THE NATURE OF PROGRESSION BETWEEN YEARLY PROJECT COURSES

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ABSTRACT

This study focuses on the *progression* between courses in a programme, meaning that the learning experiences build upon and reinforce the previous ones. The idea of mutually supporting courses is a cornerstone of *the integrated curriculum*, and hence of the CDIO approach. However, despite much use of the term, there is a lack of work to conceptualise progression. The aim of this paper is, accordingly, to provide a richer theoretical conceptualisation of progression and to apply this in analysing the implementation in a programme. In this case, we focus specifically on the progression through a series of courses based on authentic engineering projects. Such courses, called Design-implement Experiences, are a prominent feature of the CDIO framework; Standard 5 recommends at least two project courses with progression through the curriculum. The context for the study is the 5-year Electrical Engineering programme at KTH Royal Institute of Technology. It contains a series of yearly project courses starting in the first year and ending with the master thesis project. The purpose is to support students to synthesise and consolidate their learning in previous and parallel subject courses, and to develop professional engineering skills. Here, the progression between the three first project courses is described with detailed elaboration of three themes: communication, project planning and management, and ethics. The questions guiding our investigation are: What is the nature of progression across these project courses? In particular, along what dimensions is progression planned, and how is that implemented in the course design?

KEYWORDS

Progression, curriculum, learning sequence, project-based learning, assessment, electrical engineering, Standards: 1, 2, 3, 4, 5, 7, 8, 11, 12

INTRODUCTION

To support engineering students in developing the competences necessary for life and working life, the CDIO approach implies that the engineering curriculum should address both the deep working understanding of disciplinary fundamentals, as well as professional skills, approaches and judgement. The curriculum is made up by subject courses, dominated by the logic of disciplines, and project-based courses that provide a context in which students can work in the logic of problems (Edström & Kolmos, 2014). Within the CDIO community, the engineering project courses are called Design-Implement (or Design-Build) Experiences. They are authentic learning experiences giving students opportunities to consolidate and apply their conceptual understanding and develop professional competences.

A fundamental idea of the CDIO curriculum is that courses should be *mutually supporting*, meaning that we strive to create synergy between the curriculum elements. This means that connections between courses are made explicit so that learning becomes more meaningful, and that learning experiences build upon each other so that student competence progressively increases over time. Such synergy should be sought between subject courses, between subject and project courses, and between project courses. There is a temporal dimension in that students experience the connections as they go through the educational programme. Connections can be made over short time, such as between parallel courses, or they can be more longitudinal, even across years. Connections can be directed backwards, refreshing or taking advantage of previous learning, but also forwards, signalling how and when the next steps will be taken.

The aim of this paper is to consider what progression is conceptually and illustrate how this can be implemented in a programme. The context for the study is the 5-year Electrical Engineering (EE) program at KTH Royal Institute of Technology. Over the years, this program has been iteratively developed using the CDIO approach, with the explicit aim to create a coherent program with a progression of project-based and hands-on learning experiences. The latest remake, which we focus on here, came about to address longstanding problems with recruitment and poor throughput. The idea was to empower students and support their professional identity formation. In short, the program should not just support the students in *learning about technology*, but also in *becoming engineers*. A programme-driven course development approach was used, meaning that the ensuing course design was driven by the needs of the programme and its students. This study focuses on a series of project courses, one in each of the first three years. The courses support students to synthesise and consolidate their learning in previous and parallel subject courses, and the project courses are also coordinated between themselves to create progression regarding students' development of professional skills. We use our new elaborated understanding of progression to analyse this sequence of courses.

Two questions guide our investigation: *What is the nature of progression across these project courses? In particular, along what dimensions is progression planned, and how is that implemented in the course design?*

The paper is structured as follows. In the next section, we seek and review previous conceptualisations of progression, within the CDIO literature and in the general educational literature. Then follows a description of the EE programme and its sequence of project courses, with a more detailed view on how three major professional engineering skills are taught with progression across the courses. These are communication, project planning and management, and ethics. Finally, we analyse the progression exemplified by these "strands" using our new theoretical lens.

