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Using integrated programme descriptions to support a CDIO programme design process

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ABSTRACT: The *Conceive – Design – Implement – Operate* (CDIO) Syllabus provides a generic platform for writing programme goal statements. Specifically, it provides support for statements of the intended learning outcomes for personal and professional skills and attitudes, such as communication, teamwork and ethics. However, a complete programme goal statement must also include goals for disciplinary knowledge. Moreover, while a *pure* goal statement may be suitable for, and support discussions with, external stakeholders, such as industry leaders who are not involved in the programme design as such, deliberations with internal stakeholders like faculty and students often need to address both the goals for the programme and the way in which they are realised – the programme design. In response to these needs, the authors present a framework that brings together the goals and the design of the programme. This framework is called *integrated programme descriptions* (IPDs). In the article, the authors discuss the contents of these components and the process of implementing them at Chalmers University of Technology, Göteborg, Sweden, and the Royal Institute of Technology (KTH), Stockholm, Sweden.

INTRODUCTION

The importance of clear programme goals for engineering education has recently been emphasised in political statements, such as the Bologna Declaration, in requirements from accreditation bodies such as ABET and the Engineering Council, and in national programme evaluations [1-4].

In this context, the programme designer faces challenge to explicitly show how the programme design meets the programme goals, all the way down to the individual courses. However, many faculty tend to have limited knowledge of the goals of the programme that they teach in, as well as the content of other courses than their own. This leads to uncertainties concerning the contribution to the programme goals by a specific course and if the programme goals, as required by stakeholders, are being met.

The *Conceive – Design – Implement – Operate* (CDIO) syllabus provides a generic platform for writing programme goal statements [5]. Specifically, it provides support for stating intended learning outcomes for personal and professional skills and attitudes. In addition to that, a complete programme goal statement must also include goals for the learning of disciplinary knowledge. Moreover, a programme goal statement must serve the needs of two different stakeholder groups. A purely outcomes-based goal statement could be suitable for discussions with *external* stakeholders, such as industry leaders, who are not necessarily interested in how these outcomes are attained. However, *internal* stakeholders, such as faculty and students, are also involved in the programme design and execution. They need to address *both* the goals for the programme and the way in which they are realised – the programme design.

In response to these needs, the authors present an approach for programme development that brings together the goals and the design of the programme into a coherent information package. This framework is called *integrated programme descriptions*.

INTEGRATED PROGRAMME DESCRIPTIONS

An integrated programme description (IPD) describes the goals, content and structure of an educational programme, as well as how these are connected. The intent is to provide the programme chair and other key stakeholders involved in the programme design process with a set of tools that can facilitate their design process. It also deliberately promotes a design process that emphasises high-level considerations, such as setting goals and developing the programme idea. This facilitates the alignment of the goals and content of the programme with actual stakeholder needs, and may point out the necessary major changes that can be very difficult to motivate and implement when applying the more common practice of programme (re)design to modifying an existing programme plan.

An integrated programme description consists of six key components; these are detailed below.

The *programme purpose* is a high-level statement of why the programme exists, which defines the overall purpose of the programme, including its context and the future professional tasks and roles of its graduates. At minimum, the programme purpose defines the particular field that the programme addresses (electrical, vehicle, etc), the relevant lifecycle phases (conceive, design, implement) and may imply a specific focus.

The *programme goals* define the knowledge, skills and attributes that students are expected to have developed upon graduation. The programme goals can be described as a concretisation of the programme purpose into a set of assessable learning outcomes. For a CDIO programme, the starting point is likely the CDIO Syllabus [5]. However, items

in the CDIO Syllabus need to be developed into learning outcomes by connecting them to appropriate cognitive verbs and goals in order for disciplinary knowledge need to be stated.

The *programme idea* describes how the programme is designed in order to meet its goals. It states the main principles and considerations that underlie the programme design. Examples (elements) of programme ideas can be that the programme has a stated aim to fulfil the CDIO Standards, that it emphasises a particular approach to teaching mathematics, or that it has a high number of laboratory experiences.

The *programme plan* is the formal specification of what courses are included in the curriculum, their credits and placement in the curriculum.

