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Communicating Complexity To Prepare For Complexity

Magnus LILLEDAHL
Norwegian University of Science and Technology, Norway, magnus.lilledahl@ntnu.no

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Magnus Lilledahl*
Norwegian university of science and technology
Trondheim, Norway
ORCID 0000-0002-5404-2033

ABSTRACT

A trend in higher education is a stronger focus on the content of a study program as a whole rather than the individual courses that make up the program. The Norwegian university of science and technology (NTNU) has recently completed a large project, *The future of technology studies* (FTS), that attempt to describe how study programs should prepare students for a technological career in a rapidly evolving society. A central recommendation from the project is the necessity of an integrated, program-driven curriculum. Hence, there is a need for a useful description of the content at the program level.

However, a typical description of the learning outcomes of a study program is very brief, often just a set of bullet points that is in no way sufficient to describe the complexity of a study program.

Two study programs in physics and mathematics at NTNU are in the process of revising the study program following the recommendations of FTS. We found that the current framework for documenting the content of the study program is not sufficient. We are proposing a new scheme where the content is documented in a *master document*.

Some new features of the master document that are typically not part of conventional program descriptions are: Specific target audience, not only what but also what not, and why and why not, using a natural language, and maintaining complete revision history.

*Corresponding author

1 INTRODUCTION

> - that this *University*, under God, shall have a new birth of freedom — and that government of the *faculty*, by the *faculty*, for the *students*, shall not perish from the earth.
>
> *freely after Abraham Lincoln, Gettysburg address (changes from original in italic).*

We will in this paper present thoughts and work we have done on how to develop a description of the curriculum of a study program that is actually used by faculty when they teach and develop courses in the program. It is our experience that current descriptions of the curriculum are often tailored to fit top-down frameworks and are not useful or actually employed by staff when they conduct their teaching. We believe that a bottom-up description of the program, developed by faculty as whole, is necessary.

1.1 Context

The context of this work is a 5-year engineering program in physics and mathematics (MTFYMA) [1] and a 3-year bachelor program in physics (BFY)[2] at the Norwegian University of Science and technology (NTNU). MTFYMA is a joint program between the Department of physics and the Department of mathematics.

NTNU recently completed a university-wide project titled *the future of technology studies* (FTS) [3]. The aim of this project was to identify the necessary competencies that engineers will need in a future job market, as well as best practices for a modern engineering education. The project resulted in several reports that were synthesized into 10 principles for how programs should be offered, and 12 general competencies that all students should acquire.

To follow up these recommendations, the study program boards of MTFYMA and BFY decided to initiate a revision of the study programs. It was through this process we found the current description of the program to not be sufficient.

1.2 Bakground

The first of the FTS principles states the students should develop "...holistic and integrated competencies.". The sixth principle states that "...the studies should be developed through a program-driven approach" (authors translation). Our interpretation of these principles is that the program should put more emphasis on how the various courses are connected and that the desired competency is built through the sum of various courses. A program-driven approach entails a stronger focus on the overall *curriculum*

[1] `https://www.ntnu.edu/studies/mtfyma`

[2] `https://www.ntnu.edu/studies/bfy`

[3] `https://www.ntnu.no/fremtidensteknologistudier`. (only in Norwegian)

rather than the isolated courses. It is important to emphasis that in our institution this represents a significant shift from the current culture where individual courses have a very weak connection to the overall program and other courses. The instructor has almost full freedom to adapt courses and the courses evolve primarily in the context of a single course and along the interest of the instructor, rather than the program.

The term *curriculum* can carry different meaning in different contexts. In this paper we will use a broad understanding of the term to encompass the stated learning objectives, but keeping in mind the notion that the actual learning and tacit learning are important aspects of the curriculum (Blackmore and Kandiko 2012). A practical definition provided by Hicks (Hicks 2018) states that the curriculum consists of

1. What is being learnt
2. Why it is being learnt
3. How it is being learnt
4. When and where it is being learnt
5. The demonstration that learning is taking place.

We will build upon this definition later in the paper.

The curriculum that students eventually encounter at a university and the way it is documented are affected by requirements or recommendations from organizations at multiple levels. These organizations can to a varying degree enforce these requirements, through law or incentives, or be limited to publishing reports and recommendations.

At the international level we find as an example the European qualification framework (EQF), which through national legislation (e.g. the Norwegian qualification framework for lifelong learning (NKR)), puts requirements on how the learning outcomes of the program are to be described, and how course workloads are to be quantified (ECTS). NKR requires that the learning outcomes of the program are structured into 1) knowledge, 2) skills, and 3) general competencies. In our institution, in the program description, each of these components are described by a short paragraph and a few bullet points. If one compares the national template with the program description one can see that the program description is very similar to the national template with just generic terms, e.g. *field of study*, replaced by something specific, e.g. *physics and mathematics*.

At the institutional level there may be policy documents prescribing particular learning outcomes or competencies to be achieved by all students at the university. E.g. some currently trending terms are *sustainability competencies* or *digital skills*. Particular programs are then often required to document that they meet these requirements, e.g. by providing a matrix (often referred to as a curriculum mapping) with learning outcomes on one axis and different courses on the other axis and a check mark if the

course contributes to the learning outcome. These check marks are highly subjective and the common approach seems to be to search for how the current program can be interpreted to fill the matrix rather than use the matrix to change the current program.