CONCEPTUALISING PROGRESSION – LITERATURE REVIEW

Progression in the CDIO Literature

Progression has from the outset been a central idea in the CDIO approach. It is implied in various ways, though sometimes indirectly and by using other terminology. An early example is when Malmqvist et al. (2006:2-3) mention "*the planned learning sequences for learning outcomes that are developed through integrated learning experiences throughout the* *curriculum*" and "*development routes for knowledge and skills that are taught in a number of consecutive courses*".

CDIO Standard 3 calls for a curriculum designed with *mutually supporting disciplinary courses*. The CDIO book elaborates: "*The curriculum is coordinated, with mutually supporting elements, each taking on a well-defined function. The elements work together to enable students to reach program learning outcomes*" (Crawley et al., 2014:86). The authors further suggest mapping program goals with courses, "*assuring that no program goal is neglected and that there is a deliberate learning progression in the program*" (Crawley et al., 2014:89). The idea is to productively coordinate the design of learning experiences across the curriculum: "*Sequence is the order in which student learning progresses. If sequence is properly developed, learning follows a pattern in which one experience builds upon and reinforces the previous ones*" (Crawley et al., 2014:104).

The term progression is used in numerous CDIO works. A well-documented example of program development with deliberate progression across the curriculum can be found in the integration of sustainability in the Mechanical Engineering programme at Chalmers (Enelund et al., 2013). Another example is the *Electronic Engineering Ladder* at NTNU, consisting of four tightly coordinated courses (Lundheim et al., 2016). Here, to support students' development of communication skills, the teachers deliberately keep some aspects *constant* across courses, e.g., the same teaching team, while they introduce *variation* in others, e.g., professors give feedback in the first semester and in the second students give feedback in peer review (Larsen et al., 2016). In another case, Spooner et al. (2008) describe a series of project courses: "*The yearly projects confront students with different forms of teamwork in an intense but gradual, dynamic but controlled experiential process*". Citing the spiral curriculum model, Yang et al. (2021) present an educational program designed "*to support the levelling up of knowledge and skills from one semester to another, from one module to another*".

We note that the focus in the CDIO literature is typically on practical curriculum development while efforts for more elaborate conceptualisation are limited (see also Edström, 2020). For instance, Gunnarsson et al. (2009) found different underpinning views on progression when comparing the CDIO implementation at Linköping University (LiU) and the Technical University of Denmark (DTU). Both universities had mapped the high-level program goals with courses, to show what each course contributed to the program as a whole. Interestingly, they had operationalised these connections differently. The method at LiU was to characterise the learning activities used in the courses to address each goal (introduce, teach, utilize), but at DTU they classified the relevant course learning outcomes according to Bloom's taxonomy. The authors noted the difference but refrained from analysing it further, taking a more practical and descriptive approach:

> "*Characterizing and quantifying knowledge and skills is a complex task with many dimensions and, to the best of our knowledge, there is no universal and generally accepted way of dealing with this task. The aim of this part of the paper is to present and discuss the approaches that have been used […], rather than discussing this vast topic in general*" (Gunnarsson et al., 2009:9).

This paper is an attempt to make inroads into this vast topic. The next step is therefore to consult the general literature about progression.

Disambiguation of the term

As we trace the conceptualisation of progression in the educational literature, we see that the term is used in three ways, so there is a need for disambiguation. The first meaning refers to the *students' progression through the education*, either across stages, for instance how many continue from secondary school to engineering programs, or within a program, for instance how many students continue to the second year. Progression is then used as a synonym of retention, i.e., as the opposite of drop-out.

