ENABLING LIFELONG LEARNING BY USING MULTIPLE ENGAGEMENT TOOLS

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ABSTRACT

This study aims to identify effective engagement tools and strategies that may strengthen student learning processes with a long-term impact. The context of learning plays an active role in student performance and needs to be carefully considered when designing collaborative learning environments. In the framework of a CDIO course entitled Project Course in Applied Physics (12 ECTS), master's students in applied physics, electrical engineering, biomedical engineering, material science and nanotechnology work in groups of four to seven people for realizing their own project idea given three broad requirements: (i) use gas sensors, (ii) manage a certain maximum budget to purchase components, and (iii) build a working prototype for any indoor air quality monitoring application of interest for them and their customer. Groups are generally multicultural and multidisciplinary. Qualified supervision and skills training activities are adapted to facilitate the students' progress and guarantee the success of their project work. Based on observations, feedback, and results over a five-year period, this approach appears more engaging and inspiring for both students and teachers compared to more defined projects. Encouraging the students to conceive their own original ideas, involving them in the co-creation of the learning process, and building knowledge, understanding, and skills through a variety of engaging experiences, helps their motivation, interest, active participation, and creativity with a direct impact on the quality of their learning. As an example of successful project work, here we report on two groups of students at Linköping University, Sweden, who have recently designed, developed, and tested an innovative sensor system prototype for smart monitoring of gas and particle emissions from cooking activities. The project course has received 5.0/5.0 as an overall students' evaluation.

KEYWORDS

Lifelong learning, Experiential learning, Active learning, Skills training, Multicultural environment, Engagement, Standards: 1, 2, 5, 6, 8, 11

THE CONTEXT OF LEARNING

In light of experiential learning theory (Kolb, 1984), learning is 'the process whereby knowledge is created through the transformation of experience'. Therefore, people learn from experience and through it, during their whole life, they acquire their own learning strategies which help them to face daily situations and solve problems, but also influence their behaviors and decisions. Each person has its own personal cognitive styles, also called “learning styles”, which may differ depending on, e.g., culture, age, or gender (Barmeyer, 2004), and may contain both strong and weak points (Jonassen and Grabowski, 1993). According to Hofstede (1986), our cognitive development is determined by the environment where we grew up, and our skills are shaped and reinforced in relation to the patterns of a specific society, consisting of family, school and university, work environment, and community. Many studies insist on the importance of culture and its impact on the students’ learning process. Nevertheless, culture is not deterministic: individuals are an expression of their native culture, but also a product of dynamic and continuous interactions with the environment where they live, at home or abroad (Signorini et al., 2010). The individuals simultaneously modify and are modified by the environment while fitting themselves in it. Adaptation to external conditions belongs to the learning process, therefore, the latter may be negatively affected when adaptation does not occur due to, e.g., the individual’s resistance to a situation or change (e.g., because it causes uncertainty or reconsideration of the own habits). Some studies suggest that students in intercultural educational settings are able and willing to change and behave differently in response to demands and teaching styles in the new educational context. However, these changes are not uniform. They vary between individuals also based on their expectations, views, knowledge, skills, attitudes, current and past experiences. International students are, on average, more inclined to adapt to changing conditions, as moving abroad is their own choice, but not always national students are willing to adapt to an international context that they have not chosen. Therefore, higher educators in each specialization area are responsible for ensuring that the learning processes and methods they use have elements that students from different cultures and backgrounds can understand and accept (Joy and Kolb, 2009).

Conceptually, culture is considered to reside both in groups and individuals, and it is often associated with national differences. However, in today’s globalized world, culture cannot be simply equated to the concept of “nation” as it can no longer be confined to a physical space (Signorini et al., 2010). Due to the changing nature of culture in the new global context of higher education, of which Sweden is a prime example, equating “culture” and “nation” may be highly problematic. National culture is important, but it is not the only indicator of individual’s learning identity, which is shaped by cultural and ecological characteristics of the learning context.

