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UPSCALING A CHALLENGE-BASED AND MODULAR EDUCATION CONCEPT (CMODE-UP)

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ABSTRACT

In 2019, a course at a Dutch University of Technology was redesigned towards challenge-based and modular education. The course was received positively by students and their learning outcomes (grades and engagement) increased compared to previous years. This redesign was quite intensive, and case-specific. It did not deliver a specific set of design principles that can easily be used to redesign other courses within the university or even other universities. Therefore, a follow-up project was started, that aims to deliver a framework to scale-up the course redesign tested in the previous study (CMODE; Challenge-based Modular On-demand Digital Education). This framework will be designed using practical principles and will be evidence-informed. The project consists of three stages: (1) informal interviews with key actors at our university, experienced in studying and/or designing modular instruction, a systematic literature review on challenge-based education and modular instruction; (2) a test of the design principles that were developed using the interviews and literature review; and (3) a test of the CMODE-up framework that was built on the results from the second stage, using think-out-loud protocols. In the current study we specifically focus on the first stage. A first look at the already existing literature around challenge-based education and modular instruction shows us that both concepts have been around for a long time in higher engineering education. Since education has become more and more digitized (and the development of MOOCs), it appears that the concepts have taken a quick increase in relevance. However, both concepts have only been studied minimally in relation to each other. We deem it thus highly relevant to first build a clear and proper view on both concepts, the strengths and weaknesses, and where both (can) meet. So that anyone who has intentions like ours - to implement both in higher education - can do this in an evidence-informed manner.

1. INTRODUCTION

In this paper, part of a project is presented that aims at presenting a framework to design challenge-based, modular education courses in engineering education. Merks et al. [1] have described a course redesign focused on making a course challenge-based and modular at Eindhoven University of Technology. In order to help teachers within that and other universities to redesign their courses as well, or in other words, to scale up the work done by Merks et al. [1], an evidence-based framework for challenge-based and modular education is essential. The project (CMODE-up) consists of three phases: (1) the development of a preliminary set of design principles for challenge-based modular education, resulting from (1a) informal interviews with key actors at our university, experienced in studying and/or designing modular instruction, (1b) a systematic literature review on challenge-based education and modular education instruction; (2) the development of the CMODE-up framework after a test of the previously developed design principles; and (3) a test of the CMODE-up framework, that was built on the results from the second stage, using think-out-loud protocols. This paper specifically focuses on phase 1 (both a and b).

Modular education or modularization as a concept, has been around in higher education since Harvard University initiated an elective course system in the late 1800s [2]. Since then, many educationalists have adapted a modular perspective to education, but throughout time, modular education has taken different meanings; e.g. many studies refer to modularization as it was first used at Harvard University, other studies mean that within a course, different modules can be defined and students go through these modules in chronological order, or they even choose themselves what modules they take and in which order [2]. The latter type, where the modules are independent of each other and non-sequential, can be considered the most ideal type of modularization, since it offers students the autonomy and flexibility to follow the modules as a mix and match program, while still ending up with regular certification [3, 4]. Following a modular course structure, students achieve success in multiple course modules as well as create connections between these modules [5]. Key features in all these perspectives on modularization are flexibility, frequent feedback, self-paced learning and adaptations to individual students' needs [6, 7]. For CMODE-up, we are interested in modular course structures, regardless of whether the modules are independent and non-sequential. In research, the modular perspective to course design has its roots in learning theories such as programmed instruction, and student-centered pedagogies [8, 9, 10].

1.1 Modular course design

The higher education literature presents design and development of modular course structures. An example course design focused on maker education. The researchers required some of the modules to be mandatory but also left the rest of the modules to be chosen by the students upon their interests and learning needs [11]. Another course was developed with a modular approach for mechatronics engineering students. The course modules combined theoretical knowledge and learning activities for the students to apply what they learn as they create solutions to the design challenges at hand [12]. In line with the framework of challenge-based learning (CBL), several educational modules were designed that included course learning outcomes and the learning experiences. The modules were designed to facilitate mastery of the content and the skills that the students would need to finalize the challenge [12]. The CMODE framework by Merks et al. [1] is another example of the movement towards modular education for higher engineering education. In this redesign, a traditional course was restructured into several theory modules, centered around a challenge that was also ‘modularized’ into deliverables accompanying the theory modules. Testing this redesign showed that dividing a single CBL course into modules with specific learning outcomes and learning activities can lead to positive student learning outcomes.

To take on a modular approach to course design, multiple aspects in higher education need to be considered: a) the educational program to be modularized, b) the students and their background (e.g., prior knowledge, needs, interests), c) teacher preparedness, d) learning and instruction, and e) organizational support [2]. Given the lack of an empirically-grounded framework targeting higher engineering education, the iterative development of a framework can provide a valid structure for designing courses with a modular approach. This study aims to present design principles to be used in an evidence-based framework for modular course design.

