MODULARISATION IN ENGINEERING EDUCATION

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ABSTRACT

The present study is concerned with the modularization of courses in engineering education, in particular mathematics modules in/for physic education, at a Dutch university of technology. One of the project objectives is to develop and validate a framework to support teachers with their modular course design; another to provide supporting tools for students to navigate through a modularized system. This paper draws attention to the first stage of the project, which focuses on a state-of-the-art literature review regarding modularization. After a thorough literature review conducted in a systematic manner, with specific keywords, all relevant research papers were categorized under the following three dimensions: instructional activities and learning materials for modular courses; assessment procedure; and supporting systems needed within modular systems. According to the results from selected countries (e.g. UK, Ireland, Australia, Netherlands, and Germany), we have chosen to highlight those where modular system experiences were shared from the point of new instructional methods and learning materials created. Another group of articles were concerned with feedback mechanisms and assessment tools used in the modular courses. The last group concentrates on the ways how both students and instructors are supported in a modular system. This study reports on an overview of articles in terms of the three key criteria required to develop and validate a framework to support teachers at TU/e with their modular course design.

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1 INTRODUCTION

In the world of globalization, higher education is inevitably affected due to the increase of transnational flow of people, knowledge, and resources. The social arrangement within and around the universities take on a new significance as internationalization. Internationalization is actively encouraged by the Organization for Economic Co-operation and Development (OECD), European Union (EU), and United Nations Educational, Scientific and Cultural Organization (UNESCO).

One of the important impacts of internationalization is the emerging need for instructional systems in higher education to be made available to larger number of students in a life-long learning concept. Moreover, these new instructional systems also have to offer an individualized learning experience for students with different educational needs and backgrounds. Modularised systems come into prominence in order to provide the opportunity to perform the mentioned issues effectively. Modularisation can be defined as [1]:

> the process by which educational awards are broke up into component parts of a more or less standard size. These parts may then be assessed separately and independently, so that students can study individual modules in a variety of different sequences.

Modularisation of the curriculum is a shift from a time-based to a credit-based structure that caters for the needs of a more diverse student groups. It is also based on a fundamental principle to divide learning into measurable, quantifiable units of knowledge called modules. Students earn credits for modules that can lead to a qualification requiring a certain number of credit points [2].

Modular systems possess prominent features that can be seen to provide an attractive alternative to traditional-based ones. Flexibility in choice and mobility are the key elements of modularization, and they hold the reason to its current popularity. Due to flexibility and mobility, students can continue their education according to different circumstances or interests. Modular system schemes are actively student-centered, and students can shape their courses according to their needs, such as proceeding at their own pace, following individual learning paths and arranging personal learning times. Besides, courses in the system include a wide range of instructional activities that allow students to choose their learning modes. Additionally, assuming that not all the students have the same areas of interest and motivation goals, a larger variety of topics are typically introduced. One of the most notable advantage is that students can 'walk through' the module at their own pace, repeat or change the learning mode, which help students to identify their own weaknesses and strengths, and to achieve to complete the module with a fuller understanding [2,3].

The study reported in this paper is part of a large-scale curriculum reform project at a university of technology (in the south of the Netherlands), which aims to change its

curriculum from a rather 'traditional' engineering curriculum to a challenge based one [4]. Within this scope, it expected to take the advantage of modularisation as offering students opportunites for designing their own learning trajectories with respect to their individual needs, interests and aspirations via knowledge bites modules that can be taken 'just in time'. In this paper we aim to identify particular issues (from the literature) that would help course designers in engineering education to design modularized courses, so that students can develop their own learning trajectories. Our research question is the following:

According to the literature, what are the issues that a course designer/teacher has to consider for the design of his/her modular course/s?

After this introduction part, we provide an explanation of how the study was conducted. In the third section, we present the results from our study of the literature, under related subheadings. In the (fourth) conclusion section, we present the important issues for modularizing a course in engineering curriculum.

The study

From the methodological perspective, this paper is not a systematic "review study" [5], but rather a state-of-art review of the literature, which has been conducted in a systematic manner as described below.

