

A Model for the Development of a CDIO-Based Electrical Engineering Curriculum

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Abstract

This article discusses a paradigm that provides an organised technique for designing engineering curricula. The model was created to demonstrate the key influences on curriculum design as well as the relationships between them. Engineering science, the corporate world, the academic environment, and professors and students are all considered as influences. Each of them is detailed, as is their effect on the curriculum, as well as the sources of information on the influences. The CDIO syllabus has been developed as part of the foundation for Bachelor of Engineering degrees at the Technical University of Denmark, implying that the university environment has a significant direct influence on the final electrical engineering curriculum. The resultant Bachelor of Engineering curriculum is given, and its compliance with the curriculum creation approach is reviewed. The key conclusion and advice is that deliberate use of the model provided in the study may structure and enhance curriculum creation, resulting in a well-founded and organised curriculum.

Keywords: *Electrical Engineering, CDIO, Programme Development, Curriculum Development*

INTRODUCTION

Many variables impact the evolution of engineering courses. The curriculum's

history is an essential factor to examine. Curricula are often constructed in stages, with adjustments to current programmes

introduced in a more or less methodical manner. However, it may be beneficial to review curriculum creation and take a new look at the influence of many elements driving curriculum development. The CDIO Syllabus [1] is an example of how to use a holistic approach to curriculum building. It establishes a set of broad objectives for engineering education and a technique for defining particular content with the participation of focus groups representing various stakeholders. [2] is another paradigm for summarising important influences on curricular development. This approach was created with a particular focus on curriculum building for nanoelectronics and microsystems programmes. In this paper we discuss a generalization of the model from [2] and we show the application of the model to the development of a curriculum in electrical engineering. The model aims to capture the most significant influences on curriculum development in a systematic manner while being basic enough to be used in practise without needing extensive study. The model is a direct counterpart to Leavitt's description of organisational evolution in [3]. The tasks to be accomplished by the organisation, the technology, the structure of the organisation, and the people in the organisation are all connected influences

in Leavitt's model for the evolution of organisational changes. Similarly, we consider four interrelated influencers in curriculum development: the business environment in which students work, engineering science as the foundation for engineering disciplines to be included in the curriculum, the university environment as the framework for educational programmes, and the teachers and students who participate in the programmes. Changes in one of the influencers will effect not just the curriculum but also the other influencers, according to the model. Thus, a breakthrough in engineering science, for example, has an obvious influence on the disciplines and courses that should be included in the curriculum, but it also has an impact on instructors and students, as well as the industry. These connections exist regardless of whether you utilise them or not. A curriculum developed with the interdependencies in mind is likely to be more effective than one developed with simply a subset of the influences in mind.

THE Model

Figure 1 depicts the development model in a general version. Curriculum development is at the heart of the approach. The four ellipses surrounding the curricular development represent the key

influences on the development, and the arrows show how all of the model's aspects are interdependent. The model shown in fig. 1 is a general model for engineering curriculum development. It may also be used to construct courses in subjects other than engineering with minor adjustments. The methodology is then applied to electrical engineering programmes utilising the CDIO syllabus as a programme idea.

Engineering science

Engineering science is the foundation of engineering. Electrical engineering capabilities are expanded by new discoveries and breakthroughs in physics, mathematics, and computer science. The

construction of roadmaps is a well-known strategy for projecting the technical breakthroughs to be expected in the near future. The International Technology Roadmap for Semiconductors [4,5] is perhaps the most significant roadmap for electronics. This roadmap, which covers many fields of electrical and electronics engineering, forecasts the growth of technology during the next ten years. Moore's rule [6], which asserts that the number of components on a chip doubles every 24 months, lies at the heart of the forecasts. Smaller device geometries, bigger chips, and innovative devices all contribute to this rise. The plan, in particular, addresses three distinct development paths:

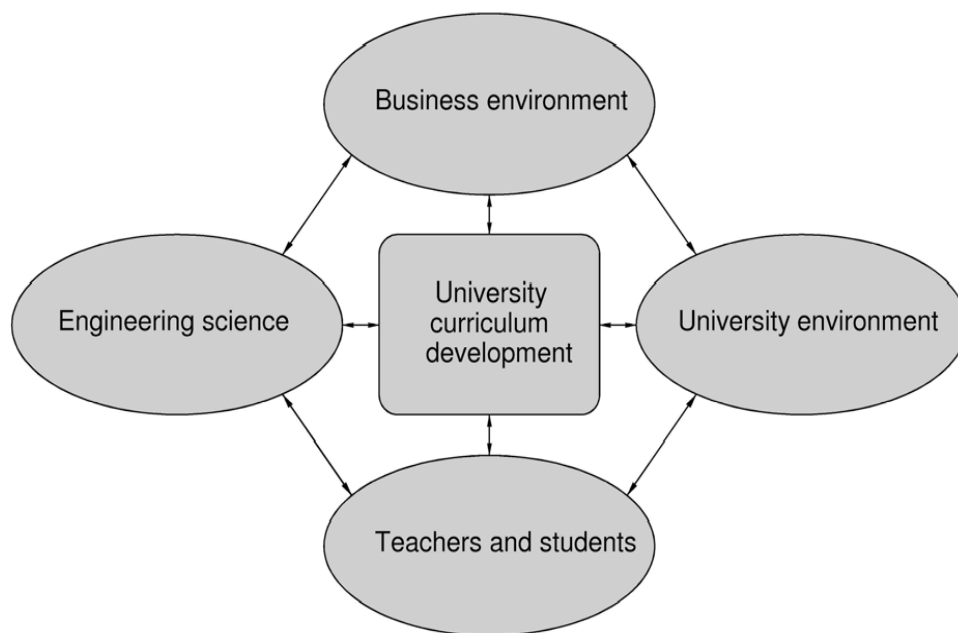


Figure 1: Major influencers on university curriculum development

- There'll be more Moore. The straight extension of current CMOS technology employing smaller device geometries is described in this course. Scaling has the effect of allowing systems of gigascale complexity (measured in terms of the number of components on a chip or in a package) to be built using typical CMOS processes. Within the next decade, device geometries are likely to encounter a fundamental limit.

More than Moore: This track explains how conventional CMOS is being combined with other types of microelectromechanical devices (MEMS), RF circuits, analogue circuits, bio-devices, chemical devices, and other technologies. Microsystems/nanosystems become conceivable as a result of this technological fusion.

Beyond CMOS: This course focuses on the development of novel nanoelectronic devices. Within the next decade, standard CMOS device scaling capabilities will be exhausted, necessitating the development of new technologies to keep the number of components on a chip growing.

The three pathways each point to a distinct curriculum: The 'More Moore' approach, as stated in [2], points to computer

engineering degrees where the key problem is figuring out how to use growing complexity in bigger systems. Of course, this path also requires technological advancement, but nanoscale CMOS process development takes occur mostly in the Far East or the United States, not in Denmark.

The 'More than Moore' route alludes to electrical engineering schools where an electrical engineer's talents may be used to the design of systems and products that use several types of electronic equipment.

Because the major issue in this track is still the creation of innovative physical device architectures that can replace today's CMOS transistors, the 'Beyond CMOS' track leads to programmes in physics engineering. Before new devices are established as the devices for future electronics engineering, a significant amount of further research and development is required.

One of the outcomes of Moore's law is that computer and signal processing electronics hardware has gotten much more powerful, and many development chores have shifted from dedicated, particular hardware creation to software development utilising generic hardware platforms. As a result,

engineering's role has evolved, and the balance between hardware and software development is always shifting. Similarly, the balance between analogue and digital electronics is shifting, with as many functions as feasible moving to the digital domain, where design automation is simpler and hardware platforms may be reused via application-specific software development. Examples of these developments may be observed in the evolution of mobile phones and smart phones, where the phone's software content defines the phone's functionalities. Digital signal processing and digital amplifiers have also taken over from analogue designs in applications like audio amplifiers.

Environment of Business

This section of the model is concerned with the employment market for which engineering students are prepared. The progress of engineering science has had a significant influence on the industrial employment sector on a global scale. Many aspects of electrical design have migrated from hardware to software, and many aspects of hardware design have shifted from discrete components (transistors, resistors, small-scale ICs, and so on) to integrated circuit design. Integrated circuit design volume

production is shifting away from Europe and concentrating in the Far East. Modern integrated circuit manufacturing facilities are so expensive that only a few major multinational corporations can afford to keep up with the development of new CMOS techniques with increasingly lower dimensions [7]. In addition, the manufacture and assembly of electronic systems based on printed circuit boards, as well as numerous electronic subsystems, is being outsourced to nations with cheaper labour costs than Europe.

This indicates that the employment market for electronics engineers in Denmark has the following characteristics: There are no really enormous corporations, no corporations in mass consumer markets, and no corporations in semiconductors. Rather, in professional and OEM sectors, Danish electronics businesses are small and medium-sized enterprises (SME's). They usually deal with specialist items, and in certain cases, Danish enterprises control a significant portion of the global market (hearing aids, wind mills, different types of biomedical equipment). Denmark boasts a thriving and innovative energy industry, as well as a thriving and innovative health-care sector. In addition, Denmark features a slew of electronic-related start-ups. Companies arise in

power electronics and audio systems based on engineering competencies in the 'More than Moore' track, for example, in creating new piezo-electric based power systems or new MEMS-based microphone systems. Engineers required in start-up enterprises must have skills in product idea, design, and execution, as well as practical application and operation. As a result, the CDIO concept is ideal for small businesses.