The second use of the term refers to the learner's development or maturity. *Learning progressions* are "*descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another*" (National Research Council, 2007, p. 214). There are many frameworks to measure, or assess, student learning. Often, the quality of learning is operationalised in a *taxonomy*, an instrument to classify student learning. Perhaps most familiar are Bloom's taxonomy (for a useful overview, see Krathwohl, 2002) and the SOLO taxonomy (Biggs & Collis, 1982). In CDIO literature also the Feisel-Schmitz taxonomy has been used (Crawley et al., 2014:152). What is often lacking in the literature on learning progression, however, is the discussion of the educational experiences. Student development is studied on its own, independent from how they learned or how the curriculum is designed. There is little focus on why students are at a certain level of understanding, or how the educational outcome could be improved. One exception is when Brabrand and Dahl (2009) map the intended learning outcomes to a taxonomy to obtain the average levels addressed in different stages of a degree program.

The third meaning of progression takes a teaching perspective and focuses on how to support the students in their learning progression, through curriculum design and teaching. This is the *planned progression across the curriculum*. As seen above, this is the meaning of the term that has been central to CDIO, and which we focus on in this paper. Guided by their intentions as to what the students should learn, teachers plan and coordinate sequences of learning experiences in the programme, to support students in achieving increasingly advanced learning outcomes in appropriate stages. There are however different views regarding how to sequence learning over time. Traditionally, engineering education has leaned towards a *deductive* approach meaning that all new theoretical knowledge must first be introduced to the students before they are given the opportunity to apply it. Conversely, an *inductive* approach means that students are first exposed to application helping them discover what they need to know. New knowledge is presented after the students have understood the need for it. This can be seen as a more student-centred approach. Inductive instruction encompasses many different teaching methods, such as problem- and project-based learning, inquiry learning, and just-in-time teaching (Prince and Felder, 2006).

Progression as a Spiral Curriculum

Models of curriculum design have been suggested to promote student's progressive learning. Bruner presented the idea of a *spiral curriculum* based on the notion that every subject consists of core ideas. The curriculum "*should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them*." (Bruner, 1960, p. 13). Hence, the spiral curriculum does not simply repeat the topics being taught, but deepens them, with new learning building on the previous and as a result the students' competence increases. Harden and Stamper (1999) point out that the value of a spiral curriculum lies in reinforcement, a move from simple to complex, integration, logical sequence, higher level objectives and flexibility.

Much of Bruner's inspiration stemmed from science and mathematics education (Bruner, 1960), however, it has been successfully implemented also in other fields such as medical education (Harden & Stamper, 1999). It has also been used in vocational training as a method of incorporating theoretical aspects of the training into more practical job-oriented areas while iteratively deepening the students' knowledge and skills (Dowding, 1993).

The spiral curriculum has also been proposed for engineering education. Clark et al. (2000) applied the model in conjunction with problem-based learning in engineering education to prepare students for "*demanding careers that not only require technical competence in an engineering discipline but also require communication, teamwork, and life-long learning skills*" (Clark et al., 2000, p. 222). Sheppard et al. (2009) suggest that the curriculum should take students "*on a trajectory from novice to competent performance as practitioners*". They describe how instructors should gradually increase the complexity of the problems and their contexts, until similar to actual professional practice. They state: "*This process should happen both in individual courses and over a program*" (p.26). However, they leave it to educators to spell out any implications.

In the context of medical education, Harden (2007) emphasises the multidimensional nature of progression and suggests a model with four dimensions of progression. *Increased breadth* implies that the student can extend their mastery of a specific learning outcome to new topics or different contexts, whereas *increased difficulty* instead focuses on the depth of knowledge or difficulty of skill. The third dimension, *increased utility and application to practice*, focuses on the transition from theoretical understanding to practical application. The fourth dimension, *increased proficiency*, represents areas in which the student shows more efficient performance such as being better organised, being more confident, taking less time to complete a task, making fewer errors, etc.

PROGRESSION IN THE ELECTRICAL ENGINEERING PROGRAMME AT KTH

Background – the Programme

The Electrical Engineering (EE) programme at KTH is an integrated 5-year Bachelor and Master, see Figure 1. It has a long history as a traditional, course-oriented program with a solid theoretical foundation. After many years of poor recruitment and throughput, the programme was redesigned using the CDIO approach to increase attractiveness and motivation for the students.