As a first step, with the aim of getting an overall idea about modular systems and their difference from traditional ones, an initial search was conducted with the following keywords: modularisation; modularisation in higher education; modularisation in engineering education; modular systems. As the main aim of our project was modularisation of courses in engineering education, specifically mathematics modules in and for physics education, as a second step, we narrowed down the search with more specific keywords: modular courses; mathematics and physics in engineering; mathematics in physics; mathematics in physics courses; mathematics in physics modules; assessment in modules; assessment in modular systems; assessment in modular courses. A total of 122 papers were deemed to be suitable for analysis, and they were grouped in an excel sheet according to the keyword search.

In a third step, these searched articles were then filtered by screening the titles with the following criteria:

- the paper is related to modular systems in higher education or engineering education;
- the focus of the paper is related to mathematical knowledge in physics courses or modules;
- the paper provides information on assessment methods in modular systems or modular courses;
- the paper is published in a peer-reviewed scientific research paper, and
- it is written in the English language.

This resulted in 57 relevant papers. In order to answer our research question, we then analyzed and grouped these papers to help to identify criteria for developing a framework intended to be used for helping the designers/teachers to design and evaluate modular courses.

2 RESULT

As a result of our systematic literature review, we could categorize the 57 papers under three main headings:

- Instructional activities and learning materials
- Assessment procedure
- Supporting Systems

In terms of 'instructional activities and learning materials`, we collected all papers which mention the required issues for the new modularized learning environments from the point of instruction and learning materials, the specifically designed or constructed learning materials for the modular courses, and also the newly built instructional systems.

In the design process of a modular course, using efficient and comprehensive assessment tools are important, in particular for evaluating students' knowledge when they start a module (i.e. pre-knowledge), and when they exit a module (i.e. what they have learnt), but also in feedback loops to help students to assess where they are in their knowledge development and how to move forward. The 'assessment methods` category brings together the papers in which evaluation methods and techniques specific to modular courses are investigated.

The papers gathered under the `supporting systems` category assist us in exploring the ways of how all the stakeholders (students, instructors, assistants, etc.) of the modular system can be supported from different perspectives.

In the subsequent sections we report and explain our findings under the three headings.

2.1 Instructional Activities and Learning Materials

For the integration of an engineering curriculum into a modular form, from the point of instructional strategy the research literature suggests that classroom based and web-based modules have to complement each other to achieve higher rates of success in terms of student learning. While the classroom modules generally focus on the fundamental aspects of the topics, the web-based modules are said to assist with providing background knowledge and resources to help students learn with computer-assisted instruction and visual learning. With the advantage of computer assisted learning, students are provided with fast inquiry-based learning experiences and also allowed to proceed at their own pace and within their own schedule. Visual learning enables the use of graphics, images and visual supportive materials to engage students in active learning and help to make their learning experience richer [6].

In the modular systems, students have to create their own learning paths and make their own decisions through the modules. With implementing new education and instructional approaches (associated with e.g. problem based learning, competence based learning, or challenge based learning) to the modular systems, it is emphasized that within the courses conducted students acquire ownership of their learning experiences and become motivated self-directed learners [7-9]. It is also claimed that this offers students the chance to engage with real-life problems [7-9]. Another advantage is that students may become self-directed learners at an early stage of their undergraduate education [9].

A helpful point is expressed in the paper of Kezerashvili et. al. [10]: they claim that the integration of e-learning and e-teaching mechanisms support the active learning period of modular system. Based on their use and analysis of Blackboard and Website communication systems, they contend that greater student-instructor and student-student interaction were achieved [10].