Environment at a University

On a worldwide basis, the university structure has undergone numerous significant changes. One is the Bologna model for university programmes [8, which consists of three-year undergraduate (bachelor) programmes followed by graduate programmes, which in many countries are comprised of two-year master's programmes and three-year PhD programmes. This leads to a harmonisation of university curriculum, allowing for easier student and course interchange across institutions. Another trend is increased globalisation, with more master's and doctoral degrees being offered in English.

Few people are aware of the tremendous growth of new technical domains and opportunities.

Only a few colleges – if any – can provide engineering majors in all sectors. As a result, universities become more specialised. Some colleges offer strong programmes in some subjects, such as electronics, while others specialise in others, such as chemical engineering. Only a few institutions offer specialised degrees such as arctic technology. Students, on the other hand, are becoming more mobile, and the establishment of a standardised framework for educational programmes makes student interchange between institutions easier. As a result, it makes sense to form alliances between institutions with complementary or matching competencies in order to offer collaborative programmes in subjects that are not completely covered by a single university. This is a critical stage in the development of educational networks.

Local laws, rules, and regulations, in addition to the worldwide trends mentioned above, have an impact on the development of educational programmes. Based on a ministerial decree from 2002 [9], the Technical University of Denmark (DTU) provides Bachelor of Engineering programmes (B.Eng.). This directive specifies B.Eng. programmes as 210 ECTS credits (equivalent to 312 years) of study with the goal of preparing students for

professional engineering careers. DTU also provides Bachelor of Science (B.Sc.) and Master of Science (M.Sc.) programmes in accordance with another ministerial decree [10]. The B.Sc. programmes are distinct from the B.Eng. programmes in that they are mainly designed to provide a foundation for advanced study in M.Sc. programmes. The Bologna model is followed only by the B.Sc. and M.Sc. programmes. DTU's policy stipulates that bachelor's programmes are taught in Danish, primarily for Danish-speaking students, whilst master's programmes are offered in English, mostly for foreign students. Naturally, this imposes certain restrictions on the kind of educational networks that may be created. In the B.Sc./M.Sc. programme line, the international component is now significantly stronger. DTU has also said that the CDIO curriculum will be utilised for all B.Eng. programmes, but not necessarily for B.Sc. and M.Sc. programmes. The B. Eng. curriculum in electrical engineering is directly aimed at providing engineers with top-class abilities in design and development of electronic systems for the professional Danish electronics industry, whereas the B.Sc./M.Sc. curriculum in electrical engineering aims broader, including an international job market and

jobs in research and development. Each programme is led by a programme coordinator who also serves as the driving force behind the creation of the curriculum within the overall framework established by ministerial directives and university policy.

Students and Teachers

In the construction of a curriculum, teachers and students play a critical role. The curriculum must be able to attract students from upper secondary school programmes who have relevant experience. Teachers that are passionate about the topics covered in the curriculum must be accessible. There must also be instructional facilities, classrooms, and laboratory space available.

Students are mainly recruited to engineering in Denmark via the STX (Gymnasium) programme, which focuses on general education and study preparation, and the HTX (higher technical examination programme), which focuses on courses in the technics and natural sciences. Approximately 25,000 students finish the STX or HTX curriculum each year. Roughly 540 of them picked a B.Eng. degree at DTU, and about 80 of them chose the electrical engineering programme, which accepts students in

September and January. This is an intake that is substantial enough to foster strong study habits and collaboration among students while being reasonable in terms of laboratory space.

The professional interests of the instructors have a significant impact on the curriculum's content. At DTU, all educational programmes share a single corps of instructors, suggesting that teachers in all programmes, including B.Eng. degrees, are active researchers. This establishes a connection to engineering science and suggests that most professors are enthusiastic about research. Many professors also retain close ties to industry, providing the required basis for thesis work and trainee service collaboration with industry.

CURRICULUM DESIGN IN ELECTRICAL ENGINEERING

One of the problems in curriculum design is to take each of the influences in the model above into consideration in a methodical manner. The model aids in the structure of the process and the identification of relationships between the influencers, but it is required to gather adequate information on the influencers in order to properly evaluate them.

