INTEGRATION OF THE PHYSICS LAB IN THE CURRICULUM SEQUENCE 'ENGINEERING EXPERIENCES'

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The classical physics lab, focusing on cognitive learning and the development of some professional competencies among first-year engineering students, has disappeared and is included in an innovative new course, part of a curriculum sequence called 'Engineering Experiences'. The reasons behind this reform are explained and the perceptions of the students after the first year of implementation are described. We can conclude that the immersion of the physics lab into an integrated learning environment has not harmed physics, on the contrary.

Keywords: physics lab, professional competencies, integrated learning environment.

INTRODUCTION

Laboratory and practical work are characteristic features of a Bachelor's programme in any engineering discipline [1]. The benefits are clear: develop competencies that will enable graduates to operate professionally as an engineer; deepen the understanding through relating theory to practice and motivate students by immersing them in authentic assignments.

The physics lab, mostly situated in the first year of the Bachelor's programme, contributes definitely to these objectives [2]. However, the methodology and specific learning outcomes have evolved over the span of the last century [3]. During the first half of the 20th century the focus of the physics lab was on vivifying conceptual and analytical knowledge of the most important facts of physics and carrying out precise measurements in order to reduce error. This more fundamental view evolved into a more societal oriented view mid-20th century to keep in touch with industry and the rapidly changing technologies. At the end of the 20th century this resulted in additional learning outcomes in the physics lab such as teamwork and lifelong learning [3]. Nowadays, physics labs serve a broad set of learning goals and they are organized in many different ways according to institutional culture, student population and the objectives pursued. The possible approaches are among others:

- Project- and problem-based design [4-5];

- Model-based design [6];
- Learning environment for several competencies [2];
- Single experiments (learning objects), relating the phenomenon to real life and introducing boundary conditions [7];

However, the learning outcomes envisaged by these different visions are rather similar [3]:

- Constructing knowledge;
- Modeling;
- Designing experiments;
- Developing technical and practical laboratory skills;
- Analyzing and visualizing data;
- Communicating physics.

Professional competencies are inherently part of these learning outcomes. It should be emphasized that we use 'professional competencies' instead of 'soft skills' since the latter has negative connotations [8]. The inclusion of professional competencies in the physics lab is a great step forward. It allows to decrease the gap between physics education and the way professional engineers rely on physics in their engineering practice. Following this reasoning, we have constructed a completely new curriculum sequence in 2019-2020 in the reformed Bachelor's programme in the Faculty of Engineering Technology at KU Leuven: 'Engineering Experiences'. In this curriculum sequence students are challenged to use, integrate, and apply all the competencies acquired in other courses, both technical and non-technical, in order to tackle authentic assignments. These assignments are carried out individually or in teams and become increasingly complex and realistic, requiring more and more independence while progressing through the Bachelor's programme. This gives students an insight into possible future professional practices and supports them to find out where their interests and strengths lie. This curriculum sequence counts a significant number of ECTS credits, i.e. 24 ECTS credits spread over the entire Bachelor's programme. The required space in the curriculum was created thanks to the integration of labs and projects from different disciplines.

In this paper we report on the first step in this curriculum sequence at Campus De Nayer: the physics lab (and others) immersed in the course 'Engineering Experiences 1'. We focus in the first paragraph on the content and the goals of this new approach and in the second paragraph on the consequences for the physics lab. Afterwards the experiences of the students are discussed and we finish this paper with a conclusion.

NEW APPROACH: ENGINEERING EXPERIENCES

The first year of the Bachelor's programme includes 'Engineering Experience 1'. During this 9 ECTS credits-course, we introduce the students to the integrated approach and the way engineers work: coordinate multiple competencies to accomplish a goal [9]. This course runs during the whole academic year and starts in the first semester with what we call 'the integrated lab' (2 ECTS credits). During the second semester we proceed and challenge them with 'the project' (3 ECTS credits). These two assignments are accompanied by two courses: 'spatial insight and CAD' (3 ECTS credits) in the first semester and 'seminars professional competencies' (1 ECTS credit) during the whole academic year.

In '**spatial insight and CAD'**, students are familiarised with the spatial thinking process and the foundations of the technical drawing language. The aim is to gain insight into a technical drawing so that, regardless of their further education, a drawing can be read and understood easily. The knowledge and skills gained with this course during the first semester are applied directly into 'the project' where they have to design and draw a technical construction.