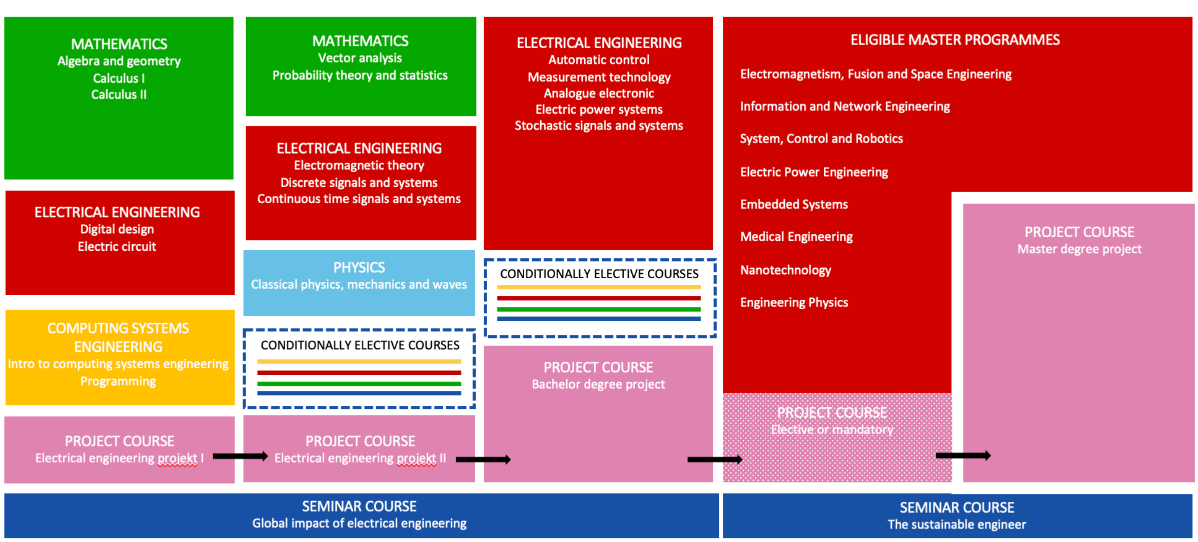

Figure 1. Program design, Electrical Engineering at KTH.

To coordinate the courses and ensure progression in terms of the technical content, four teacher teams were formed, in *Electronics*, *Signals and systems*, *Electromagnetics*, and *Programming and computer engineering*. To strengthen students' development of professional engineering skills, a sequence of practical experiential learning experiences was implemented. Each year contained a project course based on design-build challenges, designed to strengthen the program profile and connect with the subject courses.

In this paper, we focus on the project courses in each of the first three years (Bachelor level), ranging from 6 to 15 ECTS credits. Their current design was made around 2012 (for descriptions of earlier versions, see Lilliesköld & Östlund, 2008; Bengtsson et al., 2008). On the master level, students have at least one more project course and an individual thesis project (30 ECTS) for the degree of Master of Science in Engineering.

In the following we will first give an overview of the three project courses. Thereafter we turn to a thematic description of the progression across the courses for three selected aspects.

A Series of Connected Courses

Year 1 and Electrical Engineering Project I (7,5 ECTS)

Just like in most EE programs, the first year includes basic mathematics, electrical engineering (electric circuits & digital design) and computer engineering (programming and computer systems engineering). The project course, *Electrical Engineering Project I*, is designed to tie the first-year courses together with emphasis on *Design* and *Build*. Inspired by Simone Giertz and her "Shitty Robots" (Giertz, 2018), students are given the challenge to build a robot. With an Arduino board as the brain, the robot should interact with the physical world and solve a problem in everyday life. Apart from that, there are no requirements on the robot. Inspired by the iterative process structure of design thinking (Dym et al., 2005), students present and get feedback on two or three rapid prototypes in an early assessment activity. They are then encouraged to review and improve their overall design ideas before starting to build. The robot task makes students draw on knowledge and skills from the courses in programming, electric circuit, digital design, and computer systems. The role of the teachers is to provide *process support* rather than cover any new technical content.