There are a variety of information sources accessible. The systematic overview of development trends provided in roadmaps like the International Technology Roadmap for Semiconductors [4,5] is an important source of information for engineering science, but general knowledge about current and future research topics gathered from active researchers at DTU is also a valuable input to curriculum development.

The CDIO Syllabus [1] advises including focus groups, including a group of industry representatives, in the business environment (in addition to groups including faculty, current students and alumni). Each department at DTU has an advisory board with industry representatives, and the substance of the B.Eng. curriculum in electrical engineering has been addressed with the Department of Electrical Engineering's advisory board. The Danish Society of Engineers and professional groups such as the Confederation of Danish Industry and DI ITEK may also provide information on the business climate (the Danish ICT and electronics federation for it, telecommunications, electronics and communication enterprises). Direct interaction with industry, which many

instructors have on a professional basis, is also an useful source of knowledge.

In terms of the university environment, information for curriculum development can be obtained from both internal sources (such as university policies) and public organisations that define the curricula framework, such as the Ministry of Education and the Ministry of Science, Technology, and Innovation.

Internal sources with numbers for student intake, faculty staff, workspace facilities, and so on, as well as external sources (Ministry of Education) with information

on the students' background from their upper secondary education, provide facts and figures on students, teachers, and teaching facilities.

All of this information must be gathered by the programme coordinator and formulated into a curriculum proposal, which must then be discussed by a study planning committee comprised of teachers and students, as well as formal university bodies (department study committees, inter departmental programme committees), before being reviewed and approved by the Dean of Education.

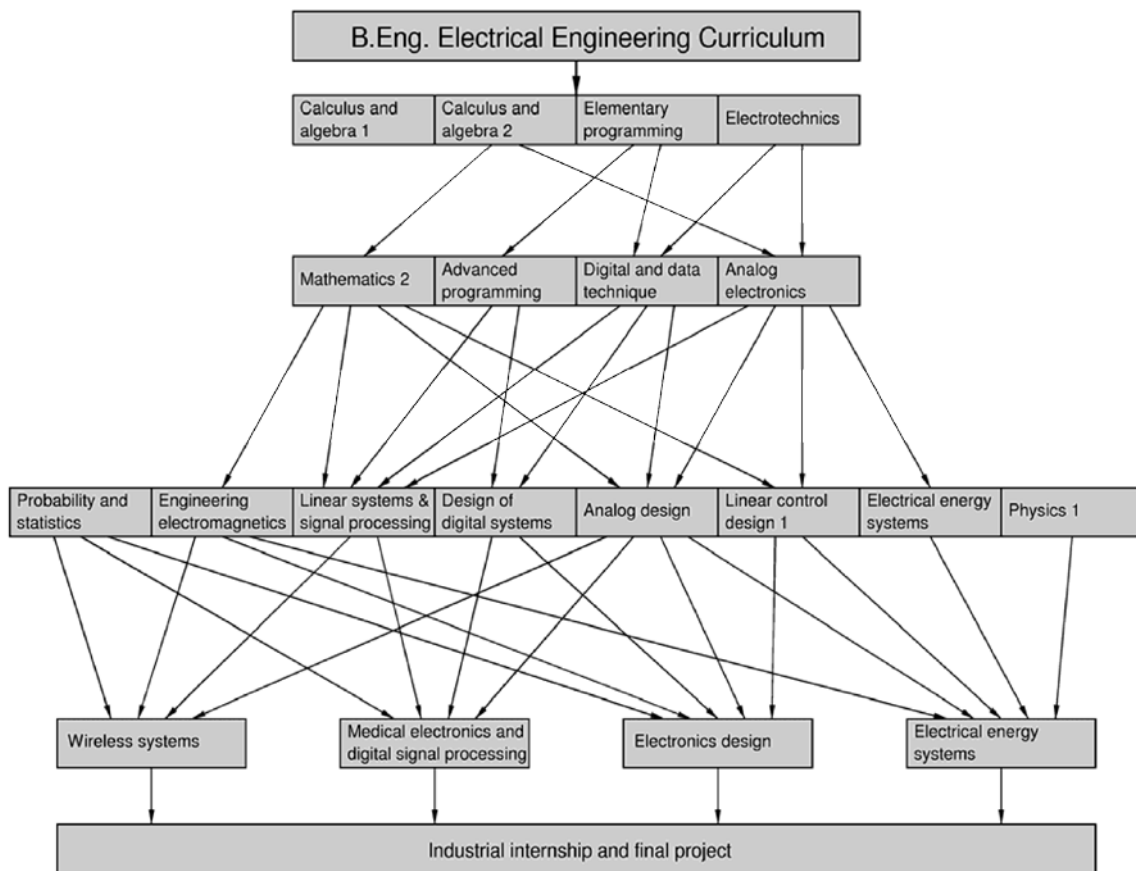


Figure 2 Bachelor of engineering program for electrical engineering

Figure 2 depicts the result of this procedure in terms of the CDIO-based B.Eng. programme in electrical engineering. [11] provides a full summary of the curriculum and how it relates to the CDIO standards. Some aspects of the research plan will be compared to the model outlined above in this section.

