Research Proposal Innovation Fund

Project Title:

Challenge Based Modular on-Demand Digital Education Upscaled (CMODE)-UP

Project Team:

I Lopez Arteaga
SHM Stollman
C Mesutoğlu

Eindhoven University of Technology

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1.Introduction

1.1. CMODE-UP: Project Information

In Challenge-based Modular On-demand Digital Education (CMODE) project (2019-2020), a traditional engineering course was redesigned towards challenge-based and modular education. The course: "4DB00 Dynamics and Control of Mechanical Systems" was modified towards modular education that could be provided digitally and more in line with students' learning preferences. The course was restructured into 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. The course was received positively by students and their learning outcomes (grades and engagement) increased compared to previous years (Merks et al., 2020).

CMODE-UP was a continuation of the previously granted project; CMODE summarized above. CMODE project did not deliver a specific set of design principles for creating modular courses. CMODE-UP Project (January, 2021-January, 2022) presented in this report, was initiated to achieve this aim and more specifically to help teachers with evidence-based design principles to modularize their courses.

1.2. Conceptual Background

The TU/e vision statement strongly highlights the importance of a modular approach to education and students taking responsibility of their own learning paths (TU/e Strategy 2030, 2018): "With regard to education, we need to offer courses in a flexible and modular way to provide learning opportunities tailored to the individual. Making courses modular and lectures available online, and develop coherent packages of online courses for (future) on-campus students and life-long learners. Digitization is indispensable for students to learn when and where they want. We will also use it to innovate our learning and assessment systems and to support the interaction and feedback between students and their coaches" (p. 31). Instructional design principles that can help teachers in modular course design has merit in accomplishing these goals. Following a modular course structure, students achieve success in multiple course modules as well as create connections between these modules. A modular approach to course design has multiple benefits for student learning and motivation with its unique characteristics e.g., flexibility, frequent feedback, self-paced learning, computer-assisted learning and serving individual learning needs. The listed characteristics have an important role in further improvement of innovative learning environments designed for TU/e engineering students.

Challenge-Based Learning

CBL is included as one of the fundamental future goals for TU/e: "In 2030, challenge-based learning will be a distinctive element of studying in Eindhoven; an important added value of campus-based education over online education" (TU/e Strategy 2030, 2018, p. 30). In their systematic literature review, Gallagher and Savage (2020) examined 100 articles to reveal the main features, design considerations, and benefits of CBL. According to their results, the key characteristics that define CBL are: a) global themes, b) real-world connection, c) collaboration between students, academic and the industry, d) technology, e) flexibility, f) multidisciplinarity, g) innovation and creativity, and h) how the challenge is defined. In design of CBL courses, these main characteristics can act as a guide.

Modular Education

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 (Botma et al., 2015; Dochy et al., 1989). Accordingly, the set curriculum was replaced and the students were given the freedom to decide and take courses in the program that matched their learning needs. 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 (Botma et al., 2015; Dochy et al., 1989). The latter type, where the modules are independent of each other and non-sequential, can be considered the desired 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.

1.3. Purpose of the Project

The TU/e vision (TU/e Strategy 2030, 2018) not only focuses on modularization but also on engineers who can contribute to the solution of local and global challenges. In theory, modularization and CBL seem a logical combination, however in the literature both approaches to higher education have only seldomly been studied alongside each other. It is therefore imperative that we pay special attention to it in this project. Given the lack of an empirically-grounded framework targeting modular engineering education, the iterative development of instructional design principles can provide a valid structure for designing courses with a modular approach.

The objectives within the scope of this research project included: a) exploration of the possibilities of on-demand modular education within the current curriculum structure and b) establish best practices, do's and don'ts and a roadmap towards broader implementation of design principles for modular courses in higher engineering education. More specifically, this research project aimed to present design principles to be used in an evidence-based framework for modular course design.

2. Method

CMODE-UP project consisted of three stages: (Stage-1) informal interviews with key actors at TU/e, and a systematic literature review on higher engineering and modular instruction; (Stage-2) a test of the design principles that were developed using the interviews and literature review; and (Stage-3) a test of the design principles using think-out-loud interviews with teachers. CMODE-UP project resulted in design principles to scale-up the course redesign tested in the previous study (CMODE).

Figure 1 summarizes the three stages of the project.