In the CDIO (Conceive – Design – Implement – Operate) framework, experiential learning is a form of active learning (CDIO Standards 3.0, Standard 8). Active and experiential learning methods are used to directly engage students in taking on roles and responsibilities as well as in thinking and problem-solving activities. In the case study here presented, we implemented Standard 8 through small-group discussions, questions and answers sessions, feedback from students about their progress, concept questions from the instructors (supervisors, customer, examiner, scientific advisor), and demonstration of the product (a working sensor system prototype) at a final workshop, which is also part of the students’ learning assessment (Standard 11). Engaging students in thinking about possible project ideas, taking responsibility for their choices and working on problem-solving increases students’ motivation to achieve the intended learning outcomes and develop habits of lifelong learning. However, this engagement process needs to be accompanied by continuous support from the instructors to avoid that the students may feel lost or overwhelmed. The supportive presence and constant availability of the supervisors and other instructors helps to monitor and review, if necessary, the students’ learning activities, facilitate their progress, and gradually lead them towards organizational independence.

Our course is characterized by the presence of local, national, and international students from different study programs. This diversity ensures a variety of learning styles that influence work dynamics and learning processes in several ways. The multicultural and multidisciplinary environment creates a totally new learning experience that may be used to facilitate, on a hand, the acquisition of knowledge via transformation of experience, and stimulate, on the other hand, adaptation to external conditions. Furthermore, observing the group dynamics and assessing the project outcomes over a medium to long term can help to identify strengths and weaknesses of CDIO implementation in such a learning environment. Matching people with the environment, i.e., understanding the different needs, attitudes, interests, and skills of our students for creating the most suitable and sustainable learning environment, is an effective way to ensure the achievement of the students' learning outcomes (Standard 2).

LEARNING AS A COLLABORATIVE RESPONSIBILITY

When students and teachers come from different cultures, like in our CDIO course, cross-cultural learning situations are naturally developed. Mutual understanding, awareness, and sustained efforts from both teachers and students are required to avoid premature judgements (Hofstede, 1986), misunderstandings, or unfruitful learning situations.

Our cognitive development is determined by the demands of the environment in which we grew up, and it is rooted in the pattern of a society. We become good at doing something if we do something that is important, meaningful, familiar, and repeated frequently. This means that people from different societies process information in different ways, acquire different skills, and consider important different things. Also academic learning is affected by this process, especially when referred to cross-cultural learning. Transparency, open communication, and constructive feedback help the realization of collaborative processes that are beneficial to both students and teachers for increased engagement, learning, and learning retention. Benefits from collaboration may occur at different levels: between students, between teachers, and between teachers and students. Several studies suggest that students and teachers learn more and at a deeper level, are more engaged, and have a higher rate of achievement and retention when working in a collaborative environment rather than alone (Totten et al., 1991; Chiriac, 2014). In addition, a collaborative environment helps students to build or improve personal, interpersonal, and social skills that are important in preparing them for the labor market, where collaboration, teamwork, problem-solving, and other joint missions are key elements of many careers. Collaborative environments allow students to surpass individual limitations, increase reflective and critical thinking, and enhance depth of understanding (Meseke et al., 2010). Positive outcomes from collaborative learning can also be related to teachers' performance in terms of increased commitment and sense of shared responsibility, reduction of isolation, acquisition of new strategies and skills, exchange of information and experiences. Collaboration can be seen as a positive peer-to-peer transfer of knowledge and the occasion to develop social and cooperative skills (Meseke et al., 2010).

