TEACHING ELECTRONICS-ICT: FROM FOCUS AND STRUCTURE TO PRACTICAL REALIZATIONS

Jo Verhaevert, Patrick Van Torre

Ghent University – imec, IDLab, Department of Information Technology (INTEC), Belgium

ABSTRACT

We present a four-year electronics-ICT educational master program at Ghent University in Belgium. The students develop knowledge and skills from novice to experienced electronic circuit designers. In the corresponding topics, the immersion into engineering problems is deepened. The horizontal and vertical alignment of courses in the four-year master program at our university is discussed. The curriculum of the four-year master program is highly project-oriented and all topics are clustered around a well-considered set of standards. This clustering supports the logical structure of the program, with students gradually acquiring the necessary competences. All standards and their mutual interaction are extensively discussed in the paper. We also focus on four design-implement projects included in the electronics-ICT program, explicitly following CDIO-guidelines. Whereas the first-year project has a limited level of difficulty, the challenges increase significantly in the course of the next years. Students learn that product design is an iterative process on different levels, where the design strategy can be changed continuously based on important and crucial feedback. Different evaluations have demonstrated that our students are not only aware of CDIO-principles, but are also convinced of the quality of the results obtained by following the standards.

KEYWORDS

Design-Implement Experiences, Engineering Workspaces, Integrated Learning Experiences, Active Learning, Learning Assessment and Program Evaluation, Standards: 5, 6, 7, 8, 11,12.

INTRODUCTION

In the Belgian system for higher education, one can study technological topics at three different levels. The first level is a three-year study and is called professional bachelor. The second level requires four years of study, consisting of three years of (academic) bachelor and one additional master year. The third level consists of three (academic) bachelor years and two additional master years. Whereas the differences between pursuing a professional or academic degree are rather straightforward, the differences between the second and third level are not that clear, because both levels lead to an engineering degree. The third level (with five years of study) however, focuses on fundamental knowledge and theoretical research, resulting in products and solutions for the market in the far future. The second level (with four years of study) works on applied engineering sciences and solves today's problems, with engineers working in multidisciplinary teams.

With the last curriculum reform at Ghent University, the four years study program of electronics-ICT was reorganized, stressing more than in the past on the connection between the important theoretical basis and the practical applications in the study field of electronics. At the same time, many extra CDIO-principles have been added to our program. Because more project courses are offered, horizontal and vertical alignment of the curriculum is essential. A similar reorganization was presented by Shen (2015).

After elaborate internal consideration, it was decided to restructure the curriculum throughout the four-year study program in 6 different standards, thereby clustering all relevant topics. Besides basic engineering outcomes – as core of the program – a number of specific outcomes are defined. The cluster for elementary scientific topics, the engineering topics, the research topics and finally specialized electronics and ICT topics are the classic outcomes, whereas innovation, sustainability and communication skills are the specific ones.

Especially for the project-oriented courses, an alignment of the topics and the level of difficulty is of paramount importance. Students learn that product design and development is an iterative process at many levels, where constant feedback helps to adjust the design strategy to obtain a high-quality product as the final result. Creativity is stimulated by allowing many degrees of freedom to define the final product. The project definition not only needs to challenge every student on state-of-the-art subjects but should also drive them to apply recently taught knowledge. Interaction between the professors responsible for those project courses is very important and is organized on a regular basis. The increasing project complexity is also described in Kjærgaard et al. (2012) and is in complete agreement with CDIO Standard 5. The four projects of increasing complexity go hand in hand with the four years of study. The second bachelor year project course was described in Verhaevert et al. (2016), whereas the capstone project of the third year was discussed in Van Torre et al. (2017).

This paper is organized as follows. In the next section, the learning outcomes are structured and extensively discussed, showing the horizontal and vertical alignment within our curriculum. The following section elaborates on the project courses and the increased difficulty level during the studying years. The section thereafter handles the CDIO-benchmarking of the engineering learning outcomes. This paper is finalized by the conclusions in the last section.