The '**seminars professional competencies'** aim at teaching very specific learning outcomes. In the first semester, students are first introduced with the Basic CFrame. This framework includes the basic communication principles that facilitates to communicate effectively to different audiences. The Basic CFrame is the foundation in any other communication course in the Bachelor's programme. Other first semester seminars are: information literacy, scientific writing, critical reflection and 'health, safety and environment'. In the second semester, the focus is on presentation skills, project management and team dynamics. These seminars are limited to only 1 ECTS credit because the training of these competencies on the one hand and the feedback and evaluation by peers and the teaching staff on the other, is done during the 'integrated lab' and 'the project'. The integrated approach is strongly supported by research: engineer's technical work is inseparably intertwined with professional competencies [9]. By consequence, the professional competencies cannot be taught in isolation from the technical context in which they will be used. Nonetheless, these seminars are on purpose explicitly included as 'seminars' in 'Engineering Experiences 1', since it is proven that this explicit attention is essential for learning [10]. Because the training and assessment are organized during 'the integrated lab' and 'the project', the teaching staff of these seminars is also part of the multidisciplinary team that supports and challenges the students during 'the integrated lab' and 'the project'.

During the first semester, students carry out well-defined hands-on assignments in '**the integrated lab'**. These assignments are closed, authentic tasks with a specific predefined outcome, designed according to the traditional cookbook laboratory approach:

- Measure the properties of mechanical vibrations via sensors;
- Program a car to drive as efficiently as possible in order to pass several traffic lights;
- Optimize heat loss through the facades of an on campus-building;
- Build a galvanic, electrolysis and fuel cell.

We call these tasks 'integrated' because various disciplines and competencies come together like in the real world.

The '**project**' runs during the second semester. At that moment students already have some more disciplinary knowledge and laboratory-experience. Teams of four students are challenged by open assignments linked with Sustainable Development Goal 12 'Responsible Consumption and Production' [11]. 'The greenhouse of the future' is defined as our central theme, and students can choose to approach the challenge from four different disciplinary perspectives:

- Civil engineering: design a greenhouse structure on top of an existing building;
- Chemical engineering: recycle the water of a greenhouse with the help of algae cultivation;
- Electromechanical engineering: build an adjustable hatch for a greenhouse;
- Electronical engineering and ICT: control environmental factors in a greenhouse.

The project approach has different advantages. First, by addressing the domains of the various majors, the project helps students to refine their choice of the major which they have to make after the first Bachelor's year. Second, these team-based projects are considered to be a valuable approach to develop a broad set of professional competencies, such as project management or team dynamics [10]. Third, first-year students experience for the first time the feeling of 'operating like a real engineer'. This motivates the students and improves their retention [12].

CONSEQUENCES FOR THE PHYSICS LAB

The 'old' physics labs that have disappeared in order to create space in the curriculum for this integrated approach, had the following goals:

- deepen the understanding of the theoretical concepts (such as heat flux);
- measure and process physical quantities in a correct and precise way;
- provide opportunities to work together;
- write a report;
- motivate students and stimulate their interest in the subject.

All these goals are still present in the actual course 'Engineering Experiences 1'. The concepts (and sometimes also the material) of the 'old' physics labs are explicitly part of 'the integrated lab'. Due to this integration it is even more clear for the engineering students that they need concepts from physics to solve 'engineering' problems. Previously, the physics labs focused on more conceptual themes such as 'measure the thermal conductivity', whereas now it is part of a more authentic setting to 'optimize heat loss through the facades of an on campus-building".

In the project assignments, the link with physics is less explicit. But students now get the chance to train their professional competencies more intensively and under supervision of coaches. Although the same competencies were also a goal of the 'old' physics lab, students now also learn that these professional competencies are not linked to one course only, but are essential to solve engineering tasks in general. The chances of transfer over courses in a semester, year or whole curriculum are increased, in line with the idea of lifelong learning.

STUDENTS' EXPERIENCES

The reformed Bachelor's programme in the Faculty of Engineering Technology at KU Leuven was implemented for the first time in 2020-2021. At the end of that academic year, we consulted the students and asked for their experiences on how they perceived some of the key elements. We collected data anonymously during the physics college.