Technical knowledge:

The program's technical knowledge is a mix of scientific knowledge and basic engineering principles in math, physics, and computer engineering (programming), as well as engineering fundamentals and advanced subjects in electrical engineering. Several B.Eng. programmes share the same underlying engineering concepts. As a result, their content and definition are tightly linked to DTU's educational strategy, with these courses being taught by mathematics and physics departments rather than engineering departments. Engineering departments, particularly the Department of Electrical Engineering, outline the foundations and advanced issues in electrical engineering. Analog and digital electronics, electromagnetics, signal processing, and electrical energy systems are all included in the engineering basics. Analog and digital electronics get about the same amount of attention. This may appear strange at first (in opposition

to the general trend in engineering science), but it reflects the teachers' interest, the types of job functions (often in SME's working in the 'More than Moore' domain), and the fact that DTU offers another B.Eng. programme with a focus on computer engineering and digital systems. The remaining engineering principles were chosen to complement the advanced courses in wireless systems, medical electronics, and electrical energy systems. These advanced subjects were chosen due to a mix of the professors' strong enthusiasm and experience, as well as a solid industrial grounding in Danish industry.

Personal and professional skills:

The CDIO syllabus structure comes into play when it comes to personal and professional abilities. A 'Handbook for CDIO in the B.Eng. programmes at DTU' [12] has been prepared by DTU. This guidebook provides guidance for developing learning goals for courses in such a manner that professional skills are built via a development of technical knowledge. In addition, the manual contains rules for project definition. This is an example of the university environment's effect on particular curriculum creation, first via DTU's acceptance of the CDIO concept based on worldwide university

trends, and then through the handbook's implementation recommendations. Before establishing the CDIO-based B.Eng. programmes, an examination of industry attitudes toward the abilities described in the CDIO syllabus was done in order to integrate this academic impact with industry influence. The findings of this analysis show that business places a premium on professional capabilities. [13]

Interpersonal skills: The CDIO guidebook [12] addresses interpersonal skills as well, demonstrating the considerable effect of the university setting on curriculum development. The other influences in the model in fig. 1 have a smaller effect, but it is a general tendency in both engineering research and industry that achievements are increasingly produced via cooperation needing interpersonal skills rather than independent effort. This tendency is also evident among instructors, who are allocated to segments of the educational curriculum in groups rather than as individuals. In the educational curriculum, teacher collaboration also functions as a cultural structuring factor [11].

Conceiving and engineering abilities: These are general engineering skills (not electrical engineering skills) that deal with the design and execution of systems. The CDIO syllabus places a strong emphasis

on these skills (Conceive – Design – Implement – Operate), which is in line with the trend in electrical engineering science, where systems are becoming more important for the electrical engineer than circuits, as well as the Danish business environment, where systems, typically for professional customers, are a common product. Again, DTU's university policy mandates that conceiving and engineering skills be integrated into educational programmes through the CDIO curriculum, as outlined in the DTU CDIO handbook [12].

RECOMMENDATIONS AND CONCLUSIONS

A model has been devised and detailed that describes four major influences on curriculum creation. Engineering science, corporate environment, university environment, and professors and students are all influences in the model. Because the influencers are interconnected in such a manner that changes in one of them affects the others, they cannot be dealt separately. A purposeful exploitation of the relationships between the influencers may result in a superior curriculum than one based just on a subset of the influencers. The approach is being utilised to construct a CDIO-based electrical engineering curriculum at DTU. The fact

that DTU has chosen the CDIO syllabus as the foundation for the B.Eng. programmes has a direct impact on curriculum development from the university environment, but the CDIO syllabus already takes into account some of the stakeholders in engineering programmes, including industrial representatives, teachers, students, and former students. The other model influences are included into the curriculum development in this manner, not just directly but also indirectly through the CDIO syllabus.

The resultant B.Eng. programme in electrical engineering is illustrated, and it is concluded that this programme was established with the CDIO syllabus in mind, as well as the features of the Danish corporate environment and the DTU faculty.

The general advice is that deliberate use of the approach outlined in this work may organise and enhance curriculum creation, resulting in a well-founded and structured curriculum.

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