LEARNING OUTCOMES STRUCTURED

Learning outcomes

The term learning outcome is an educational concept related to the alignment, the structure and the coherence of a study program. Learning outcomes clarify how a curriculum is composed logically so that students gradually acquire certain learning outcomes and how it is monitored that specific scientific themes throughout the study program are adequately addressed. Setting up a thorough program requires consulting stakeholders such as students and professors, as well as industrial advisors. Keeping the intended learning outcomes up to date also requires ongoing regular interaction on content, teaching principles and testing methods between the involved professors.

A number of desired learning outcomes are generally implicitly or explicitly included in study programs. Besides the classic learning outcomes, more specific learning outcomes such as communication skills or sustainable development enjoy a growing interest. Classic learning outcomes express the core of the curriculum and occur in many courses throughout the curriculum. These learning outcomes usually relate to different course learning outcomes and sometimes even to a complete field of competence. Mapping these learning outcomes is often a relatively easy exercise. One selects some global goals from the study program and places all course units there. This is a puzzle that usually falls into place quickly.

Equally, individual courses can also have specific learning outcomes. These relate to more specific topics such as communicative skills, entrepreneurship and sustainable development. These can be themes the course has traditionally focused on for years, which are typical for the curriculum. However, they can also be previously unexplored or highly fragmented themes for which more deployment or visibility is important in the future. A theme such as 'sustainable development' is a good example and can be covered in many courses. However, in the past, student surveys highlighted a lack of attention to this topic. These specific learning outcomes are often more difficult to implement because one has to search in which course units the theme can be properly addressed. That is why we integrated these themes in the learning outcomes, which will be explained further on.

Vision and operationalization

Learning outcomes provide insight into the program and the mutual coherence of the course units. As a result, they promote communication and form a good basis for internal consulting within the educational staff. For example, if one wants to put more emphasis on a particular topic in the program, this does not necessarily have to result in a large program reform. By elaborating the learning outcome around this theme, possible fragmentation is avoided. Additionally, the horizontal and vertical alignment is often very useful in shaping an appropriate test policy within the study program

When a study program is launched, there has been a lot of preceding discussion on the design and implementation of the overall alignment. Making the learning goals and outcomes explicitly available in a graphical way, does not only ensure that external parties quickly obtain information about the study program, but it also makes clear to (new) professors to which particular learning outcomes their course contributes. Moreover, learning outcomes can also make clear to students at which stage they are in the learning process.

The program committee is in charge of the structure and the quality control of the educational study program and consists of 9 professors, 3 assisting teachers and 6 students, sometimes supplemented with members from the industry. This committee defined 6 educational goals, as a vision and mission statement on the education of electronics-ICT engineering students. They focus on electronics-ICT engineers who will be able to:

1. anchor theoretical elementary sciences directly based on intensive practice and practical sessions
2. turn scientific ideas in a creative and innovative way into products for the society of tomorrow
3. sell ideas and products in a communicatively strong way
4. be team-oriented and directly employable in the professional field
5. perform multidisciplinary and academic research
6. be experts in the fields of 'analogue and digital electronics', 'information and communication technology' and 'data processing and multimedia'

These goals were translated and converted into 6 different learning outcomes: elementary scientific learning outcomes, entrepreneurship and sustainability learning outcomes, communication learning outcomes, engineering learning outcomes, research learning outcomes and finally electronics-ICT learning outcomes. They are visualized in different colors in Figure 1.