In Stage-1, informal interviews were conducted with 13 professionals who had experience with modular instruction in higher engineering education contexts at TU/e. Also, in this stage, a systematic literature review was conducted following a content analysis method (Fraenkel et al., 2012). Multiple searches were conducted in the databases: Ebsco, Web of science, Scopus. The review was conducted with articles retrieved from the literature following the administration of exclusion and inclusion criteria and also manual searches in journals (e.g., European Journal of Engineering Education). Completion of Stage-1 resulted in a set of design principles, that in Stage 2 received improvement points from five experts (professionals and teachers within TU/e). With the completion of Stage-2, two documents were created: a) *eight design principles* and b) a *teacher guide* with the best practice articles identified from the literature to represent each design principles. With Stage 3, think-aloud interviews were conducted with eight TU/e teachers who have experience in designing modular courses. Following the completion of Stage-3, the researchers optimized the *design principles* and the *teacher guide.*

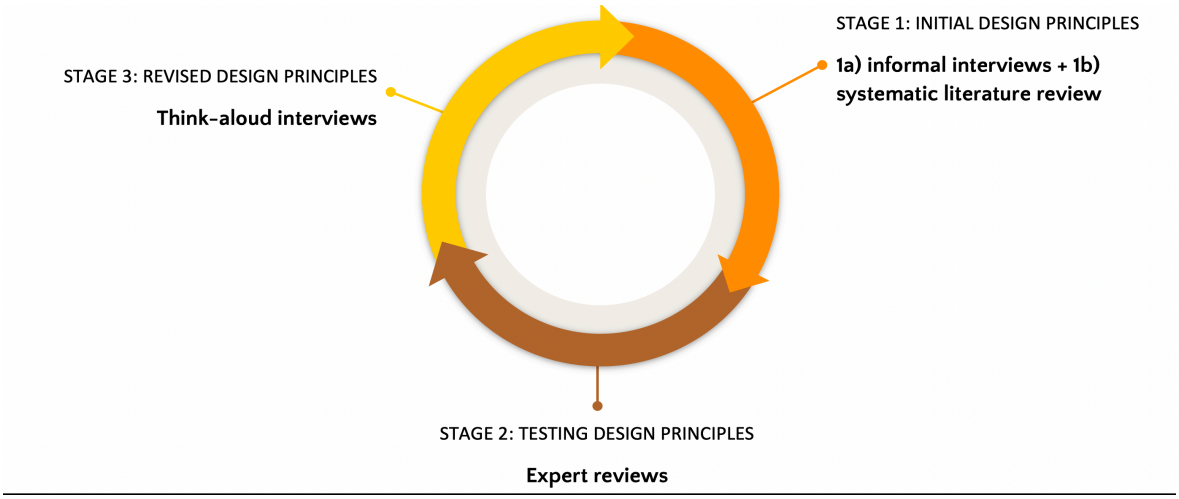

Figure 1. Methodology of the research project

2.1. Data Collection and Analysis Procedures

Stage-1

Systematic literature review

The initial step consisted of conducting multiple searches in databases e.g., Web of Science using keywords such as "engineering education" and "modules". The search focused on published peer-reviewed articles. Next, a number of exclusion (e.g., studies that address higher engineering education) and inclusion criteria were used to arrive at the final tally of articles. For example, as for the inclusion criteria, only the articles that one of both criteria applied to were 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. 83 articles constituted the final number of articles examined in this review. Codebooks were created to summarize commonalities in the reviewed articles for effective modular course design.

In stage-2 of this research project, the codebooks were used with results of the informal interviews to come up with design principles.

Informal interviews

The interviews were conducted with 13 TU/e professionals who have experiences in designing modular courses for higher engineering education. The interviews questions included: "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 carefully read the field notes taken during the

interviews several times. As a result of descriptive analysis (Fraenkel et al., 2012), general categories were created to summarize the findings.

Stage-2

Expert reviews

Short interviews were conducted with another sample of six TU/e professionals. The experts included lecturers and professionals working for teacher support. Previously set interview questions were not used. During the expert interviews, experts were first presented with the emergent modular course design ideas that surfaced from results of Stage-1. Then the experts together with the researcher brainstormed on how these course design ideas can be transformed into a set of design principles. Experts' ideas were summarized to reach an overview of all suggestions.

a) *Design principles* and b) a *teacher guide* were prepared as a result of Stage-1 and Stage-2 findings.

Stage-3

Think-aloud interviews

Think-aloud interviews were conducted with eight TU/e teachers. Appendix A presents the interview protocol.

The teachers came to the interviews with the title and learning outcomes of a modular course that they have taught before. During the interviews, the teachers worked on each design principle to design their modular course. All interviews were audio recorded. In the data analysis stage, the verbatim transcripts were used. The results were summarized in an analytical table that included teachers' cognitive processes for each design principle. Teachers' recommendations to improve the design principles were transformed into a summary. The cognitive processes together with teacher suggestions resulted in the revision of the design principles and the teacher guide for their final version.

