Electric kart project to develop research-related skills for engineering students

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INTRODUCTION

An engineering curriculum not only provides solid scientific and technical skills, also more generic competences are important. Since a modern engineer has to be a good 'entrepreneur', a loyal team-mate and an attentive communicator, project based learning is required when educating future engineers [1].

At the KU Leuven – Technologiecampus Oostende, problem based learning and project based learning are integrated in the curriculum enclosing a four year learning trajectory starting in the first year of the academic bachelor program and finalizing in the master program. This learning trajectory includes classical laboratory sessions, problem based laboratories containing open assignments, a multidisciplinary project work, specialized project laboratories and a final master thesis.

The multidisciplinary project work is organized in the third semester of the academic bachelor program [1]. When starting this project, the students already have a basic scientific and technical background and they also have some laboratory experience. The multidisciplinary project is performed by project groups of five or six students under the supervision of a project coach, i.e. a member of the teaching staff. One of the student team members acts as project coordinator but all students are together responsible for the group activities.

From a technical point of view, the multidisciplinary projects are devoted to a large number of topics to give different assignments to different groups of students. The project topics included e.g.: home automation, hydropower, towers of Hanoi, E-health etc. During the academic years 2012-2013, 2013-2014 and 2014-2015, special project topics concerning the engineering of an electric kart have been introduced.

Designing and building an electric kart within the scope of a project work with engineering students is not new and many experiences are described in literature [2,

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3, 4]. An electric kart provides a lot of technical aspects relevant to engineering students and it motivates students to learn topics in motion control [4]. Here, a different teaching approach is used starting from a kart in working order. The project mainly focused on condition monitoring and EMC-related aspects that are closely related with the research activities at the campus. In this way, the own research is integrated in the engineering program stimulating research-based learning [5].

1 PROBLEM AND PROJECT BASED LEARNING TRAJECTORY

Everybody agrees graduated engineers need a solid knowledge of sciences as well as advanced technical skills. The universities teaching engineers have a lot of experience in teaching these ‘traditional’ learning outcomes. However, today’s engineering graduates also need to have strongly developed ‘soft’ skills such as communication and teamwork, which they sometimes haven’t. They also need to have a broader perspective of the issues that concern their profession such as social, environmental and economic issues but sometimes they haven’t. They are graduating with good knowledge of fundamental engineering science, but sometimes they don’t know how to apply that in practice [6]. When educating ‘industrial engineers’, a practical approach in combination with a well-founded theoretical background is important in the curriculum. By introducing problem and project based learning activities in a structured learning trajectory, the teaching staff aims to teach and practice not only the traditional learning outcomes but also the additional and equally important skills. This learning trajectory passes through the entire curriculum containing a three years bachelor (180 ECTS) and a single master year (60 ECTS).

1.1 Structure of the learning trajectory

The approach applied in the learning trajectory is based on three principles:

- Gradually minimizing the instructional specifications of the laboratory assignments in order to stimulate the autonomy of the student i.e. only the problem is described and not the strategy for the problem solving. It is important the student gains a clear understanding that there are several valid approaches to reach the result [7].
- Emphasizing it is important the students prepare the laboratory work before the laboratory starts in order to have a structured strategy. They have sufficient time to try more than one approach within the laboratory time. Still, a well thought-out structural approach remains necessary [7].
- Realizing projects with an increasing complexity and project size [6] requiring a specialization, a multidisciplinary approach and a cooperation between an increasing number of people (students and coaches).

In the learning trajectory a continuous and gradual evolution is built in. In the first two years of the bachelor program, the laboratories contain closed well-defined exercises based on detailed instructions, some open elementary problems and also small projects involving only one single area of engineering specialization. In the third year of the bachelor program and in the final master year, the curriculum contains project laboratories where large, complex and technically specialized projects are realized.

The multidisciplinary project in the third semester of the bachelor program bridges the gap between the basic laboratory sessions in the first two years and the specialized project laboratories. For the first time, the students realize a “large” project linking the technological theory and practice within the context of social, environmental and economic issues. Furthermore, they train for communication and teamwork skills. The instructional concept of the multidisciplinary project facilitates the transition to the subsequent project laboratories and the final master thesis.