In the CDIO framework, the design and implementation of experiences of increasing complexity (Standard 5), in the form of both individual and group assignments, may be offered to help students to reinforce their understanding and integrate prior knowledge and skills for developing new technical disciplinary knowledge and consolidating their hard and soft skills (Standard 2). In our approach, the collaborative environment is considered the foundation of effective and lifelong learning. In other words, we propose an alternative way to apply Standard 1 by considering the framework, and not the product, as the context of learning in which the technical knowledge and several skills are taught. A desired effect of this change of perspective is that the students can feel even more motivated and involved in the learning process because they not only actively participate in the educational processes and contribute to the development of engineering solutions but co-create both processes and solutions together with their instructors. Nevertheless, although most studies warmly applaud the benefits of collaborative learning, there are notable issues to be considered. For example, unprepared peers (e.g., free riders) may be able to pass undeservedly the final examination task or, conversely, may be the cause of weak or dysfunctional groups. Also, problems may arise when group consensus cannot be achieved (Meseke et al., 2010). Besides, there are students who do not feel comfortable to work in group, share information, distribute tasks, and would prefer independent work and individual assignments. How is it, therefore, possible to establish both independent and collaborative routes towards both individual and common objectives? Empowerment of the individual, on a hand, and increasing interdependence between individuals, on the other hand, constitute the new identity of modern Western societies. This simultaneous independence and interdependence is called collaborative individualism (Limerick and Cunnington, 1993). In this context, collaboration and individualism come together into a balance, in the sense of the simultaneous assertion of both. Collaborative individuals are responsible for their own actions while being collaborative and working with others towards common goals. In an engineering learning workspace using the CDIO model, teaching and learning activities aiming at reinforcing both individual and collective skills and competencies at a high cognitive level may use constructive alignment and performative feedback as two powerful tools to help students to develop critical thinking, independence, problem-solving, and creative skills, and to apply them in meaningful ways. Building skills concurrently with disciplinary knowledge and providing opportunities for social learning may help to overcome individual limitations and improve the quality of teaching and student learning (Standard 6).

CASE STUDY

The CDIO course entitled Project Course in Applied Physics, TFYA99 (12 ECTS), is offered to master's students in applied physics, electrical engineering, biomedical engineering, material science and nanotechnology at the Department of Physics, Chemistry and Biology (IFM) at Linköping University, Sweden. The course is designed and developed to meet different backgrounds and interests of multidisciplinary and heterogeneous target groups. During the course, our students develop engineering knowledge, competence, and skills as well as the basics of project management, working as a team in an industry-like environment, using the CDIO concept. The core-part of the course includes the realization of a project in multidisciplinary applied physics that shall lead to the development of a product with large innovation and application possibilities. Projects may be either experiment- or theory-oriented, and application focused. Here, we report on experiment-oriented projects and their impact on our students over the past five years. As an example of successful project work based on the proposed methodology and implementation of CDIO principles in a practical setting, we present the project results of two groups of students who have successfully designed, developed, and tested an innovative sensor system prototype for real-time monitoring of cooking activities using an electric stove (year 2021).

Implementation of the collaborative environment in a practical setting

Our students are highly involved in all phases of their project work. At the start of the course, they form autonomously their groups (typically, four to seven members) and distribute roles and tasks within each group. We only suggest them to be strategic on creating a multidisciplinary team with complementary knowledge, interests, and skills. At least one supervisor is assigned to each group. Active participation within the group and continuous interaction between the groups and with the teaching staff shape the communication styles within the collaborative environment. Introductory lectures and workshops, skills training activities, feedback, and supervision, are offered to support the students' learning and ensure advances in their project work. The CDIO model is used for the entire product lifecycle (Standard 1). To boost active learning (Standard 8) from the beginning, our students are not assigned a project to develop, but encouraged to conceive their own original ideas to pitch at a first decision point meeting with their instructors (examiner, customer, supervisors, scientific advisor). After the approval of the selected idea, they may start working on the design-implement phase. The project ends with the demonstration of a working sensor system prototype in operational environment and the approval of a technical report. Assessment of the students' learning is conducted continuously during the course by ongoing individual as well as group assignments, presentations, skills training and practical activities, technical documentation, students' reflections, peer and self-assessment, observations of students' performance, time management and level of participation at all proposed activities (Standard 11). We observed that inviting students to propose project ideas, to find agreements within their respective groups, and to provide feedback to the other group, is a simple and effective way to enhance teamwork, cooperation, and communication, and engage them directly in their own learning (Standard 6). Offering students the possibility to personalize their learning experience based on their individual and collective interests, skills, and educational backgrounds stimulates their creativity, promote active participation, and increases their interest and motivation towards achieving maximum learning outcomes (Standard 2). The activation of such a virtuous mechanism is important for a course like this where a pass/fail grade could otherwise reduce the students' ambition to achieve the minimum requirements to pass the course.