2. METHODOLOGY

2.1 Phase 1a: Informal interviews

The interviews were conducted with 13 professionals who have experiences in designing modular courses for higher engineering education. The interviews questions include: “1) What are your experiences in modular instruction in relation to higher engineering education? and 2) in what ways is modularity extending CBL and higher engineering education further?” The researchers’ field notes are used during data analysis [13].

The researchers carefully read the field notes taken during the interviews several times. As a result of descriptive analysis [13], general categories were created to summarize the findings.

2.2 Phase 1b: Systematic Literature Review

Content analysis method is adopted to conduct the systematic literature review [13]. Multiple searches were conducted in the databases: Ebsco, Web of science, Scopus. The keywords used to locate the articles included: “engineering education”, “challenge-based learning”, “modules”, “modular courses”, and “content modules”. These keywords were used in different combinations to locate as many appropriate articles as possible. The search was limited to articles published in peer-reviewed journals between 2000 and 2021. Books, book chapters and conference proceedings were not included in the search. The removal of duplicates decreased the located number of articles from 545 to 486. Of the 486 unique articles, titles and abstracts were studied using exclusion criteria: a) studies that do no not target higher engineering education, b) publications such as commentaries, reports, short documents, c) studies not written in English, and finally d) studies that either report modules as software or device (e.g., protein module, solar module, modular simulators) or discuss modular approach only in their recommendations. If one of these exclusion criteria was applicable to an article, the article was excluded from further analysis. Application of these criteria decreased the total number of articles to 201. A further examination will later be completed using inclusion criteria. Only the articles that one of both criteria apply to will be included: a) explained modularization of a course, curriculum, or a program in a higher engineering education context and b) described how the modules are created.

Later in this phase, the authors will individually examine the retained articles using a codebook. The codebook will include the themes and the codes based in their total occurrences found in the data. Use of a codebook will facilitate the organization of the findings [13].

3. RESULTS

3.1 Phase 1a

The informal interviews have provided an overview of what challenge-based learning and modular education look like at Eindhoven University of Technology, at the moment. Table 1 provides an overview of the range of practices and perspectives at TU/e regarding these concepts.

Table 1. Categories that surfaced in the interviews

Categories	Description
Higher engineering education context	Challenge-based, design-based course contexts
Structures that resemble modularity	Structures that lie somewhere between traditional courses and modular courses, the course is not entirely modular but students are highly encouraged to personalize the

	instruction and learning by other means
Degree of modularity	The variety in modular course structure; the courses allow multiple degrees of sequence, flexibility, choice and individualized instruction for the students
Characteristics	The benefits and limitations of modular courses for higher engineering education
Instructional principles	Conceptual background; how the course is structured (e.g., steps followed, interdisciplinarity, alignment to the design challenge, assessments)
Computer-assisted learning	The value and role of digital platforms in modular course structures
Roles	The roles of teachers and students in a modular course structure
Teachers	Teacher preparedness and the importance of teacher professional development
Organizational aspects	The institutional vision towards modularity in higher engineering education, existing and planned support

3.2 Phase 1b

As this paper is being written, the coding of the included papers is still going on. In line with the findings from the informal interviews, general categories that emerged in the literature review so far and which can help coding the articles include general characteristics, conceptual background, structure (e.g., framework, principles, steps), teacher professional development, and engineering context (e.g., challenge-based learning, design-based learning).

From a first scanning of the articles, some emerging themes were found. When constructing an instructional design framework for challenge-based modular education certain elements should be taken into account: a) describe how an effective team can be established, and who should be part of that team (e.g., course designers, educators, teachers), b) how different student profiles can be taken into account, c) the requirements of the challenge, d) identification of the course(s) relevant to the challenge, e) instructional principles such as the number of modules, a rather flexible sequence of the modules, content of the modules (e.g., learning outcomes, learning activities, assessment), f) plans for interaction, regular face-to-face meetings, selecting a leader for each student team, using online platforms, and g) plans for teacher involvement and institutional support.

4.NEXT STEPS

The ongoing steps include: a) administration of inclusion criteria to the 201 articles, b) finalization of the codebook, and c) comparing the informal interview findings against the codebook; and d) coding the articles from the review. Completion of these steps will result in a set of design principles, that in phase 2 will be tested with some of the previously interviewed professionals and other teachers within Eindhoven University of Technology in order to come up with the initial version of a framework for instructional design for challenge-based instruction. Later in Phase 3, the framework will be validated. The think-aloud tasks will be based on the initial version of the framework and on helpful sources on cognitive interviewing, higher engineering education and modular course design [7, 14, 15, 16].

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