It is our experience that these top-down processes often have negligible effects on the actual program. At the program level the process is more about figuring out how the current program can be claimed to satisfy the requirements rather than creating actual changes in content. This passive approach has a dual negative effect. First there is little actual change. Secondly, the lack of interest at the program level triggers even stronger regulation from the institutional level, and the lack of flexibility might lead to quality reduction at the program level.

We believe that there are several effects that contributes to this lack of response from faculty. First, the requirements can be very general (“more active learning”, “solid sustainability skills”) and seem far removed from the core content of the program and the expertise of the faculty. Often a very syntetic language is required when stating the learning outcomes. E.g. *at the end of the study program the student should be able to [some active verb] [some overarching concept]*. This use of language which is very different from how faculty typically discuss their own subject matter, also contributes to faculty distancing themselves from the top-down approaches to curriculum change. Second, usually few or none of the faculty have been involved in developing these requirements and it is difficult to grasp their content without having been part of the development.

There is also a cultural aspect where in the past, professors have been given complete freedom to control content and delivery of courses and are reluctant to relinquish this right.

The result is that all documentation that describes the content a program and its individual courses are top-down, and with little engagement from the faculty. This results in a very weak connection between the description of the curriculum at the program level and the content of the individual courses.

1.3 Proposed solution

What is missing is a documentation of the curriculum of a program that is written for the faculty by the faculty. The key feature being that this documentation of the curriculum is not written to appease some quality assurance body but to generate a, primarily internal, understanding of what are the goals and learning outcomes of the given program. We believe this to be essential to realize a “holistic and integrated” program.

The documentation will also be relevant for external stakeholder professionals, making it easier to offer concrete advice on what could be improved in a given program. It is easier to provide feedback on concrete descriptions rather than general, overarching principles.

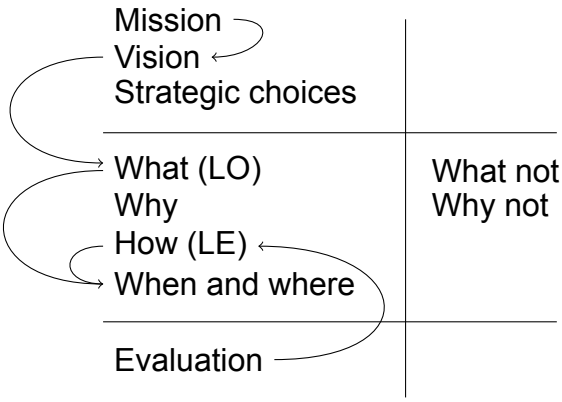

Fig. 1. Sketch how the main components of the master document and how they are connected. We believe that a documentation of this parts are necessary to have a complete description of an integrated curriculum.

The document should also provide clear documentation of the connection between the learning goals and content of the individual courses. This requires that the learning goals are sufficiently detailed and organized in some sort of hierarchy to be manageable.

This document should be the governing description of the program. In the following we will refer to this as the *master document*. Any other descriptions of the program and courses, e.g. to adhere to quality assurance requirements or similar, are to be derived from the master document.

2 METHODOLOGY

2.1 The master document

The previous section introduced the need for a document that describes the content of the study program, aimed at the people that actually provide the program. The main goal of the *master document* is to communicate to the faculty and external professional stakeholders, the curriculum of the study program. Notably, students are *not* a primary target audience for the document. The document should be available for students, but other ways of communicating the curriculum to students might be more appropriate.

Fig. 1 illustrates the main parts (chapters) of the master document that we believe are essential to document. First, the program must have a clear *mission* to meet some need in society or for the individual. Without a clear idea of this, further work is difficult. A *vision*, which is an overarching description of the learning outcomes of the study program, documents how the program target the needs described in the mission. The actual learning outcomes (LO), are derived from the vision and describes *what* competencies the student will acquire. The LOs must be sufficiently detailed to inform *how* the learning experiences (LE) should be designed. For a 5-year program this will result in a large amount of LOs and a sensible hierarchy will be necessary to provide sufficient overview the program. Every LO should also be accompanied by a

reason for *why* it is included. When future revisions need to prioritize what should be included and not, it will be very valuable to understand why something was included in the first place. Once the what (LOs) and the how (LEs) are in place one can determine *when and where* in the study program these should be developed.

We believe that an almost equally essential feature is to also describe *what not* to inlcude in the program and *why not* this has been prioritized. Explicitly stating what is not to be included can create a clearer boundary for the content of the program. This should then be accompanied by the reason for not prioritizing the content. We believe that this is important to avoid courses becoming bloated with too much content. This will invariably lead to more superficial learning. This effect is own seen when new instructors each add additional content they find interesting. The teaching at our institution is often described as *fire-hose pedagogy* which is quite descriptive.