RESULTS AND DISCUSSION

In this section, we present and discuss the results of student course evaluation and the technical results of two student projects (case study) as evidence of a successful CDIO implementation in a practical setting using an active and experiential learning approach.

Feedback from the students' course evaluation

Figure 1 shows a summary of the student course evaluation during the period 2018-2021. We discarded the results from 2022 because they were deemed statistically inconclusive. The timeframe considered is characterized by iterative improvement of the course based on the feedback received from the students, both oral and written, during group discussions, informal conversations, e-mail communications, and final course evaluations, as well as our personal experience, observations, and feedback shared with and received from the other involved instructors and guest lecturers. Furthermore, this is the period of significant changes in the course syllabus, design, contents, engaging tools, teaching staff, and methodological approach. It is worth noticing that the period considered includes the years of COVID-19 pandemic outbreak that determined highest levels of uncertainty, limited access to laboratory facilities, and significant changes to the learning workspace (Standard 6) and design-implement experiences (Standard 5) during 2020 and 2021. The three questions extracted from the course evaluation refer to the relevance of the teaching and working methods used (Q1), evaluation of the course components (Q2), and overall evaluation and relevance of the course to student's education (Q3) from the student perspective. The results are satisfying in all cases and show an average increase in the mean values from 2018 to 2021. The measures taken during COVID-19 pandemic outbreak to better adapt the teaching and working methods (Q1) as well as the different course components (Q2) to the changing and uncertain situations worked well and produced tangible results, see 2018-2019 before pandemic and 2020-2021 during pandemic. Overall student satisfaction with the course as a positive result of implementing the proposed strategy (Q3) is demonstrated by high rating throughout the period considered and a 20% net increase from 4.0/5.0 in 2018 to 5.0/5.0, in 2021. The positive trends recorded over the years of increasing implementation of engagement tools indicate a general preference for this new approach compared to previously more defined projects.

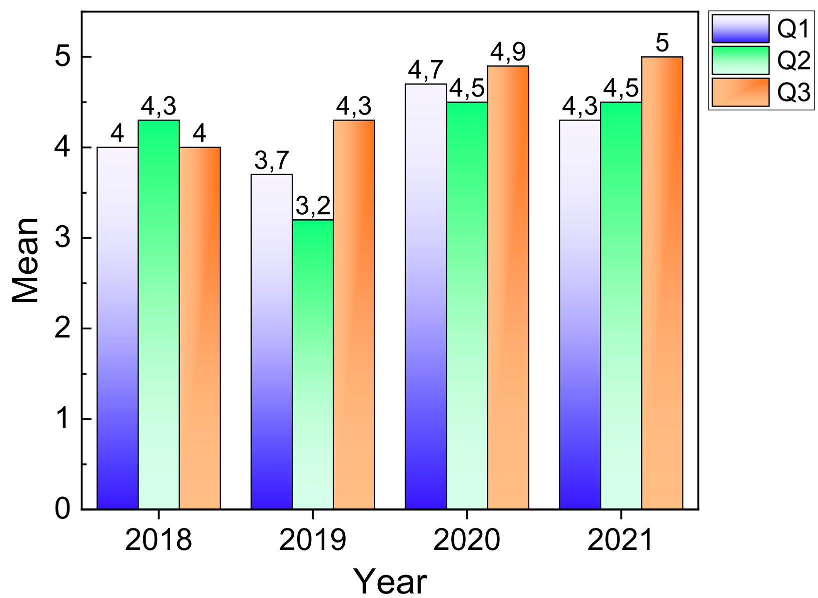

Figure 1. Students' answers to three of the questions contained in the course evaluation during 2018-2021.