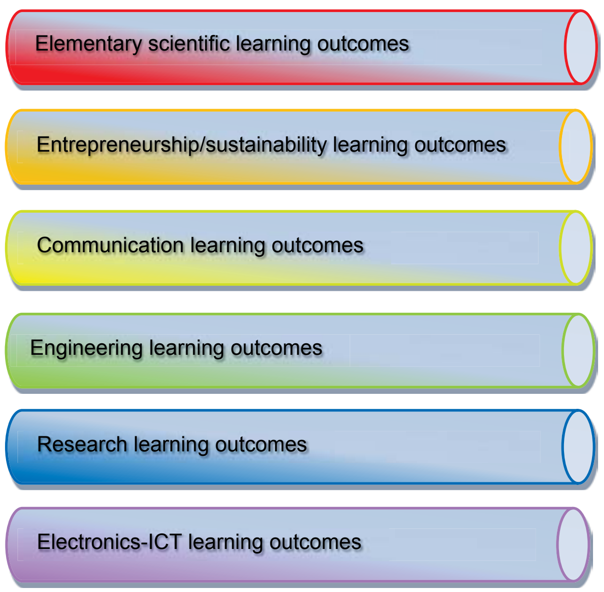

Figure 1. 6 different learning outcomes

Specifically, the program committee wants to realize its vision and mission statement through:

1. knowledge creation as a fundament of creativity in practicums and seminars organized in small groups
2. a multidisciplinary approach in which the unknown poses a challenge rather than a threat
3. the use of a wide and varied range of teaching methods that acquire communication skills
4. presenting complex issues in which each team member is challenged to 'dare to think'
5. guidance of keen academic thinking in projects and guided self-study
6. accountability of theoretical knowledge through practical applications

The above operationalization of the vision and the mission statement explicitly states how the program committee outlines the education of the electronics-ICT engineers of the future. Those operational goals can be directly linked with the vision and mission statement and also with the learning outcomes. However, different cross connections are possible. For instance, operational goal 6 (with practical applications) can be part of the research learning outcomes and can also have a match with communication skills at the same time.

Applied on the study program

Deploying the operational goals results in a horizontal and vertical alignment of the courses. The colors of the 6 different learning outcomes are used to visualize the complete study program throughout 8 semesters of study, or 240 credits (with 30 credits per semester) in Figure 2. To each of the learning outcomes, various courses are connected, taking into account that the study program is a balanced sequence of course units, supporting each other. A number of course units link with 2 or even more learning outcomes and were therefore assigned 2 or more colors.

A number of courses in Figure 2 are framed in yellow. This indicates that more attention is paid to communication skills in comparison with other courses. It is also important to be aware of the fact that none of those colored courses may be interpreted too strictly. For instance, in course units being part of the red elementary scientific learning outcomes it is of course allowed to teach and test skills of other learning outcomes, but in a more limited way.

DESIGN-IMPLEMENT PROJECTS IN ELECTRONICS-ICT

In this section of the paper, the focus lies on the different courses of the engineering learning outcomes. More than in other courses, the students learn to think and act as an engineer. In the electronics-ICT educational program, these design-implement projects are the core and are meant to support and to complement the other theoretic courses, not only from the previous semesters but also from the same semester (Svensson & Gunnarsson, 2012).

Specifically for the engineering learning outcomes, a horizontal and vertical alignment is extremely important. Before the program reform, many small projects existed in almost every engineering course. By setting up an alignment the many small projects disappeared and large annual projects resulted in less overlap, more challenge and last but not least more enjoyable learning. This section is focused on the different courses involved and on their gradually increasing difficulty, as is described in (Kjærgaard, Brauer & Andersen, 2012), according to CDIO Standard 5. As can be seen in Figure 2, Engineering project is the first project course. It is followed by a technically more demanding Multidisciplinary engineering project in the second year and the Bachelor thesis in the third year. The four-year educational program is finalized with a Master thesis as a capstone of the curriculum.

Besides other courses in Figure 2, the courses related to the engineering learning outcomes are also yellow squared, indicating that communication learning outcomes are involved, according to CDIO Standard 7. Combined with technical and engineering skills, the students are trained in communication skills, such as a paper or a (poster) presentation. They are encouraged to exercise these communication skills by communicating about particular design choices and preliminary project results to the other teams.