The program must also be evaluated. This evaluation serves two purposes. The first is to ensure the qualification of the candidates (summative assessment). The other is to assess the quality of the LEs. It is essential to document and have a collegial understanding of both these aspects. With regards to the summative evaluation it is well known that it is a very strong driver for the learning environment and the students behavior. The assessment method will therefore have significant implications outside an individual course. To assess the effectiveness of the LEs it will be necessary to have some consistency in the assessment tasks over multiple semesters. An example of such an organized evaluation scheme is the Research and evaluation framework (Kelder, Carr, and Walls 2017). Formative assessments are included as part of the LEs.

We have also included a part named *strategic choices*. These are choices for what is included and how the program is organized that is not strictly driven by the mission but rather by external constraints, regulations, existing culture, historical identity, political issues and so on. These are equally important to document so that future program leaders understand why certain choices are made and can modify them accordingly if external factors change.

For this document to be a useful and living document we believe it should be guided by certain principles and aims:

- Foremost, the document should develop by and for the main users of the document which is the faculty/instructors. To this end it should be written in a language and in a format that is appropriate for this target group.
- Secondly, it should be informed by the main stakeholders in the curriculum, that is, employers and students.
- It should be sufficiently detailed to be able to describe connections between the what, why, how and where (as described above), but also not grow so large that it is unmanageable.

- The document should be *informative*, i.e. it should state non-obvious choices and priorities. E.g. in the current program description, the first statement is “The students should have a solid foundation in physics and mathematics”, which is not very informative for a study program in physics and mathematics.
- An important aim is to inform new staff about the mission of the program as well as the teaching and learning culture.

Even though the document is developed by and for faculty it should not reside in some ivory isolation. It will be the role of study program managers to bring in input from external stakeholders and reports and translate this information into a language that is meaningful to and can be integrated by the faculty of the given program. Similarly study program managers will have the role of translating the master document into other formats to adhere to the various mandatory quality assurance systems.

2.2 Development

We believe that a key factor for making a document that is actually used is that it is also *developed* by the faculty, for the faculty. For the study programs MTFYMA and BFY there is about 100 scientific staff across two departments (mathematics and physics) that contribute to the courses in the program. In addition there is about 200 temporary staff (PhDs and PostDocs) and 650 students. Not to mention external stakeholders (industry) and university management. How can we engage such a large group in the development of the master document in an efficient way? Sending around a Word-document with track changes enabled is a recipe for disaster. Such a large scale involvement has been described as Participatory curriculum development (Taylor 2000). A limiting feature has been noted to be appropriate meachnisms or tools for such large scale involvement (Alexander and Hjortsø 2019).

Luckily there exists technology for organising large scale contributions to text. In the realm of programming, *version control systems* (VCS) have been developed to enable hundreds of programmers to work on the same code simultaneously, and ensure that nothing is lost when changes are made. Even though the technology is not designed for working with prose, we belive that it will work quite well for this purpose as well.

The branching technology of version control systems enable multiple groups to work on multiple parts of the document at the same time and changes will (usually) be seamlessly integrated on merging the various inputs. Another valuable aspect of version control systems is that a complete revision history is maintained so that it is always easy to go back and look at what the document said 1 day or 10 years ago.

Our current plan is to divide the development of the master document into subprojects where each subproject works on a separate topic of the curriculum and the documentation is developed in a separate branch in the VCS. The method of engaging faculty might vary (e.g. hearing, working group, seminar, etc.) but for any such process the result

should be a suggested modification to the master document that is proposed through the VCS

We are currently using *git* as a version control system and *github* as a central repository for the master document. The document can be found at `https://github.com/maglil/mtfyma-bfy`. Unfortunately the document is currently only in Norwegian but we are exploring how we to efficiently also maintain an English translation to ensure international bench-marking of the program.

The version control system requires that the encoding of the document is a pure text file and we are currently using LaTeX as a markup and typesetting system.

3 RESULTS

We have not yet tested the idea of a master document in large scale editing procedures, however we have presented the idea of the master document in our preparation for a revision process. To initiate the revision process we needed to ensure support both at the management level (head of department, dean) as well as among faculty. The management level was positive to the idea of a detailed description of the program and that the document was sufficient to indicate that we were working on generic skills (collaboration skills, sustainability skills) but translated and organized in a way that is more meaningful to staff.

We have also conducted meetings with all the research groups at the two departments (12 in total) where we proposed the idea of documenting the content of the program in a master document. Even though many of the staff provided very clear opposition to many of the ideas for how to change the program, none voiced any objections to the idea of having a document that describes the content of the program. Quite on the contrary, many relayed anecdotes of how they had been given responsibility of courses but without any information about who the students are, what the learning outcomes where or how it related to other courses.

To start the engagement of the staff we conducted two seminars where we worked on a proposed description of experimental and digital skills. From a program manager perspective we found it very efficient to send a particular version of the master document as a base for the seminars and then being able to revise the document based on the input using multiple branches in the version control system so that multiple people could work on the document on the same time.

3.1 Conclusion and future perspectives

So far we have had positive experiences with the concept of a *master document* as presented in this paper.

However, we have not yet started the real work of engaging multiple working groups to work on the document in tandem. There is also the open questions of how the

faculty will actually use the document in their planning of teaching once the document is finished.

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