2.2 Assessment Procedure

Modular courses typically offer many opportunities for students to develop their own learning paths, also linking to students' differing backgrounds. Therefore, it becomes essential to consider and plan effectively potential prerequisite routes through the curriculum, and to create and provide comprehensive, effective and efficient assessment tools/methods.
In the literature, it is highlighted that there is a necessity for shifting perspective from "assessment of learning" towards "assessment for learning [11]:

> A student focused approach is necessary if educators are to prepare a diverse student body, for diverse professional roles and if engineering education is to continue to progress, bold reforms of curricula and assessment need to be attempted and evaluated in a cycle of constant improvement

Another important point highlighted in the literature is connected to assessment procedures to be spread over the semester. It is recommended that these assessment 'steps' have to be conducted after certain parts of the module, to help students develop (a) self confidence in their own learning, and (b) conceptual understanding of the subject over modules and tests. In conventional courses, students are assisted at certain times via resubmission, feedback and coaching before the final assessment period. These steps are much more difficult to be processed in the constructed and pressured form of modular courses, and the assessment usually takes place at the end of each module. Hence, it is important to provide feedback loops throughout the module that 'feed forward' and potentially help students to move on. If the learner revisit the module at a later stage, there will be an opportunity for the feedback to have an effect on students` own learning path (or in the process of learn to learn strategy). As indicated by Cornford, many of the

problems of learning and assessment associated with modular courses can be overcome through planning for multiple and formative assessments [12]. Moreover, a mechanism (named 'feedback profiling tool') has been designed and shared by Hughes, Smith, and Creese. Its aim is to categorize the feedback and comments in the modular system and feed forward from one module to another to enable students act on feedback, so to develop student capacity to recontextualize disciplinary-specific skills throughout a programme [13].

In addition to the above mentioned issues, for assessing the progress of the modular approach, it is stated that building an evaluation team is an effective way for conducting the necessary principle tests: for instance conceptual pre- and post-tests, in-class and follow-up exams, the attitudinal pre- and post-surveys, focus group interviews, etc. [14].

2.3 Supporting Systems

Differences between traditional and modular systems create a necessity of supporting all the essential stakeholders, namely students and instructors, in many aspects.

One of the proposed suggestions is the employment of student assistants or graduate student instructors [14], with the aim of supporting the modular courses, running the discussions and laboratories and helping the students finding their paths through modules. Furthermore, due to increasing number of students enrolling, McGovern, Collier, and Magina proposed the intelligent learning assistants as an alternative solution to support students in their choice of modules via their learning and personal preferences, and academic capacities [15].

Another critical issue expressed in both papers by Gutwill-Wise [14] and Kieran and O`Neill [16], is the requirement for a professional development department (for teachers) or unit specific to modular system. If most of the students, student assistants and lecturers are used to traditional methods, it is advised to speed up their 'adaptation' to a modular system: for example, in terms of underpinning philosophical issues and main differences from traditional methods, of implementation ways/techniques of modular approaches, and also of the essential steps they can follow (typically conveyed through an established modularization education programme).

3   CONLUSIONS

The shift from traditional to modularized education is often associated with a change of mindsets from teacher-centered to student-centered education. The course designers/instructors, rather than thinking about the presentation of the course content, have to consider the students' learning paths through the content from the students` perspective. This means considering what students' needs might be and

how to arrange or organize the modular courses to make it easier for students to find and position themselves in their chosen learning trajectory.

From the literature, we have identified issues related to modularization, and we have categorized them under three main categories: instructional activities and learning materials for modular courses; assessment procedure; and supporting systems needed within modular systems. Under these three categories, according to the experiences reflected in the selected papers, we have put forward the important issues required in terms of what kind of support students need in a modularized system and what designers might want to consider when modularizing a course.

To put it differently, we consider that effective connections should be made (1) (starting with student prior knowledge brought to the module) within modules to help students develop a coherent learning strategy; or (2) between modules to link the learnt to other modules, and hence to develop their own study path towards their desired study goals and ambitions. This can be done by relating the learning goals (of each module) to the instructional activities and learning materials (digital or non-digital) of the modular learning environment, and further to the assessment procedures within each module – all the time considering the issues we highlighted from our review. The supporting systems needed for such a set up are manifold (e.g. blended systems). However, in our view it is crucial to also provide support for the teachers, as designers of the modularized courses, both in terms of materials resources as well as professional development.

As our next step, we plan to develop a framework consisting of guiding questions for the course designers or instructors to ease their period in the adaptation and implementation to the modular systems.

ACKNOWLEDGMENTS

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