Year 2 and Electrical Engineering Project II (6 ECTS)

In the second year, students go deeper into mathematics and EE courses, including vector analysis, statistics, electromagnetic field theory, physics, signals and systems. This provides the basis for the second-year project course, which can therefore have a much more technical focus. Now, students work more independently and there is only one lecture to introduce this year's challenge; all other teaching is in the form of supervision sessions. The course follows a full Conceive – Design – Implement – Operate structure, driven by its assignments. The first is a requirement specification (*Conceive*) including how the requirements can be tested, with a rough timeline and resource plan as appendix. Next assignment is the system design (*Design*), where the students present their solution, from input to output. A delimitation in this course is that the students cannot use premade parts. If they need a coil, they must buy the copper wire, and design and produce the coil themselves. The same goes for any system parts. After the Design is approved, the students start building it (*Implement*). The building phase ends with a demo day, where all students and faculty are invited to view the students' different solutions to the challenges. Once the solution is demonstrated, the students continue with measuring their solution and make a gap analysis on their design vs the actual working product (*Operate*). This analysis is then presented in the project report.

Year 3 and the Bachelor Thesis Project (15 ECTS)

The bachelor thesis project is carried out in groups of two. The challenges vary from typical design-build projects to more theoretical challenges within the research projects of the faculty. The project is part of a context, that addresses some type of challenge in society, and contain 3-6 subprojects under each context. Hence, the pairs belong to a larger "context group". For instance, context can be The Smart Home, and subprojects can be optical detection of a person falling, heat regulation, or security of IOT devices. A challenge can be to hack the camera of a robot vacuum cleaner or an alarm camera.

Progression Across the Project Courses

We will now zoom in on the progression between the three courses along three strands: *Communication*, *Project planning and management*, and *Ethics*. We note that a drawback of this thematic narrative is that it understates the natural interplay of the themes within each course. Focusing on the three courses also fails to demonstrate how other courses in the programme contributes to the themes. For instance, the responsibility for teaching ethics and societal impact is shared between these project courses and the longitudinal seminar course Global Impact of Electrical Engineering (see Figure 1).

Progression in Communication

In the first-year's project course, learning to communicate is more important than the actual technical outcome of the project (the robot as such). This is reflected in the learning objectives and the assessment where the quality of the robot determines only a small part of the grade. Students get to practice several different types of communication that they could expect to meet in an industrial development project and recognise the importance of adjusting both tone and content to the purpose and target audience in each particular case. For instance, they describe and discuss the project with stakeholders without too much technical detail. Students write a project plan, status reports and a "lessons learned" report. In the end of the course, they summarize the technical outcome and learnings from the project in a technical report. Each individual student writes a peer review of the technical report of another group (hence each group gets several reviews on their report). They present the project orally with other engineers as target audience, and they demonstrate their robots to a mixed audience in a public robot exhibition. The assessment also includes making a YouTube video that shows the purpose and functionality of the robot to the general public. These are premiered in a mini film festival – complete with a popcorn machine.

In the second-year project course, students communicate through a number of reports or demonstrations. They make a requirement specification, preliminary design, poster presentation, technical report and an individual peer review. These reports are now far more technical in character as they draw on much deeper and broader technical knowledge. Students also present their design in a seminar, and their final solution and poster at a fair.

Many communication aspects of the bachelor thesis mirror those that are practiced in research. One is the context summary, with a section on ethics and a popular science summary for the public. Final reports are formatted as scientific papers, using an IEEE journal template, and presentations are organised like a one-day scientific conference with opposition. Each student also writes a peer review. Mirroring academic aspects is not only appropriate to satisfy some of the learning objectives for the degree – it also seems to increase the enthusiasm among faculty for supervising and assessing the bachelor thesis.