These very positive results are clear proof that the improvements introduced in the course work well and are well perceived by the students.

Conceive-Design-Implement-Operate a working system

Our CDIO course is a project-based course that uses an experimental and experiential approach to facilitate and stimulate students' active learning through multiple engaging experiences (cfr. Kolb, 1984, and CDIO Standard 8). In 2021, two groups of students designed, developed, and tested an innovative sensor system prototype for smart monitoring of cooking fumes, heat, and steam, and automated control of a stove hood. Each group consisted of six students. By use of a budget time of 240 hours over a period of about four months (September-December), the two groups of students demonstrated that, depending on the measured concentration, the system can switch the fan on/off and regulate its speed with the effect of suppressing pollutants that are released while preparing food, and reducing power consumption.

Both prototypes included three main subsystems, even if designed and implemented differently: (1) a sensor unit for monitoring typical indoor air pollutants emitted during cooking activities, namely particulate matter (PM), total volatile organic compounds (TVOC), formaldehyde (CH_2O), carbon dioxide (CO_2), plus temperature (T) and relative humidity (RH); (2) a control unit for signal reception, processing, and transmission to the hood; and (3) and a cooking unit containing an electric stove and hood for experiments. Best-in-class commercial sensors for measurement of the mentioned pollutants and environmental parameters were selected based on certain requirement specifications. In the case of prototype #1 (Figure 2), the housings for the electronics and sensors were manufactured using 3D printing technology, whereas in the case of prototype #2 (Figure 3), the chamber hosting all hardware components of the system was realized using recycled waste materials as a sustainable choice.

(a) (b)