3.Results

3.1. Stage-1

As part the systematic literature review, the researchers individually examined the retained 83 articles using codebooks. The review resulted in two separate codebooks: a) a codebook for descriptives (e.g., year and location of article) and b) a codebook for course design aspects. The second codebook included codes such as learning outcomes, student self-pacing, student feedback, status of course or module (online, hybrid), foci of modules, pedagogical framework adopted. All codebooks presented the frequencies and percentages based on counting the number of articles for each code.

Appendix B presents selected parts of the two codebooks.

The informal interviews provided an overview of what engineering education and modular education look like. Table 1 provides part of the 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
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

3.2. Stage-2

Below list summarizes some of the improvement points received as a result of an overview of expert reviews.

- Avoiding use of technical language
- Attention to online interaction
- The idea of teacher manual
- In order to transform into design principles, giving teachers options to choose from, help teachers decide
- Presenting teachers what happens when they choose whatever option,
- Embracing a more practical view
- Embracing a more visual presentation
- More effective integration with CBL

Initial versions of: a) *design principles* for modular courses and b) *teacher guide* were prepared as a result of Stage-1 and Stage-2 findings.

3.3. Stage-3

Think-aloud interviews were conducted to finalize the design principles and the teacher guide.

For each design principle, we identified two aspects: a) whether the design principles is clear and b) the cognitive processes for each design principle. We presented our findings related to these aspects separately for each design principle using an analytical table.

Table 2 below demonstrates part of this analytical table; the results related to clarity and the cognitive processes of the teachers, regarding the first design principle.

Table 2. Results for the first design principle

Clarity	Cognitive processes
Not clear	Attempts to integrate principles 1&2
	Thinking demonstrates a need for a prior step that shows the overall course design
	Questions the purpose and added value of selecting some of the course learning outcomes
	Considers whether there is an overarching project/challenge

The full analytical table led to the final version of the two products of Stage-2. With the completion of Stage-3, final versions of: a) *design principles* for modular courses and b) *teacher guide* were presented.

3.4. The Resulting Products of CMODE-UP

Design principles

The first product contains *eight design principles* for the teachers to consider as they design their course with a modular approach. Two exemplary design principles are relevant to the two questions: "How do you want to group and sequence the modules?" and "What are the strategies to facilitate students' effective use of modules?" The design principles are expressed with questions and several options below them. For each principle, the teachers first examine the related part of the second product; the teacher guide. Based on the option(s) chosen, the teacher is recommended to examine the teacher guide for more information.

Teacher guide

The second product; *teacher guide* seeks to further support teachers in designing courses by showing them selected illustrative articles. This teacher guide is a practical source to show

how the design principles have actually been implemented in the literature. This guide provides the teachers with example articles for each design principle. The guide does not tell the teacher to apply certain design principles, but gives examples and shows how and why a teacher might choose from different design options. For each of the eight design principles, the teacher guide shows:

a) a short summary of the goal of the design principle,
b) example articles from the literature that demonstrate how different options of the same design principle can be applied, and
c) critical information from the articles (e.g., teaching methods, findings) that can help teachers in their choice among the options.

Appendix C presents the introductory part of the teacher guide.

4. Conclusion

Using the results of CMODE, the CMODE-UP project aimed towards creating evidence-based design principles for teachers to design their courses in engineering education with online modules. The goal of CMODE-UP was to deliver evidence-based design principles; tailored to the needs of TU/e teachers and course designers; a practical tool that can support TU/e community in modular course design in engineering education.

The two products of CMODE-UP were the final versions of: a) *design principles* for modular courses and b) *teacher guide*. The implications for research now will include further empirical validation of the products. The evidence-based design principles of CMODE-UP are now grounded on a systematic review of the literature on modular courses in higher engineering education. The design principles need to be further strengthened and adapted using new empirical data and practical implementation. These listed needs will be addressed in the continuation of CMODE-UP, using data coming from practice as our products are used by the teachers to design and deliver courses.

Dissemination

Our findings are disseminated through:

- conference presentation; the 49th SEFI Annual Conference, September 13-16, 2021, Technical University Berlin (virtual), and
- an article in a peer-reviewed journal.

References

Botma, Y., Van Rensburg, G. H., Coetzee, I. M., & Heyns, T. (2015). A conceptual framework for educational design at modular level to promote transfer of learning. *Innovations in Education and Teaching International*, *52*(5), 499-509.

Dochy, F. J. R. C., Wagemans, L. J. J. M., & de Wolf, H. C. (1989). *Modularization and student learning in modular instruction in relation with prior knowledge.* Netherlands: Centre for Educational Technological Innovation.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). New York: McGram-Hill Companies.