Across this sequence of courses, the training in communication is managed through a long line of reports in a great variation of formats. Students get feedback – and a second chance to address the feedback. This structure helps the student to learn, since they need to address the given feedback. Oral presentation is the exception as there is no second chance, however they start presenting in year one, and there are several opportunities. The students thus get an extensive training in most means of communication.

Progression in Project Planning and Management

The role of the first-year course is to train the students for future projects and all other courses. Therefore, they learn and practice project planning and management tools far beyond what they need in this particular project. Basic project management is addressed in lectures and the course book *Handbook for small projects* (Eriksson & Lilliesköld, 2005). A large share of the assessment focuses on project management, with the deliverables following the methodology in the handbook. Each hand-in is graded within a week, and students get a second chance to improve their work. One important topic is resource planning. Students are allowed to spend 160 hours each (corresponding to the course credits). They are asked to hand in a work breakdown schedule (WBS), time plan (milestone chart) and a resource plan visualizing all planned hours. The project plan also includes goals, responsibilities, project model, risk analysis and a communication plan. In the brief status report, they update the time plan and the resource plan and address the current status of the project. The project management assignments end with a final report focusing on the lessons learned, but also follow up the goals from the project plan. The main focus here is on what insights they will bring to future project courses.

In the second-year project course the students can instead structure the project the way they want and then evaluate. No project plan (etc) is required. Nonetheless, they must hand in a requirement specification with a strong emphasis on the goals and how to measure these goals, an important dimension in any project plan. We only ask for a high-level timeline, for the students to see key deadlines. The group still needs to keep track of the time used and report every week, retrospectively. This is to avoid them working excessive hours, and to monitor whether they need more support in their projects.

In the bachelor thesis project, we raise the requirements on being able to choose appropriate project management methods, and on being proactive. Students are not required to follow any specific method like in the first year, nor are they free as in the second year – however they are required to choose their method, either a traditional or an agile approach. There is a seminar to support the students in their choice, and an optional feedback session where groups present their plans to the teachers and other student groups. This is to support students to learn from seeing how other groups are managing their projects, whether using traditional or agile methods. The groups that choose a traditional method are required to formulate highly developed *SMART* goals, that is, Specific, Measurable, Achievable, Relevant, and Time-bound (Eriksson & Lilliesköld, 2005). They also make a WBS of the thesis work as in previous courses, however the requirements on the risk analysis are increased both in scope and in the identification of proactive and reactive actions. Finally, we ask for a project model that will give them early warnings if they start to fall behind or procrastinate. The plan is followed up by two status reports, but a final report is optional. If students choose a more agile approach, requirements are the same, but the structure becomes different. While many students choose a traditional approach, it is often with such short iterations that it could be characterised as a mixed approach.

With this sequence across the three years, we have seen good development and the quality of many project plans in the third year is very high. If we force students to follow a fully developed project planning and management structure in the first year, they are very free in the second year, and in the third year they take responsibility for choosing and proactively implementing an appropriate structure. Their experience of both the mandatory approach and the freedom is intended to afford them useful insights for the third-year thesis project.

Progression in Ethics

The first-year project course features a guest lecture on ethics in engineering. In relation to this we also have a discussion on whether there are any ethical considerations the students must consider when developing their robot, but there is no assignment.

In the second year, this is followed up by a role-play on ethics. It is designed as a hearing, where a company wants to introduce an electronic system to position kids in day care. Students play different roles to bring about various perspectives, as experts, teachers, teenagers, parents, lawyers or people who have been abused. The role play ends with a presentation on different concepts to make ethical considerations and a discussion on what responsibility we have as engineers.

The bachelor project contains a half-day workshop on ethics, followed up by an assignment where the students write an analysis on the ethical impact on the thesis work and the technology that the thesis addressed.

We find that ethics can really engage students and generate many relevant discussions. It is however important to introduce and integrate these aspects thoughtfully. Students will have difficulties making the connections if ethics it introduced in an overly philosophical or abstract way, and they will immediately see through if something is just an add-on. It is important that each course handles the topic well so that students are not demotivated for it when they encounter it in the next course. When ethics is addressed from an engineering perspective, and especially when integrated in the design-build courses, it is a topic that engage and can help to open the students' minds.