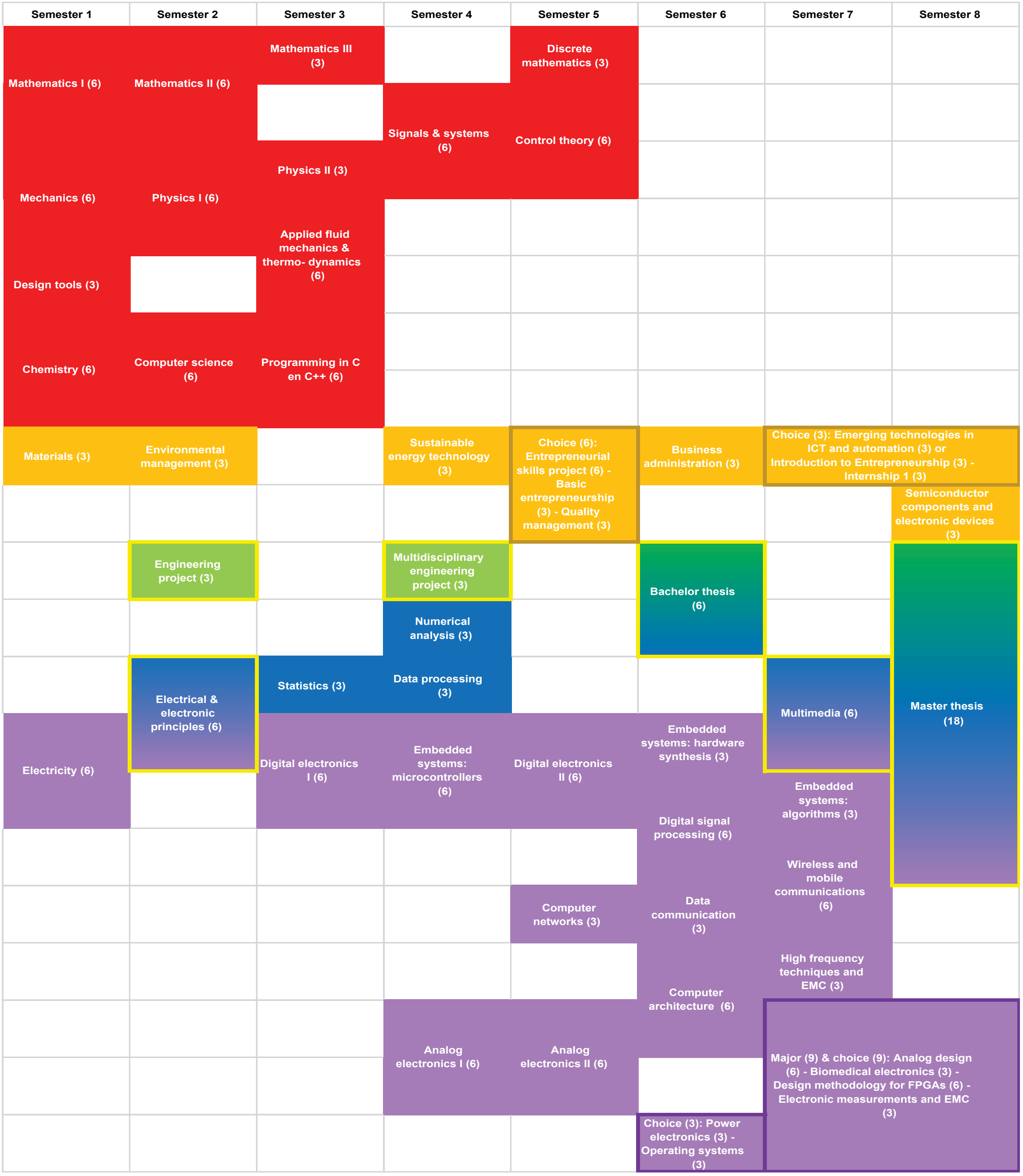

Figure 2. Structure of the study program

This interaction often leads to redesigns, forming a highly valuable experience frequently leading to a better final design. Also, academic referencing becomes more refined and important, further in the curriculum.

Every course starts with an introductory class, where not only the technical details of the project are presented, but also the project methodology and assessment parts. According to CDIO Standard 11, different assessment types are used, adapted to what is taught and practised. Writing and presentation skills are assessed by a language professor. The students are also introduced in the CDIO principles (Khan, Kristian, Ying & Jung, 2015), especially for the brainstorming and planning of the different tasks and responsibilities. The topics are all multidisciplinary (CDIO Standard 8), using concepts from other courses to provoke a deeper understanding of practical issues in the domain of electronics-ICT. Depending on the project topics, additional presentations help students to acquire related theoretical background and technical issues necessary for the project.