Gallagher, S. E., & Savage, T. (2020). Challenge-based learning in higher education: An exploratory literature review. *Teaching in Higher Education*, 1–23. doi:10.1080/13562517.2020.1863354

Merks, R., Stollman, S., & Lopez Arteaga, I. (2020). Challenge-based modular on-demand digital education: A pilot. *Presented at SEFI Conference*, 20–24 September.

TU/e (2018). *TU/e Strategy 2030: Drivers of change.* Retrieved on September 3, 2021 from: https://assets.tue.nl/fileadmin/content/universiteit/universiteit/Strategie_2030/TUE_Strategie_2030-LR.pdf

APPENDIX A

Concurrent Think-Aloud Protocol

Welcome

The participant is first greeted by the interviewer. Then the interviewer provides brief information on the research (goals and methodology steps) and the purpose of a think-aloud interview. The participant will be assured that their participation is voluntary and confidential (An Informed Consent Form will be e-mailed to the participant to sign in).

P.S. Prior to this interview, instruction on which information to bring to the interview today (*Title* and *Learning Outcomes* of the course the teacher want to design modules for) has been provided to the participant teacher.)

The interview-Part-1

The participants will be given: a) "design principles" and b) "teacher guide" to communicate their course design ideas. General instruction on how to think-aloud is read to the participant:

> "Please explain what you are thinking in every step. The purpose is to find out how teachers think when they design the modular course using these documents. Try to think aloud as you work on the course design. Tell me everything that passes through your mind during your work searching for the answer to each design step. It is most important that you keep talking. Please also reflect your choices to the design principles on the sketch paper you are given."

The interviewer is asked to think about the Title and Learning Outcomes of his/her course. Then the interviewer asks the following questions:

> *"Do you think the information given in the Hint Box is useful for you to formulate learning outcomes? How could this box be improved?"*

The interview-Part-2

The below questions/encouragements are used by the interviewer interchangeably and as necessary, as the participant designs the course, following each design principle.

"What does this principle make you think? Is it clear what the question asks you to do? How can it be improved? Are the options clear? Which options did you have difficulty in choosing from? Are all options clear, what do you think? What other probable options would you expect to see?"

"Please refer to the Teacher Guide for this design principle. (Give some time to read) What do you think about the information provided here on the manual? Is this information helpful for you to make the design choice? How can the teacher manual for this design principle be improved?

"What is your answer to the question? Please explain your choice? What aspects/factors did you consider in making this choice? Please go ahead and illustrate your choice in the sketch paper. Please say aloud everything that you are thinking."

Exit questions

1-What are your general comments about this experience?
Would you be willing to use these documents to design a course?
2-How do you think TU/e teachers will react? Would they find the documents helpful?

APPENDIX B
Part of the Codebooks

		Modules for Programs	Modules for Courses
Categories	**Sub-Categories**		
Year	2000-2005	3 (13%)	18 (23%)
	2006-2010	4 (17%)	19 (24%)
	2011-2021	16 (70%)	43 (54%)
Location	USA	3 (13%)	66 (83%)
	Europe	2	5
	Asia	7 (30%)	3
	UK	8 (34%)	-
	Other	3 (13%)	6 (7%)
Engineering discipline	Bioengineering/ Biomedical	1	8
	Mechanical	4 (17%)	11 (14%)
Delivery of module(s)	Hybrid	6	6
	Online	16 (73%)	34 (85%)
Pedagogical framework (Some, more than one)	How People Learn, STAR Legacy Cycle	2	5
	ID model (e.g., Bloom's taxonomy, ADDIE, Briggs)	5 (19%)	8 (14%)
	Other learning theories (e.g., Kolb's learning cycle, self-regulated learning, inquiry-based)	6 (22%)	12 (21%)
	Problem based/Project-based learning	3	5
	Principles/steps/frames/ID models/components defined by authors	8 (30%)	10 (18%)
	Flipped learning/ICT/Distance education	2	8
	Other (e.g., competency-based edu., empathy model, constructivism)	1	9 (16%)
Number of modules	Single module	8	11
	Multiple modules	17 (69%)	38 (78%)
Foci of modules (Some, more than one)	Sub-topics of the course (e.g., challenge section/step, sustainability)	-	33 (60%)
	Overarching skill (e.g. professional skills, problem-solving skill, lab-writing skill)	10 (34%)	10 (18%)
	Overarching topic (e.g., environmental literacy, sustainability)	13 (45%)	-
	Hands-on/practical aspect/real-life aspect	4	9 (16%)
	Difficult part of course (e.g., difficult topic, difficult tool)	-	3
	Interdisciplinary connections	2	-

APPENDIX C
Part of the Teacher Guide