At the end of the first semester, we collected the perceptions of 44 students (response rate 50%) concerning some characteristics of 'the integrated lab' via a five-point Likert scale (completely dissatisfied, less satisfied, neutral, satisfied, very satisfied) using polleverywhere. The lowest rated key element is the feedback obtained by the students during the integrated lab (Figure 1a). There was also a need for more clarity on the objectives. The students were neutral about the broad set of proposed professional competencies and they were satisfied about the content of the integrated lab, the challenging nature of the assignments, the infrastructure in the lab and the support by the staff. And finally, we were pleased that the students were (very) satisfied with the integrated character of this new activity – the highest rated key element (Figure 1b).

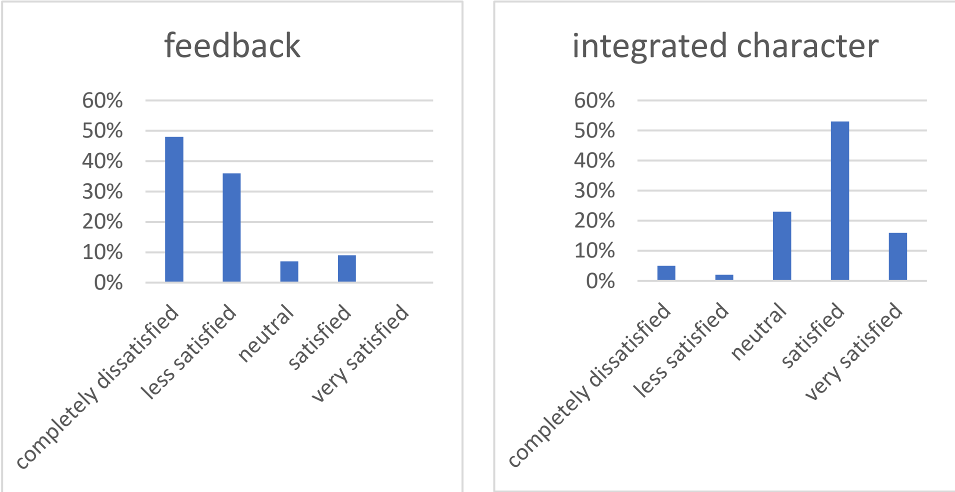

Fig.1. Lowest and highest rated key element of the integrated lab according to the students.

'The project' was evaluated at the end of the second semester by 51 students (response rate 58%) using open questions, which was made possible through Qualtrics. We asked about their views on the greatest strengths and weaknesses and obtained the following top three for the strengths: (1) independence, (2) good support by the staff and an ex aequo for (3) 'learned a lot' and 'was fun'. The most frequently mentioned weaknesses were: (1) processing new knowledge independently, (2) little support by the staff and (3) lack of clarity. The contradictions that we read here are probably a result of the fact that this population is very diverse since all of them are first-year students. Some of them like the independence, others need more support.

Also, at the end of the second semester we gauged students' views on the 'seminars professional competencies'. They appreciated very much (1) the implementation in practice, (2) the large amount of feedback and (3) the coaching. Improvements were possible for (1) the communication of the deadlines, (2) the organization of the digital learning environment and (3) the amount of reflection exercises.

CONCLUSION

Two of the three most important advantages of integrated programmes according to the literature [13] are confirmed by the students surveyed in the context of this specific course: it provides motivation to learn, and meaningful learning is easier to achieve. We believe that this integrated course also succeeded in realizing the third advantage, in casu a better management of introducing the professional competencies to students. For example, we can now guarantee a systematic approach to 'writing skills', whereas before students had to write a lot of reports without any introduction into communication or any systematic feedback while moving from one lab to another.

This academic year 2021-2022, we have made some adjustments based on the feedback of the students. We reorganized the digital learning environment in order to create a supportive learning community for the students and we introduced the first steps of a feedback ecosystem [14]. We did not change the integrated character of 'Engineering Experiences 1'. On the contrary, we strengthened it by stimulating students in the project to collaborate beyond the borders of their specific theme.

Thanks to the collaboration of experts in professional competencies and experts from sciences and various technological fields, we have exchanged a lot of information and learned from each other. The disappearance of the 'old' physics lab had some emotional impact on the teaching staff, but it turns out to be a smart move. The usefulness and attractiveness of physics as a subject and course is strengthened. Sciences, and physics among them, serve as the basis for engineering endeavors.

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