solving, testing, and electronics debugging in the class room. This practice, carried out throughout the course, made it easier for students to contact instructors. We paid attention to having the teacher-to-student ratio appropriate to keep students actively working full time rather than waiting for somebody's help.

3.3 Student retention

Student retention was 100%, in fact, new students signed up even after the course had already started. Twenty students participated and passed the course. In average, students that were present from the first week onwards earned 144 points (about 87% from the maximum) which can be regarded as high value.

4 DISCUSSION AND CONCLUSIONS

Both students and teachers found the coursework rewarding. In a course like this it is important to identify those in-class sessions that require most resources, and to have them running smoothly, keeping students active all the time. As always when creating a new course, the preparations take time. Online and construction tasks need to be planned and described well and tested well in advance. So called demo effects should be kept to minimum.

The three-sided assessment confirmed us it is worthwhile to run this course again the same way next academic year. This methodology is not limited to RF electronics. It can be applied to other subject areas and disciplines, as well. The combination of a (1) real device as an underlying course theme and (2) course backward design together with (3) the flipped classroom model worked well to strengthen student engagement and to support students' learning processes.

REFERENCES

[1] Wiggins, G. P., McTighe, J. (2005), Understanding by design, ASCD, Alexandria, USA.

[2] Bishop, J. L., Verleger, M. A. (2013), The flipped classroom: A survey of the research, Proceedings of the ASEE National Conference, Atlanta, GA.

[3] Perkins, D. (2008), Making Learning Whole: How Seven Principles of Teaching Can Transform Education, Jossey-Bass.

[4] Trowler, V. (2010). Student engagement literature review. The Higher Education Academy, 11, 1-15.

[5] Harper, S. and Quaye, S. (Eds.) (2009), Student engagement in higher education: Theoretical perspectives and practical approaches for diverse populations, Routledge, New York.

[6] Sharad, S., Robbins, T. (2010), Towards Achieving Hands-On Project Based Learning beyond Laboratories and into the Dorm Rooms, Proceedings of the

Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, IEEE, Dublin, pp. 1-5.

[7] Chesnutt, C., Baker, M. C. (2011), Incorporation of NI myDAQ exercises in electric circuits, Proceedings of the ASEE Gulf-Southwest Annual Conference, Houston, TX.

[8] Taylor, B., Eastwood, P., Jones, B. L. (2014), Development of a Low-cost, Portable Hardware Platform to Support Hands-on Learning in the Teaching of Control and Systems Theory, Engineering Education, Vol. 9, No. 1, pp. 62-73.

[9] Klinger, T., Madritsch, C. (2015), Collaborative learning using pocket labs, Proceedings of the International Conference on Interactive Mobile Communication Technologies and Learning (IMCL), Thessaloniki, pp. 185-189.

[10] http://www.ni.com/mydaq/ (Visited in 10th of May 2016)

[11] http://www.ni.com/virtualbench/ (Visited in 10th of May 2016)

[12] Kuh, G. D. (2009), The national survey of student engagement: Conceptual and empirical foundations. New Directions for Institutional Research.