ANALYSING THE PROGRESSION

To analyse the progression across the course sequence, we draw on Harden's dimensions (2007), summarized in Table 1.

Table 1. Dimensions of Progression (based on Harden, 2007).

Dimensions of progression	Explanations
Increased breadth	Broadened competency of a specific learning outcome by extending it to new topics or contexts. Existing skills and knowledge are accommodated with new ones.

Increased difficulty	More in-depth or advanced consideration of a specific learning outcome or application to more complex situations.
Increased utility and application	Transition from a more theoretical understanding to practical application to start integrating into the role of an engineer.
Increased proficiency	More efficient performance e.g., being more organised and confident, needing less time on tasks and producing fewer errors etc. The student also needs less supervision and is able to take more initiative and defend their actions.

In *Communication*, the *increased breadth* is perhaps the most emphasised dimension of progression, as the courses aim to prepare students for an extremely wide variety of communication formats, from simple and playful presentations over many professional forms of reporting and finally scientific communication. The *increased difficulty* is seen first in year 2 when *what* they communicate becomes much more advanced, whereas the increased difficulty in year 3 lies in both more advanced *content* and more advanced communication *format*. We cannot say that there is *increased utility and application* but that is just because it is fully implemented already from year 1. The *increased proficiency* comes with the multitude of opportunities for practice, and the great variation of communication tasks.

The progression in *Project Planning and Management* is less linear. While they start in the first year with full *breadth* and *difficulty*, this is instead pared down to a minimum in year 2. There is strong *increased utility and application* in year 3 when students have to customize the project model for their own needs and context. Throughout all these experiences students are required to show *increased proficiency*.

The progression in *Ethics* can be seen in the *increased breadth* in year 2 when they get to imagine multiple perspectives as well as the *increased proficiency* as they get to actively participate. Year 3 sees *increased utility and application*, as they analyze ethical issues in their own particular project and wider in the context.

CONCLUSIONS

Final Reflections

This paper described how progression is implemented in different ways across the Electrical Engineering curriculum, with some examples that are perhaps a little counterintuitive. It is important to note that the conceptual analysis of the case presented here is retrospective. The progression between the courses emerged pragmatically and organically, rather than being theory driven. The design of progression was still intentional, however much of the resulting course design was shaped by the teachers' interest, and also constrained by practicalities, resources and available space in the curriculum.

The collegial discussions before, during, and still continuing after the remodelling of the programme, show that teachers have different ideas about progression and how it should be implemented. There is, for instance, constant tensions about whether the instructions should be deductive or inductive. The teaching culture in traditional programs like Electrical Engineering tends to lean towards a deductive view on knowledge, and hence learning and teaching. This also represents what the teachers have experienced themselves as students and in most of their academic career. The series of project courses can be seen precisely as a platform to introduce more inductive elements into the curriculum, which is otherwise basically deductively organised with the basic courses early in the curriculum. As we could see above, the projects draw on students' increasing breadth and depth of theoretical knowledge from the subject courses they have taken. Hence, the setup also draws on the advantages of a deductive approach.

Future work

This description and analysis of progression refers to the *planned progression across the curriculum*, meaning that the focus is on teachers' intentions with regards to student learning and the subsequent curriculum and course design. As we have also shown, another important meaning of progression refers to students' development. However, studying the extent to which the actual student learning follows this trajectory would be a future study. Further analysis of the whole EE programme is also warranted, focusing on progression with regard to the technical subject content, the use of mathematics, and other aspects not covered here.

The theoretical contribution of this paper serves as a starting point in our work to create a conceptual framework for progression in higher education. The framework should be useful not only for retrospective analysis, but also to guide curriculum and course development.

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REFERENCES

Bengtsson, M., Lilliesköld, J., Norgren, M., Skog, I., & Sohlström, H. (2012). Developing and implementing a program interfacing project course in electrical engineering. In *Proceedings of the 8th International CDIO Conference*, Brisbane, Australia.