The *programme design matrix* connects the goals of the programme with its courses so that it is clear in which course each learning outcome is addressed. The programme design matrix also shows the planned learning sequences for learning outcomes that are developed through integrated learning experiences throughout the curriculum, typically generic competences like communication skills.

Finally, *course plans* define the purpose, goals and content of each of the courses in the programme, and include a statement that explains the role of the course in the programme and links it to the programme goals.

Figure 1 shows the relationships between the components. A programme design process that is aligned with the contents of an integrated programme description typically starts with the statement of the programme purpose, followed by the development and validation of the programme goals. The next step is to formulate the programme idea. The programme plan then implements the programme idea by defining the included courses, their credits and placement in the curriculum. The role of the programme design matrix is then to systematically interconnect the programme goals with the courses, assuring that no programme goal is neglected. Finally, the course plans are developed, by refining the programme goals assigned to the course, selecting pedagogical approaches and so on.

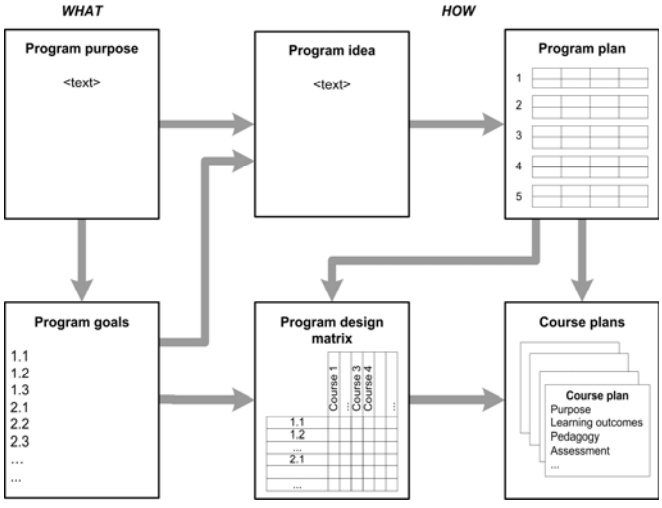

Figure 1: Components of the integrated programme description.

This sequence should not be enforced too strictly. It is important that the programme design process allows for iterations and makes several passes through the components. In particular, the assignment of goals for the learning of generic skills needs to be carried out in a combined top-down and bottom-up fashion between the programme chair and the involved faculty in order to achieve commitment for such goals.

APPLICATIONS

The concept of integrated programme descriptions is being implemented at the Royal Institute of Technology (KTH) and Chalmers University of Technology, both in Sweden. Common to these implementations is that the most of the programmes are five-year *Civilingenjör* programmes that consist of a compulsory component essentially contained within the bachelor part of the programme, followed by a range of Master programmes.

The Royal Institute of Technology (KTH)

When the redesign of the *Vehicle Engineering* programme was initiated as part of the CDIO Initiative at the KTH, an IPD as described above was given high priority. This was mainly motivated by the following factors:

- The KTH's educational system, where many departments contribute to each programme, contrasts to the programme being owned by one department only. In this situation, individual faculty may teach courses in several programmes and feel a lower degree of commitment to each programme that they teach than to their subject;
- The lack of knowledge among faculty of the contribution to the programme goals from other courses than their own;
- The lack of clear and complete learning outcomes in the programme, as well as course level;
- Insight among faculty and programme management that teaching and learning activities were poorly coordinated;
- The need for a planning tool when applying a systematic approach for covering personal, interpersonal and system building skills in an integrated curriculum.

The development of the IPD was led by the programme chair in cooperation with the programme coordinators, pedagogical experts, faculty and students. The first version of the IPD for the *Vehicle Engineering* programme was published in 2004 [6]. The contents of this document are indicated in Figure 2.

VEHICLE ENGINEERING –
INTEGRATED PROGRAMME DESCRIPTION
Table of contents
Introduction
Programme goals
Programme contents
CDIO Syllabus to second level of detail
Programme structure
Programme plan (compulsory bachelor part)
Explicit links between courses
Programme design matrix
Development routes for selected skills
Course content (bachelor part)
Courses (elective Masters parts)
Appendix
Complete CDIO Syllabus

Figure 2: The table of contents of the IPD for the *Vehicle Engineering* programme at the KTH.