Together with the reorganization of the content, some practical issues were also taken care of. The workspaces for students are now accessible every day and are user-friendly with all necessary equipment, as being part of CDIO Standard 6. On a weekly basis the students are supposed to work on the project within specific hours, but are free to spend extra hours anytime. Since the reorganization, the supervisors are not merely teachers, but act as trainers and/or coaches (according to CDIO Standard 5), helping the students to quickly achieve intermediate results. Because early success is a very important motivating factor, the project proposals include a number of small goals of increasing complexity. Different ways of active learning are included, as also reported in (Gonzáles, Hurtado, Renneberg, Bravo & Viveros, 2016).

The rest of this section focuses on the four different CDIO courses, as part of the engineering and communication learning outcomes. A flowchart with the consecutive design-implement projects can be found in Figure 3.

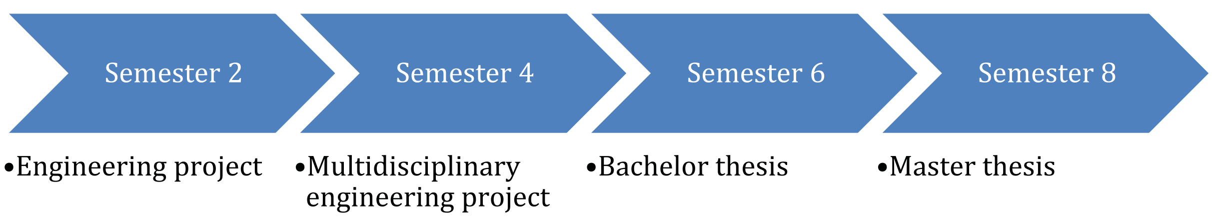

Figure 3. Consecutive design-implement projects

Engineering project

One of the first experiences in the domain of electronics-ICT is the Engineering project in the first bachelor year (Engineering project course specification, 2019). In teams of 5 to 7 students, an electric motor is designed and implemented, by using basic mechanical and electrical components such as magnets and reed switches. Every team is also required to control the motor with an Arduino microcontroller board. On a weekly basis the project progress is discussed within the team, together with the supervisors, encouraging the students to take initiative and solve problems in a creative way.

Considering the communication skills, the focus is on correct and adequate use of language in reports and reference lists. Also the concept of collaborative writing is explained, how titles and paragraphs are structured and formulated in a clear and precise, linguistically correct way. In every project meeting, another student is chairman and secretary, which offers the opportunity for every student to experience every role.

Multidisciplinary engineering project

In the second year, as visible in Figure 2, the Multidisciplinary engineering project is scheduled. This more advanced-level design-implement project (Multidisciplinary project course specification, 2019) was the topic of an earlier publication (Verhaevert & Van Torre, 2016).

Where the previous project was more initiating, this project is meant to present a first serious challenge in electronic product design. Another topic is chosen every year and a large complexity is maintained. In 2018, the students designed a receiver for DAB (Digital Audio Broadcasting). Instead of changing roles, every student in a group of 5 to 7 students needs to meet different, but dedicated job profiles (e.g. project manager, analogue design engineer, digital design engineer, printed-circuit board designer). Team meetings with the supervisor are complemented with additional lab sessions, especially toward the end of the semester. The students learn that product design is an iterative process on many levels, where feedback is used to adapt the design strategy and/or final product. The supervisor provides the necessary background for the students, by technical and scientific support.
Although a project report and a product demonstration are required, this course also focuses on oral presentation skills. Therefore, during the semester, a class is organized to teach the requirements for the presentation, especially concerning the structure and the layout of the slides. Because every team member should have an active contribution, advice on team presentations with alternating presenters is provided. The importance of body language, pronunciation and keeping the attention of the audience is also addressed and exercised in an intermediate presentation with peer-assessment by other students. Feedback on the presentation skills (by self-, peer- and tutor-evaluation) has no impact on the final marks in this stage.