The master thesis accounts for 20 ECTS points of the 60 ECTS points composing the master year. This master thesis can be a university project performed in a research group belonging to the university. Most often however, the master thesis is realized in collaboration with the industry or possibly with the non-profit sector. During the realization of their master thesis, students are supported by a coach, i.e. a member of the teaching staff. They have to report orally and by letter during the year, getting feedback from their coach. Finally, they defend their thesis in front of an external jury. As will be explained hereunder, the conceptual similarities of the multidisciplinary project are a sound preparation for the final master thesis.

1.2 Multidisciplinary project work

The learning outcomes of the multidisciplinary project work are multiple: cognitive competences (to acquire and handle information; to have a research attitude), meta-cognitive competences (to adopt an attitude of lifelong learning) and social competences (to communicate with experts and laymen, to give leadership, to cooperate in a team) [1].

In practice, the multidisciplinary project starts with an introductory seminar. The assignments are given to the students groups, each having a coach from the teaching staff. The assignments are realistic and relevant professional problems with an open formulation giving the students the opportunity to self-directed learning.

In general, the students start with a problem analysis and subsequently a literature survey and they make a plan of approach for implementing the project's objectives. Upon approval of the coach, the students carry out this plan of approach. Halfway the project, they evaluate the functioning of their team by a formative peer assessment (regarding the competences 'to cooperate in a team' and 'to give leadership'). When necessary, individual team members can improve their behaviour and the plan of approach can be adjusted.

At the end, the students present their work giving an oral presentation for an audience consisting of other bachelor students, members of the teaching staff and external people. The results are also presented in an extended report. Finally, the students reflect on their learning process and, once more, they judge their team members regarding the same competences they judged midway. This time, however it is a summative peer evaluation.

All project coaches involved apply the same permanent evaluation system [1]. The cognitive and meta-cognitive competences mentioned above and one social competence (to communicate with experts and laymen) are evaluated by the project coach. The students are responsible for the evaluation of the remaining social competences (to give leadership; to cooperate in a team).

1.3 Assessing the students during the learning trajectory

When educating engineering students, it is important to teach relevant scientific and technical topics. Teaching these topics is not the only final goal; the new accreditation requirements in Flanders and the Netherlands also focus on the question "what is being learned by the students" [6]. Engineering programs are required to prove that their graduates are achieving a set of learning outcomes. This implies that an adequate evaluation system is needed during the entire curriculum and during all learning trajectories, including the project and problem based learning trajectory.

Traditionally, distinctions between the grades of the students are mainly made using written or oral examinations on theoretical knowledge and the ability to solve exercises as opposed to the classical laboratories [7]. The exercises in these traditional laboratories give detailed instructions to the students by describing every step in the procedure and give little room for free initiatives. Rarely the marks of these laboratories play an important role in the grading of the student [7].

It is indeed difficult to make large distinctions between the grades of the students based on open problems in laboratory sessions, the multidisciplinary project work, the project laboratories and the final master thesis. The standard deviations on the marks of these problem and project based learning activities are generally smaller than the standard deviations on the marks of the classical examinations (even when taking into account that during the final years of the curriculum these standard deviations are decreasing in comparison with the primary years of the academic bachelor program). A number of reasons account for these lower standard deviations on the marks of the problem and project based learning activities.

- These learning activities are permanently evaluated implying multiple feedback of the coach towards the students before the final summative evaluation. If necessary, this allows them to improve their behaviour and obtain higher marks.
- Although being a member of the teaching staff, the coach of the multidisciplinary project is not an opponent, i.e. the coach supports the entire project group and the individual students. A similar remark applies when coaching the students during all types of laboratory sessions and the final master thesis.
- Quite a large number of competences are evaluated and different types of evaluation methods are applied.

The main goal of the problem and project based learning activities is the development of a range of cognitive, meta-cognitive and social competences by the students. It is of fundamental importance to show that graduates really achieve the learning outcomes. An extensive differentiation between the grades of the students is a minor consideration.

2 THE ELECTRIC KART

The development of the electric kart and related research activities provide opportunities from a number of viewpoints. It is an opportunity to narrow the existing gap between the research and the teaching activities at KU Leuven – Technologiecampus Oostende. It is also an opportunity to teach students a broad range of skills in all stages of their curriculum (this remark also applies in case of the multidisciplinary project when considering other topics).