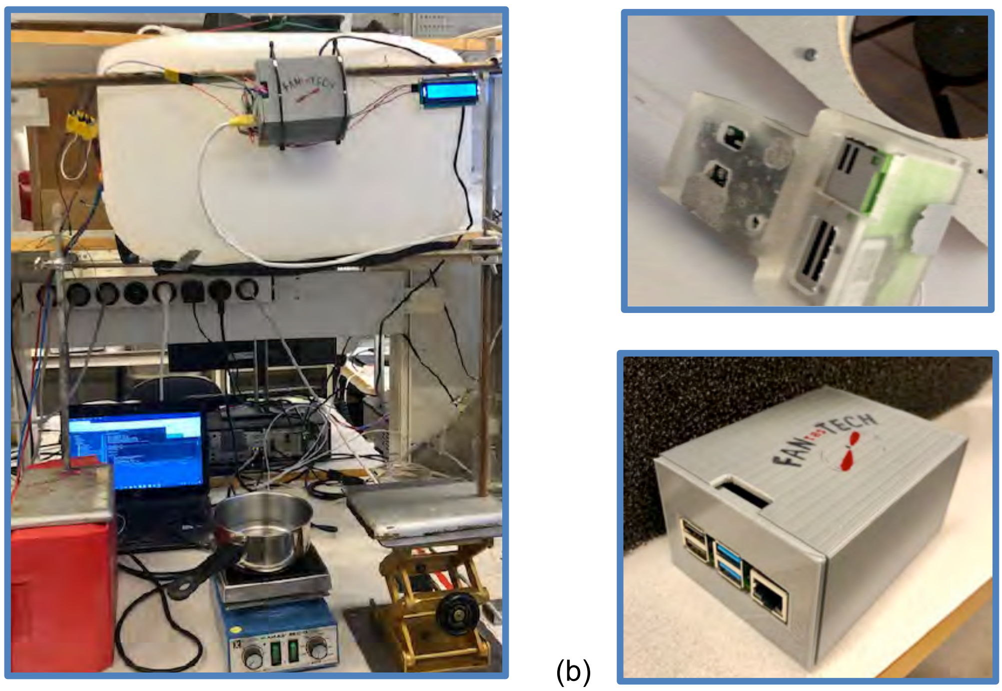

Figure 2. (a) Sensor system prototype #1 by FANtasTECH Team; (b) Containers for the sensors and control systems realized using 3D-printing technology.

(a) (b)

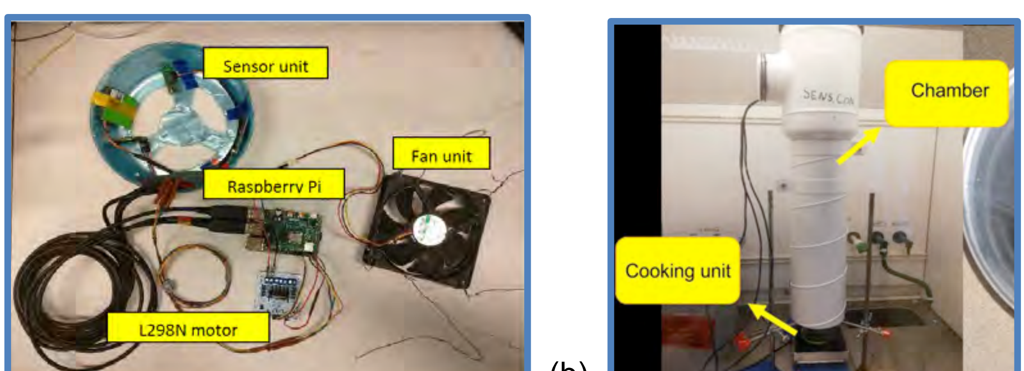

Figure 3. (a) Sensor system prototype #2 by SENS.CON Team; (b) Cooking unit and chamber hosting all hardware components of the system.

Experiments were performed in both laboratory and home environments. Gas and particulate emissions from common cooking activities, such as boiling water and frying rapeseed oil with

or without bacon, onion, and eggs, were measured over time, and the efficiency of grease filters was evaluated.
During the process of boiling water, FANtasTECH prototype #1 measured an increase of RH as well as of CO_2 concentration after about 180 s from the start of activity. The temperature increased steadily either with or without the grease filter. The PM concentration remained around zero until the water reached the boiling point, then some PM peaks were measured. Temperature and RH were used as indicators to turn the fan on when boiling water. During the process of frying rapeseed oil, PM increased after about 160 s from the start of activity. Also the temperature increased with time, as to be expected. Since the PM concentration increased significantly as the oil began to heat up, the fan was programmed to start when the PM concentration level increased by 500% from its mean value. RH percent and CO_2 concentration varied significantly during the measurement, with no clear trend or pattern, and were therefore excluded as relevant parameters.

During the process of frying bacon (Figure 4), SENS.CON prototype #2 measured a significant decrease in the TVOC index (a.u.) from 450 to 120 when the kitchen fan was switched on. Based on the conducted experiments, PM and TVOC were demonstrated as main contributors to indoor air pollution when heating rapeseed oil. An increase of CH_2O concentration was observed when frying bacon, onion, and eggs with rapeseed oil. Also in this case, the CO_2 sensor showed no correlation to the cooking process when an electric stove is used.