Bachelor thesis

The three years of the bachelor program are finalised by means of a Bachelor thesis (Bachelor thesis course specification, 2019), which was extensively described in Van Torre et al. (2017). This design-implement electronics-ICT project is characterized by an even larger responsibility for the student. For every assigned project, a team of 3 students is composed. All topics are linked to different research groups, giving the students the chance to experience the research culture. In the structure, a blue color is added to this course, linking it with the research learning outcomes. Every team member needs to profoundly analyze the entire project, resulting in a literature review, handed in as a 10-page document with a correct reference list. Afterwards the team plans the project in different subtasks, integrating all aspects in one functional analysis. Besides a fully detailed functional description, a technical implementation is realized and should be presented as a separate chapter in the final text.

Writing a project report and performing an oral presentation has already been experienced previously by the students, but in this project, the expectations are set higher. There is more focus on a professional, objective and academic writing style as well as on text structure. The report also needs to be as complete as possible, because the obtained results should be easy to reproduce. Besides a report and an oral presentation, for this project a poster is required, where the students are guided to an academic poster with correct layout and language.

Master thesis

The final bridge between education and the job as an engineer is the Master thesis (Master thesis course specification, 2019), which also completes the master program. This final project is, in fact, a research project in close co-operation with the industry. The student performs technical-scientific research individually and independently in the chosen research domain. The students prove creativity, originality, inventiveness and craftmanship in the obtained research-oriented attitude. Members of the industry act as supervisor and assist the students on the go with use cases, practical issues and other industry relevant topics, resulting in research-driven practical design-implement projects.

For reporting, both a presentation with oral defence and extensive written report are expected, with a lot of attention to the problem definition and the approach followed. The work should reflect a critical attitude and research mentality. In the Master thesis, there is a close link with the industry, with industry members reading the manuscript and being part of the thesis committee. This focus results for the student in a broader and clearer scope on the defined problem. The last part of the communication learning outcomes focuses on the professional life as an engineer. There is information on business correspondence and preparation for a job application, with special attention for job advertising, curriculum vitae, cover letter, job interview, personality test, elevator pitch, coaching, etc.

ENGINEERING LEARNING OUTCOMES BENCHMARKING

The electronics-ICT engineering program described above is embedded in domain-specific learning outcomes defined by decrees from the Flemish government. Those learning outcomes describe the teaching qualification and thus give substance to a common set of learning outcomes that all students within the Flemish region are expected to acquire within a specific program. Especially for the engineering learning outcomes, a curriculum benchmarking is required, but has not yet been defined by the Flemish government. Those engineering learning outcomes are the core of the curriculum and an international benchmarking is strongly desired.

The program committee wants a curriculum that is organized around mutually supporting courses, where CDIO activities are highly incorporated with many student design-build-test projects. The program needs to integrate the learning of professional skills such as team work and communication, to feature active and experimental learning and to constantly improve through quality assurance processes with higher aims, surpassing accreditation requirements (Crawley, Brodeur & Soderholm, 2008). The 3 overall goals of the CDIO initiative (master a deep working knowledge of technical fundamentals, lead in the creation and operation of new products and systems and understand the importance and strategic impact of research and technological development on society) and the 12 standards have been the basis for a profound program reform, with impact on every study year and for every member of the educational staff (according to CDIO Standard 12).

During the roll-out of the new curriculum, the entire educational staff was invited for a workshop, where the project topics were discussed and the new program was critically reviewed. The resulting self-assessment of compliance was composed of a check of all 12 CDIO Standards and was used to benchmark the engineering learning outcomes of the electronics-ICT curriculum. Those 12 Standards (CDIO Standards 2.1, 2019) are as follows, with the self-assessment of compliance score between parenthesis as a result of the rubrics:

1. Adoption of the principle that product, process and system lifecycle development and deployment - Conceiving, Designing, Implementing and Operating - are the context for engineering education (score 4/5)
2. Specific, detailed learning outcomes for personal and interpersonal skills and product, process and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders (score 5/5)
3. A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills and product, process and system building skills (score 4/5)
4. An introductory course that provides the framework for engineering practice in product, process and system building and introduces essential personal and interpersonal skills (score 4/5)