2.1 Research based education

When organizing research-based academic studies like the engineering education, it is a challenge to narrow the gap between the research activities at the university and the curriculum of the students. It is important to create an educational environment that integrates all aspects of research activities into every level of the curriculum [5]. According to [5], a number of possibilities exist.

- The teaching is still based on a traditional information transmission model. The emphasis is laid on understanding the research results and the know-how built up by the research activities of the teaching staff.
- The curriculum emphasizes the process by which research knowledge is produced. Attention is given to the teaching of inquiry skills and research ethos.

- Research activities are integrated as learning activities into the curriculum. Research is performed based on a collaboration between the teaching staff and the students. There is a two-way interaction between teaching staff and students.

From a technical point of view, the multidisciplinary project topics developed during academic years 2012-2013 till 2014-2015 around the electric kart are mainly focused on condition monitoring and EMC, both closely related to the research activities of the ReMI (Reliable Mechatronics and ICT) research group at the campus.

2.2 Educational approach

Three chassis of karts are bought by the teaching staff; two of them are equipped with batteries, power electronic drives and motors. Contrary to approaches described in literature [2, 3, 4], until now the driving mechanism has been realized by the teaching staff and not by the students (although the third non-equipped chassis still has this possibility). Starting from an electric kart in working order, the multidisciplinary project works of the students are to a large extend devoted to electronics-ICT oriented topics embedded in a multidisciplinary context.

- The use and calibration of sensors (e.g. acceleration sensors, Hall sensors, strain gauges,…), signal conditioning, data logging and interpreting the measurement results is practiced in a real life environment.
- Condition monitoring in cars and other appliances reveals promising possibilities to reduce maintenance costs and to increase the reliability of the system.
- Electromagnetic compatibility (EMC) i.e. reducing emission and increasing immunity is an important topic when designing electronic equipment. The importance of EMC is even rising which justifies its presence in an engineering curriculum and open project work.

Although condition monitoring and EMC are very important topics, in general they are not appealing to the mainstream engineering student. By integrating these topics in attractive context-based projects, the interest of the students towards condition monitoring and EMC is enhanced considerably.

Furthermore, self-directed learning of the students is activated by the stimulating support of their coach. The technical development can be considered as a three step approach. First, the need to integrate sensors into the electric kart and (electric) vehicles used on the road has been studied. In a second step, acceleration sensors and Hall effect sensors are integrated into a toy-grade radio controlled car. Finally, this experience is used to integrate and test the sensors in the real kart.

The students are expected to explore topics that are completely new for them. In the present examples, the students had to program the microcontroller of an Arduino Uno board using the unknown C++ programming language. Based on documentation available in downloadable tutorials, the students need to process the data from the sensors and to control an LCD display.

The electric kart project is multidisciplinary because it combines electro-technical (battery energy storage, power electronics, electrical motor) aspects with several other technical disciplines. For instance, electro-mechanical topics include equilibrating the drive shaft, monitoring the tire pressure or monitoring the tire wear. When designing and moulding a plastic coachwork, plastics engineering applications arise. Inspired by the technical background of the coach, during the academic years 2012-2013 till 2014-2015, electronics-ICT oriented topics (the use of sensors, signal conditioning, data logging, reliability and EMC) were introduced. The teaching staff intends to extend these topics in the future.

The electric kart project is performed by heterogeneous student groups i.e. in a single group students intending to study electronics-ICT, electro-mechanics, electrical energy, building engineering and plastics are collaborating. The mix of different technological interests of the students broadens the project work.

2.3 Collaborative learning

The core element of collaborative learning is working in groups rather than working individually [8], i.e. students are working in a group towards a common goal. Collaborative learning includes cooperative learning where students cooperate in a structured form of group towards a common goal while being assessed individually.

Especially the design of the driving mechanism of the kart allows possibilities to stimulate the learning process by introducing competition between different student groups. As suggested in [2] (and realized in [9] when designing a flying wing UAV) competition can increase the motivation. It can be a challenge for the student groups to design and build the kart having the largest speed or the largest range.

The availability of three chassis of karts provides the opportunity to introduce this competition (between groups of students). At present, no competition has been introduced yet; it is a premise that cooperation is more effective than competition among students for producing positive learning outcomes [8].