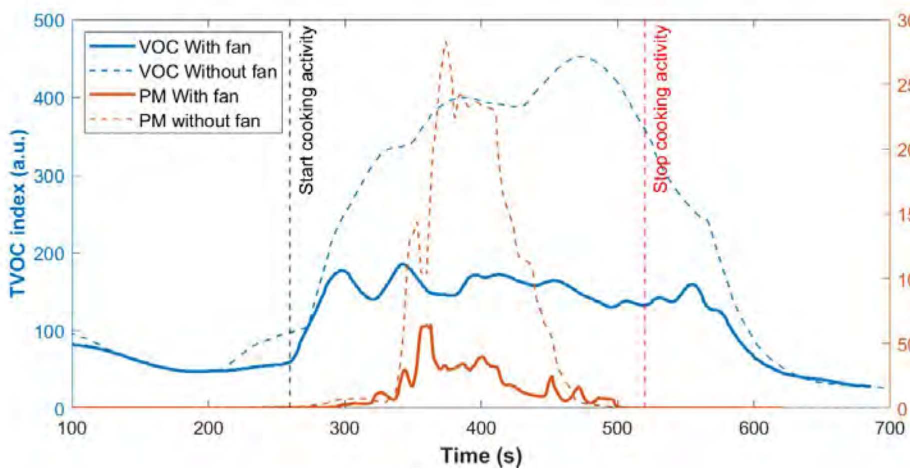

Figure 4. Cooking activity: frying bacon with (straight line) or without (dotted line) the fan activated. Emissions of TVOC (blue) and PM (red).

In summary, the results obtained by both groups are scientifically robust, relevant, and original. As proof of this, the scientific findings were presented as an oral contribution to a well-established international conference focusing on the latest scientific advances and ongoing research in the field of indoor air quality (Domènech-Gil et al., 2022). Furthermore, the student projects received attention from our university press for their novelty and scientific relevance, innovation aspects, and good example of a collaborative learning environment that can produce results beyond expectations and can therefore be a source of inspiration and motivation for others as well (Planthaber, 2021).

CONCLUSIONS

Multidisciplinary and open-ended projects can be challenging to design and implement, but also a great tool for active and experience-based learning. The different components contained in this course allow our students to design, develop, and test successfully, in about four months, their unique working sensor system prototype with potential interest for the market. The high-quality results from the case study clearly demonstrate that the students achieved technical disciplinary knowledge at an adequate level (Standard 2). The opportunity to conceive-design-implement-operate a prototypal product, co-create the process, combine multidisciplinary knowledge, and develop both technical and personal and interpersonal skills not only offers students to acquire solid knowledge and understanding on which they can build the foundation for their future, but it is also beneficial for other co-curricular activities, such as undergraduate research projects, thesis works, and internships (Standard 5). The emphasis on building a working system containing elements of applied physics combined with sensor technologies, electronics, programming, 3D-printing, and sustainability, getting inspired from daily life experiences, and envisioning possible applications in real-world contexts provides students with the opportunity to make connections between the technical content they are learning, the usefulness for their future studies and careers, and the impact on societal needs.

Over the years, the TFYA99 course has been proven to cater for diverse backgrounds and interests of international, multicultural, and multidisciplinary target groups. In the past five years, this project has received an increasing overall course evaluation from 4.0/5.0 to 5.0/5.0.
Based on the results presented, we can conclude that working in a collaborative environment that fosters, among other factors, mutual help, trust, open communication, information exchange, feedback, peer and self-assessment is beneficial to student learning outcomes and is clearly reflected in student satisfaction. This type of CDIO implementation is not only beneficial to our students. It is a useful active and experiential learning process for instructors as well. Well designed and interconnected course components, cooperative and well-functioning teamwork, adequate work environments, and dedicated mentoring accompaniment are reflected in the high level of motivation, interest, creativity, and commitment of both the teachers and the students. Success lies in the process.

Designing project-based courses and experiments related to an everyday life situation like this enables effective and lasting learning. This type of educational approach allows engineering students not only to strengthen and apply both theoretical and practical knowledge, but also to directly transfer the findings from their measurements to their personal environment, with a direct impact on their attitudes, behaviors, sustainable choices, and career paths.

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