5. A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level (score 5/5)
6. Engineering workspaces and laboratories that support and encourage hands-on learning of product, process and system building, disciplinary knowledge and social learning (score 4/5)
7. Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills and product, process and system building skills (score 5/5)
8. Teaching and learning based on active experiential learning methods (score 4/5)
9. Actions that enhance faculty competence in personal and interpersonal skills and product, process and system building skills (score 3/5)
10. Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods and in assessing student learning (score 3/5)
11. Assessment of student learning in personal and interpersonal skills and product, process and system building skills, as well as in disciplinary knowledge (score 5/5)
12. A system that evaluates programs against these twelve standards and provides feedback to students, faculty and other stakeholders for the purposes of continuous improvement (score 5/5)

This program reform and the adoption of the engineering learning outcomes have not yet reached a final point. Systematic and continuous improvement is recommended. The program committee for instance has plans to promote the realized products (from all study years), not only for the students and educational staff involved, but also for external stakeholders like alumni or industry members. We have ideas for a workshop, a YouTube-channel with videos made by students or even an electronic newsletter on a regular basis (explaining the current status of some student projects). Also, extra training in the CDIO principles for the educational staff can be useful. We should also be critical to the horizontal and vertical alignment of both the engineering and communication learning outcomes. Slight changes, like particular topics not yet taught to the students, can be solved ad-hoc by additional classes.

CONCLUSIONS

This paper described the experience with teaching electronics and ICT in engineering education at Ghent University. In the first part of the paper, the focus and the structure of the curriculum is described, resulting in different learning outcomes and a course scheme, showing horizontal and vertical alignment. In a second part of the paper, the engineering learning outcomes, combined with those for communication, are elaborated on by means of the description of four different design-implement projects throughout the four years study.

The horizontal and vertical alignment promotes focus and structure to the curriculum for both educational staff and students. The staff can rely on the logic of the program and the different courses. For the students this causes flexibility in selecting courses adjusted to their own preferences. The gradual construction of engineering, management and communication skills results in a wide variety of project topics and report results. Students are extremely motivated and result-driven, obtaining excellent team results in nearly all cases, working more hours than required or performing extra work, especially during the final phase of the project. By experiencing the complete design cycle, hands-on and with many degrees of freedom, creativity is boosted. The student assessment results confirm a wide appreciation of all these project courses.

As a weakness it should be mentioned that knowledge gaps are possible, by replacing traditional courses by project courses. As part of a team, every student is often free to select a particular role or to work on a dedicated part of the project. Some students may systematically choose a role corresponding to their own strengths, while their weaknesses stay uncompensated. This behavior is hard to exclude, given the nature of the project. Awareness for this risk needs to be part of the introductory classes, making the students responsible for their own knowledge acquisition path by selecting the right role and/or project part.

An opportunity not yet explored, is to present a variety of topics more closely related to industrial partners and hence overcoming the limited pool of projects from the educational staff. Another possibility is community service learning, where students engage in service, reflect on their experiences and also learn on a personal and civic level. The design of a proof-of-concept for third parties can be extra motivating, but a suitable level of difficulty and allowing enough student creativity need to be taken into account. Lundheim et al. (2016) suggest new ideas and relevant topics for the industrial link and Törnqvist (2015) gives a selection of such community service learning requests.

Popular students are shielded by other students, which can impact their peer-assessment. This is a risk, influencing the assessment results too much. Now it is solved by using the peer-assessment results only as a guideline, however other solutions should be investigated.

REFERENCES

Bachelor Thesis Course Specifications (2019). Retrieved from: https://studiegids.ugent.be/current/EN/studiefiches/E731035.pdf

CDIO Standards 2.1 (2019). Retrieved from: http://www.cdio.org/content/cdio-standard-21

Crawley, E., Brodeur, D.R., Soderholm, D.H. (2008). The Education of Future Aeronautical Engineers: Conceiving, Designing, Implementing and Operating. Journal of Science Education and Technology, Volume 17, Issue 2, p. 138-151.