The primary content of the *Introduction* chapter is a description of the purpose of the IPD and its relation to the programme development activities. This was necessary because most faculty had no earlier experience with this type of document. It was also stated clearly that the major purpose of the document was to describe disciplinary and pedagogical links between courses, and which courses that contribute to the student's learning of generic skills. Finally, it was made very clear that the document was not supposed to be static, but rather subject to continuous change as a result of discussions among stakeholders.

The *Programme Goals* chapter is a high-level statement of the programme learning outcomes very much in line with the then-current goals of the Swedish *Civilingenjör* programmes, as stated by the Swedish Degree Ordinance. These goals also emphasise the CDIO context of the education.

The *Programme Contents* chapter includes the statement that the CDIO Syllabus lists the detailed intended learning outcomes of the *Vehicle Engineering* programme. Learning outcomes for the second level of the syllabus are listed in this chapter, along with the complete syllabus listed in the IPD's Appendix *section*.

The next chapter, *Programme Structure*, presents the programme plan and the programme design matrix, ie all courses in the curriculum including credits and placement, as well as documentation of the connections between courses and the CDIO Syllabus topics. This chapter also highlights the selected important links between courses. These links include courses that share faculty for parts of the courses, or courses that are linked through home assignments and laboratory work. In the programme design matrix for the *Vehicle Engineering* programme, the responsibility of each course for introducing, teaching and utilising the topics of the CDIO Syllabus are explicitly stated. This is followed by a description of selected *development routes* for knowledge and skills that are taught in a number of consecutive courses using an integrated learning strategy. The objective here is to cover both disciplinary knowledge and generic skills, but in the first version, only some of the most important generic skills are addressed.

The final elements of the IPD contain the detailed plans for the courses that constitute the programme. First, the bachelor part of the programme, containing primarily courses that are compulsory for all students, is described in considerable detail. Thereafter, the associated Master's parts are described.

Chalmers University of Technology

The introduction of IPDs at Chalmers includes all of Chalmers' bachelor and Master programmes. A large number of programmes are affected; 25 bachelor and 44 Master programmes. Examples include the bachelor programme in *Mechanical Engineering* and the Master programme in *Fundamental Physics*.

The decision to rewrite all programme goals at Chalmers was motivated by several external factors. Initially, the main driver was that the 2005 evaluation of Swedish *Civilingenjör* programmes pointed out that the Chalmers' programme goal statements were too vague and too poorly linked to the curricula. Moreover, they were criticised for lacking generic skills [4]. In addition, the recent developments in the Bologna Process have caused the Swedish Degree Ordinance to be changed to adapt to the *Dublin* descriptors [7]. This change will require all Swedish university programmes to revise their programme goal statements [8]. However, the Dublin descriptor-based degree requirements are abstract and do not include any goals that are specific to a particular domain, such as mechanical engineering. Therefore, these are not specific enough to guide a particular programme development process. It will still be necessary for each programme to work out its own programme goals. After having examined that a CDIO Syllabus-based programme goal statement would fulfil all of the new national degree requirements, as well as offer a better support for programme development, Chalmers decided to base its programme goal statements on the CDIO Syllabus.

Some of the programmes have adopted a CDIO-based curriculum, including design-build-test experiences, etc. Other programmes have an emphasis on science and prepare students for a research career, rather than an engineering one. However, Chalmers' goal for the introduction of IPDs is not that all programmes should be CDIO-based. The goal is rather to make sure that all programmes have clear and comprehensive programme goals, along with a curriculum that meets these goals, and where there is a clear link between the programme goals and the course learning outcomes for each course in the programme.

