Research Proposal Innovation Fund

Project Title:

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

Project Team:

I Lopez Arteaga
SHM Stollman
C Mesutoglu

Eindhoven University of Technology

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1.Introduction

1.1. Project Background

Figure 1 outlines the project summarized in this report, CMODE-UP: Implementation, together with its two antecedent projects, CMODE and CMODE-UP.

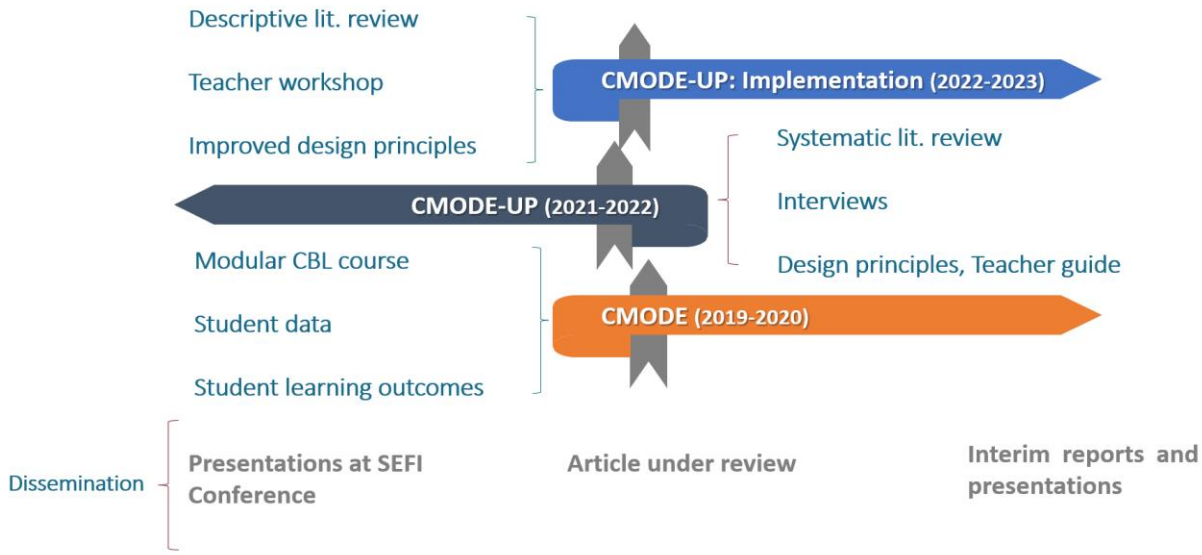

Figure 1. Summary of the three projects

In the CMODE project (2019-2020), a traditional course was redesigned towards challenge-based learning (CBL) and modular education. The 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. The course was received positively by students and their learning outcomes (grades and engagement) increased compared to previous years (Merks et al., 2020).

Since this project did not deliver a specific set of design principles, CMODE-UP project was initiated to do this and to help teachers use these design principles to modularize their courses. In 2021, in the context of the project CMODE-UP, TU/e researchers identified six instructional design principles to modularize courses in engineering education. Guided by the ADDIE model and the empirical findings of CMODE-UP, the design principles created were: (1) course content, (2) module category, (3) alignment, (4) module development, (5) implementation, and (6) evaluation (see Figure 2). Because few resources exist to incorporate principles of modular approach to course design, CMODE-UP led to important contributions

through evidence-based principles for teachers to design their courses with online modules. A teacher guide was also created to assist teachers in their design decisions. Through selected articles, the teacher guide exemplifies, for example, alignment of course LOs to modules, alignment of overarching projects to modules, examples of programming assignments, courses with elective modules.

CMODE-UP also revealed that: a) although students are mostly expected to use modules in a standard route communicated to them, there are example articles reporting on students' use of elective course modules that lead to positive learning outcomes, b) students' control over the pace of their progression within mandatory modules is also suggested, and c) aligning classroom time to module use, and to an overarching course project is critical. The above-mentioned findings and more were used in the construction of the six design principles.

CMODE-UP: Implementation (see Figure 1), was a continuation of the two previously granted projects summarized above.

1.2. Purpose

CMODE-UP: Implementation focused on delivering an evidence-based framework; 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. More specifically, CMODE-UP: Implementation (2022), aimed to present design principles to be used in an evidence-based framework for modular course design. To reach this aim, the project strongly relied on findings from CMODE and CMODE-UP.

2. Method

2.1.Research Design

CMODE-UP: Implementation included two phases to test and improve the design principles of CMODE-UP: a) a descriptive review and b) a teacher workshop. The *descriptive literature review* examined 20 research studies, which presented modular approach in relation to CBL and/or elective modules, articles (n = 9), conference proceedings (n = 9), and book chapters (n = 2). The Appendix outlines the 20 studies examined. The review was conducted to further improve the six design principles and to move towards an empirically-grounded and practical framework for teachers. The second phase, *the workshop*, was organized face-to-face and consisted of: a) an introduction about modular approach in course design, b) exercises for the teachers to reflect on courses designed using our principles, and c) a reflective discussion.