Engineering Project Course Specifications (2019). Retrieved from: https://studiegids.ugent.be/current/EN/studiefiches/E701052.pdf

Gonzáles, A., Hurtado, J., Renneberg, K., Bravo, F., & Viveros, F. (2016). Active Learning in Electronics Engineering at Pontificia Universidad Javeriana. Proceedings of the 12th International CDIO Conference, Turku, Finland, June 12-16 2016.

Khan R., Kristian N., Ying S.Y., & Jung T.C. (2015). Engineering and Design: an Integrated Course with Real World Projects. Proceedings of the 11th International CDIO Conference, Chengdu, China, June 8-11 2015.

Kjærgaard, C., Brauer, P., & Andersen, J.C. (2012). CDIO projects in DTU's B. Eng. in Electronics Study Programme. Proceedings of the 7th International CDIO Conference, Copenhagen, Denmark, June 20-23 2011

Lundheim, L., Ekman, T., Gajic, B., Larsen, B., & Tybell, T. (2016). Early Innovation Projects: First Experiences from the Electronic Engineering Ladder at NTNU. Proceedings of the 12th International CDIO Conference, Turku, Finland, June 12-16 2016.

Master Thesis Course Specifications (2019). Retrieved from: https://studiegids.ugent.be/current/EN/studiefiches/E705002.pdf

Multidisciplinary Engineering Project Course Specifications (2019). Retrieved from: https://studiegids.ugent.be/current/EN/studiefiches/E731021.pdf

Shen Y. (2015). Exploration and Practice on Project Architecture with CDIO Initiative for Mechatronics Engineering Undergraduates. Proceedings of the 11th International CDIO Conference, Chengdu, China, June 8-11 2015.

Svensson, T., & Gunnarsson, S. (2012). A Design-Build-Test Course in Electronics based on the CDIO Framework for Engineering Education. International Journal of Electrical Engineering Education, Volume 49, Issue 4, p. 349-364.

Törnqvist E. (2015). Cross Disciplinary Projects, Cooperation between Linköping University, Demola and the Surrounding Society. Proceedings of the 11th International CDIO Conference, Chengdu, China, June 8-11 2015.

Verhaevert, J., & Van Torre, P. (2016). On Design-implement Projects in Electronic Engineering. Proceedings of the 12th International CDIO Conference, Turku, Finland, June 12-16 2016.

Van Torre, P., & Verhaevert, J. (2017). A Design-implement Capstone Project in Electronics Engineering. Proceedings of the 13th International CDIO Conference, Calgary, Canada, June 18-22 2017.

BIOGRAPHICAL INFORMATION

Jo Verhaevert, PhD, received the Engineering degree and doctoral degree in Electronic Engineering at the Katholieke Universiteit Leuven, Belgium, in 1999 and 2005, respectively. He currently teaches courses on telecommunication at the Faculty of Engineering and Architecture at Ghent University in Belgium, where he also performs research. His research interests include indoor wireless applications (such as Wireless Sensor Networks), indoor propagation mechanisms and smart antenna systems for wireless systems. He is currently also program leader of the electronic engineering curriculum at Ghent University.

Patrick Van Torre, PhD, received the Electrical Engineering degree in 1995 and the doctoral degree at Ghent University, Belgium in 2012. He has been employed by Ghent University, at the Faculty of Engineering and Architecture since 1999, where he teaches theory courses in Electronics and ICT, organizes project-oriented lab sessions and is involved in hardware development projects for third parties. He is active as a researcher, in the field of wireless communication, focusing on body-centric multiple-input multiple-output (MIMO) and beam-forming systems as well as sub-GHz long range wireless sensor networks.

Corresponding author

Prof. Jo Verhaevert
Ghent University
Faculty of Engineering and Architecture
Department of Information Technology
Electromagnetics Group
Technologiepark-Zwijnaarde 126
9052 Ghent
Belgium
jo.verhaevert@ugent.be