Biggs, J., & Collis, K. (1982*). Evaluating the Quality of Learning: the SOLO taxonomy*. New York: Academic Pres.

Bruner, J. S. (2009). *The process of education*. Harvard University Press.

Bruner, J. S. (1966). *Toward a theory of instruction (Vol. 59)*. Harvard University Press.

Clark, W. M., DiBiasio, D., & Dixon, A. G. (2000). A project-based, spiral curriculum for introductory courses in ChE: Part 1. curriculum design. *Chemical Engineering Education, 34*(3), 222-233.

Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D.R., & Edström, K. (2014). *Rethinking Engineering Education: The CDIO Approach, 2nd ed*. Springer, Cham.

Dowding, T. J. (1993). The application of a spiral curriculum model to technical training curricula. *Educational Technology, 33*(7), 18-28.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103-120.

Edström, K., El Gaidi, K., Hallström, S., & Kuttenkeuler, J. (2005). Integrated assessment of disciplinary, personal and interpersonal skills-student perceptions of a novel learning experience. In *Proceedings of the 13th Improving Student Learning Conference*.

Edström, K. & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education, 39*(5), 539-555.

Edström, K. (2020). The role of CDIO in engineering education research: Combining usefulness and scholarliness. *European Journal of Engineering Education, 45*(1), 113-127.

Eriksson, M. & Lilliesköld, J. (2010). *Handbook for Small Projects*. Liber, ISBN 9789147099658.

Enelund, M., Knutson Wedel, M., Lundqvist, U., & Malmqvist, J. (2013) Integration of Education for Sustainable Development in the Mechanical Engineering Curriculum, *Australasian Journal of Engineering Education, 19*(1) 51-62.

Giertz, S. (2018). *Why you should make useless things* [Video]. TED Conferences. www.ted.com/talks/simone_giertz_why_you_should_make_useless_things/

Gunnarsson, S., Herbertsson, H., Kindgren, A., Wiklund, I., Willumsen, L., & Vigild, M. (2009). Using the CDIO syllabus in the formulation of program goals: Experiences and comparisons. In *Proceedings of the 5th International CDIO Conference*, Singapore.

Harden, R. M. & Stamper, N. (1999). What is a spiral curriculum?. *Medical teacher, 21*(2), 141-143.

Harden, R. M. (2007). Learning outcomes as a tool to assess progression. *Medical Teacher, 29*(7), 678-682.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice, 41*(4), 212-218.

Larsen, B. B., Lundheim, L., Ekman, T., & Tybell, T. (2016). Teaching freshmen engineering communication, In *Proceedings of 11th European Workshop on Microelectronics Education (EWME)*, Southampton, UK.

Lilliesköld J., and Östlund S. (2008). Designing, Implementing and Maintaining a first-year project course in Electrical Engineering. *European Journal of Engineering Education, 33*(2), 231-242.

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

Malmqvist, J., Östlund, S., & Edström, K. (2006). Using integrated program descriptions to support a CDIO programme design process. *World Transactions on Engineering and Technology Education, 5*(2), 259–262.

National Research Council (2007). *Taking Science to School: Learning and Teaching Science in Grades K- 8*. USA: National Academies Press.

Prince, M.J, & Felder, R.M, (2006). *Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases*. Journal of Engineering Education, 95, 123-138.

Sheppard, S., Macatangay, K., Colby, A., Sullivan, W. M., & Shulman, L. S. (2009). *Educating engineers: Designing for the future of the field.* San Francisco, CA: Jossey-Bass.

Spooner, D., Sanschagrin, B., Gagnon, M., Vadean, A., Camarero, R., Salako, F., ... & Poirier, D. (2008). Fostering team dynamics across an engineering curriculum. In *Proceedings of the 4th International CDIO Conference*.

Yang, K., Cheah, S. M., & Phua, S. T. (2021) Evaluation of spiral curriculum for Chemical Engineering using CDIO framework. In *Proceedings of the 17th International CDIO Conference*.

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