2.4 A broader range of aplications

The development of an electric kart and the realization of project work are not only instructive for the students, but also for the teaching staff. Although extensive research based knowledge is available concerning condition monitoring and EMC related topics in the research laboratory ReMI, the development of the driving mechanism of the kart was still a challenge for the members of the teaching staff (for instance introducing BLDC motors and permanent magnet synchronous motors operating at low voltage levels in combination with lithium-ion batteries).

Not only the project coach but also a large number of collaborating teachers and research assistants gained technical and pedagogical insight. The electric karts in working order also provide opportunities to teach students outside the earlier mentioned learning trajectory.

It is an outstanding accreditation requirement to introduce more project work when educating master students specialized in electrical energy. Based on the available infrastructure and especially due to safety requirements, realizing this accreditation requirement is definitely not trivial. Although the laboratory teaching staff designed a number of different projects during the academic year 2012-2013 (e.g. Labview based stepper motor control, temperature control of a toaster oven, simulation of a high voltage circuit breaker), the two electric karts in working order form an ideal test bench to be used by these master students. These test benches provide the infrastructure to realize a whole range of research based project work and active learning activities.

The development of stimulating projects is also useful to recruit engineering students. The karts have been used during a demonstration on the open day, allowed dissemination on a Youtube website and attracted the attention of local newspapers.

3 EVALUATION OF THE PROJECT WORK

3.1 The multidisciplinary project work

Since the starting up of the multidisciplinary project work in the academic year 2005-2006, a number of evaluations of this project work have been performed among the students (the last one has been performed in December 2014). The students agree the project work helps them to develop ‘soft’ skills. For instance, the students learn to take initiatives and they acquire self-knowledge about the way they are functioning in a project team. When starting up the multidisciplinary project work, some members of the teaching staff feared the time spent to develop ‘soft skills’ and the associated competences would reduce the time available to gain solid knowledge of sciences and technical skills. However, the students claim they learned a lot of subject matter during the multidisciplinary project work, also from a scientific and technical point of view.

The collaboration between the students and the coach is very important. Due to the multidisciplinary character of the project work, a number of consultants having specific disciplinary expertise are appointed to help the students. According to the students, obtaining support from these consultants is not always easy. Although stimulated by their coaches, the students often lack initiatives towards them. In order to reduce the threshold for the students, it can be a good practice to choose well-known consultants who already taught some courses to the students.

The students have a work schedule of twelve weeks to realize the project work, to write a final report and to give an oral presentation. A lot of student groups lack time due to time-management problems. Procrastination is the major cause since the coach helps the student groups to make a realistic time schedule at the beginning.

3.2 The electric kart project

During the academic year 2012-2013, the student group realizing the electric kart project was a strong team of five students each performing a different task. One of the team members acted as project coordinator and the other students accepted his authority. A second student mainly contacted external companies to gain information concerning the use of sensors and condition monitoring in traditional cars and electric cars. Finally, the remaining students mainly focused towards programming issues, signal conditioning and mechanical aspects.

Even such a strong and coherent team had some time pressure at the end. The initial open problem was quite broad implying the students had to find their own way, which was pressing on the time-schedule. Giving more well defined support at regular points of time might reduce that problem.

The student group realizing the electric kart project during the academic year 2013-2014 was a successful team as well. The students were able to make appropriate technical choices, to test sensors in a real-life situation, to log and to analyse the measurement results to their satisfaction. The student group during the academic year 2014-2015 mainly focused on EMC related problems.

Although the formulations of the open problems were somewhat less broad, the student teams mentioned once more the time pressure at the end of the project. Realizing a project requires much more time than expected at the beginning. Time is not only needed to realize the technical aspects but also to learn to cooperate and to find the appropriate task for every member of the team.

The participation of these students at the multidisciplinary project evaluations of December 2013 and December 2014 reveal:

- The motivation to start the project, the possibilities to gain new knowledge, the multidisciplinary aspects of the project, the opportunities to develop research skills and the need to reflect critically about the research results are more appreciated by these electric kart student groups than by the average student group.

- The satisfaction of the electric kart student groups concerning the support by the project coach and the transparency of the evaluation system is likewise high. In December 2013 the students were satisfied concerning the peer evaluation system, in December 2014 this satisfaction was somewhat lower.

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