As compared to the KTH's single programme implementation, a number of modifications were made in order to give support to the multitude of programmes and diversity of programmes affected. These are listed as follows:

- A higher emphasis was placed on the statement of goals for disciplinary knowledge with the aim to raise the precision, clarity and specificity of these goals;
- The importance of an explicit programme idea statement was emphasised. The Bologna Process provides an opportunity for programme renewal, but that also requires time and mental energy being spent on discussing the high-level, conceptual design of the programme;
- An X/0 notation is allowed in the programme design matrix;
- The validation of the programme goals are determined through dialogues with stakeholders, rather than utilising the CDIO Syllabus survey. The key fora for these dialogues are the programme boards, committees with student, faculty and industry representatives.

The programme chairs, in collaboration with the programme boards, lead the process of creating the new IPDs. The process is supported by pedagogical experts and a handbook [9].

DISCUSSION

In the above sections, the authors have discussed the concept and application of an integrated programme description. The authors will now discuss some insights of benefits and challenges that have emerged during the course of the work.

Benefits

First, IPDs promote a goal-oriented and systematic programme development process from the start to the end. Initially, a complete set of programme goals is identified and the desired levels of proficiency established with input from programme stakeholders. Ultimately, it is ensured that these goals are allocated to individual courses, and reflected in the course

goals and assessment. This is particularly important in an integrated curriculum where particular knowledge, skills and attitudes are taught in several courses.

The use of IPDs helps to shift the emphasis of programme development discussion towards high-level issues, such as programme goals and idea. Without a framework that makes such decisions explicit, it might easily happen that most of the discussion revolves around the current programme plan and how to make minor changes to it. Such an approach may be adequate under some circumstances, but it can also be very conserving in situations were major changes are necessary.

The use of IPDs also generates a common terminology for programme development at a university and collects all the information that needs be produced during the process. This facilitates the sharing of information and comparisons between programmes and faculty, and increases the transparency of the programme development process. At the KTH, it was evident that faculty presented considerable more interest in contributing to the teaching of generic skills when being aware of what almost every course in the programme contributed. KTH faculty also showed greater understanding and appreciation for the generic skills when they realised that the coordinated teaching of these skills would be beneficial for later advanced courses. It is not unlikely that this communication is more important for the programme development than the final printed document.

The IPD framework also provides a process template for programme development. Many programme chairs lack training in design methodology, but are nevertheless faced with a very complex design task that involves many requirements, issues, solution alternatives and people. The IPD process may then help them plan and carry out this task in an efficient fashion. These benefits are not dependent on the programme being CDIO-based. As is evident from the application of IPDs at Chalmers, these benefits also extend to science-oriented programmes.

Challenges

A major (perhaps the most important) challenge when using IPDs is the difficulty for many faculty to shift their mindset towards the formulation of appropriate learning outcomes, rather than on the topical content of a course. This is related to difficulties many faculty have when considering the content of their courses in terms of what is beneficial for the programme and students, and not for the disciplinary content itself.

A second challenge is to determine the appropriate level of the detail of the knowledge and skills defined in the CDIO Syllabus. The level of for each category of goals must be carefully incorporated into the particular programme. Too high a level of detail may result in a very large programme design matrix that is difficult to overview and understand for someone who has not been involved in the development of the matrix.

A third challenge is to translate the CDIO Syllabus to a terminology that is appropriate for the engineering discipline of the programme. Although the language of the syllabus is chosen to reflect as many different engineering disciplines as possible, faculty and other stakeholders may have difficulties using and accepting the syllabus and the integrated programme description if they consider the terminology to be inappropriate.

A fourth challenge is related to the level of realism in the programme concept. Ideas that are too radical may not be possible to implement, eg if faculty lacks the appropriate competence and knowledge or just dislike the ideas.

CONCLUSIONS

The use of integrated programme descriptions (IPDs) promotes a goal-oriented and systematic programme development process from start to finish, ensuring that the developed programme has clear and validated goals and a curriculum that matches these goals. The use of IPDs further supports communication between the actors in the process, increasing transparency and commitment.

This concept has been applied at the KTH and Chalmers for a wide variety of engineering degree programmes, and is thus adaptable with respect to differences in subject area for the programme, degree awarded and underlying pedagogical philosophy. Challenges include determining the appropriate level of detail for programme goals and the (optional) adaptation of CDIO terminology to that utilised in a particular subject area.

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