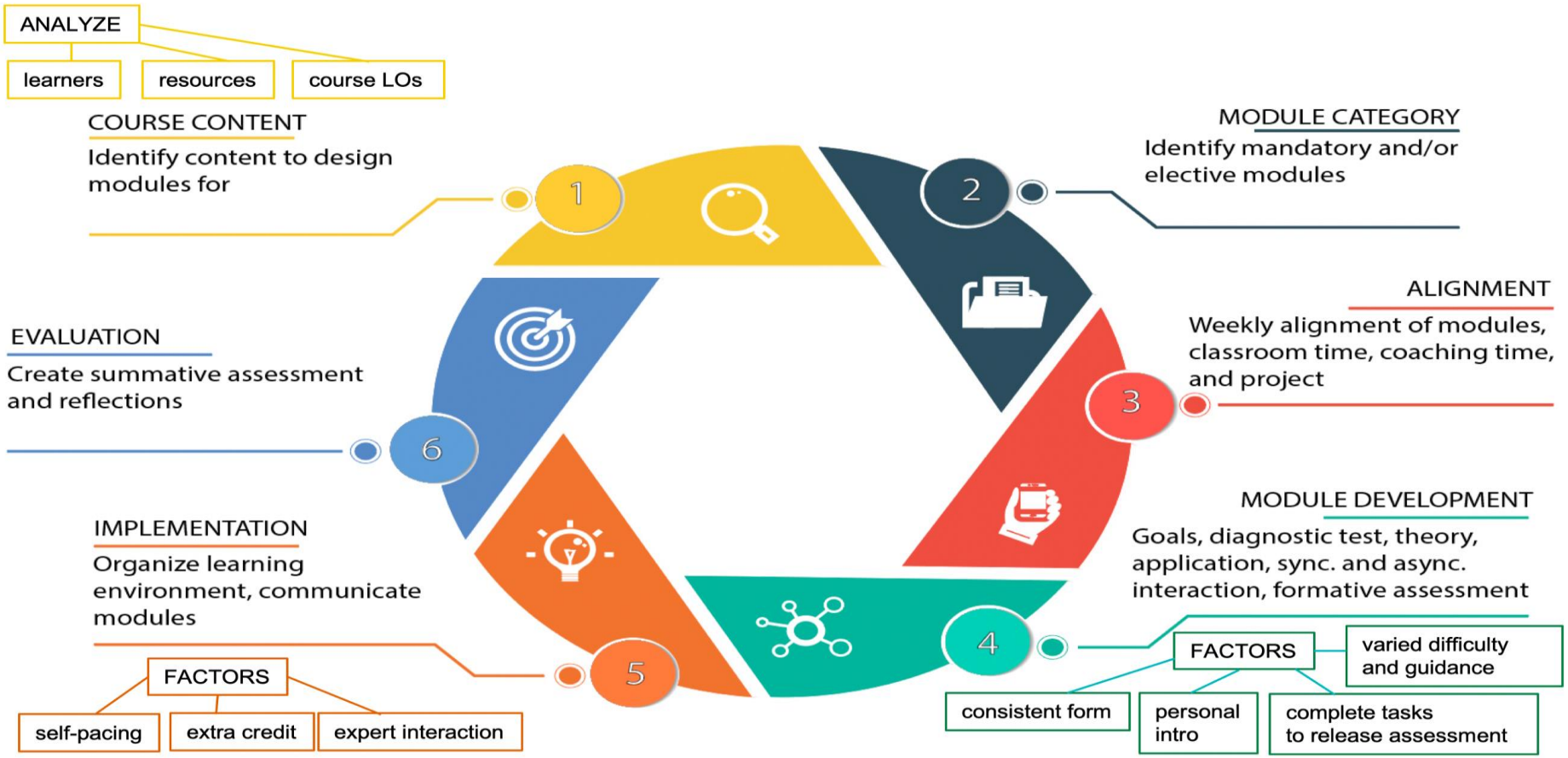

Figure 2. CMODE-UP design principles

2.2.Data Collection and Analysis

The *descriptive review* (Fink, 2019) followed three complementary steps: 1) literature search and selection, 2) individual study review, and finally 3) a comparison. The key search terms identified to locate articles in the first step were "modular course", "engineering", AND "elective/voluntary", "project", "challenge-based learning", "self-pacing". The researchers carried out a screening to eliminate studies not in the scope of this review. In doing this, two inclusion criteria were helpful. Accordingly, the studies must have had reported modular course design in relation to explicit mention of elective modules, self-pacing, alignment of modules to other course components, and/or overarching course project/challenge. Applying these criteria to the abstracts resulted in 20 studies. During the next step, individual study review, with the six design principles in mind (course content, module category, alignment, module development, implementation, evaluation), the researchers individually examined the articles carefully. Then the studies' main points to help revise the design principles were summarized in an analytical table during the step, comparison. Clustering the main points of the articles led to the three major categories: 'thinking of overall course structure', 'starting module development', and 'identifying module content' as detailed on Table 2.

Prior to the *teacher workshop,* approval from the university Ethics Committee was received for data collection. Signed informed consent forms were also collected from the teachers. Two teachers, a professor at the department of Chemical Engineering and a lecturer at the department of Applied Physics were the participants. During the two-hour workshop, the teachers engaged in structured discussions and exercises on modular courses using the design principles of CMODE-UP shown on Figure 1. Some of the discussion questions were:

- "Do you think that the design principles bring novelty to course design? If so, how?
- What is the value presented?
- What else would you expect the design principles to include?"

The teachers were presented with two example modular courses, as shown in Appendix; 'CBL course' and 'Research course'. The discussion questions around the example courses were:

- What are some challenges the teachers might face during preparation?
- What are some challenges the teachers might face during implementation?

The audiotaped discussions during the workshop constituted the data. The researchers transcribed all discussions verbatim. To arrive at a narrative description of the findings, the transcripts were summarized into key categories, commonly mentioned by the two teachers.

Table 2. Descriptive review results

Categories	**Codes**
Thinking of overall course structure	Algorithmic recommendation tool Consider logical order of content Flexibility is in 'when' Mandatory not sequenced Matrix of courses vs modules ((M)Madatory+(E)Elective) E for (a) further study/support or b) non-existing knowledge Es as extra, assigned no credit Take one/some of the Es Module can be E for one course, but M for another same module can be mandatory in different courses List of pre-req. modules for each module Unlocking module only by completing prerequisite module(s) Classroom to finish module + activities + feedback + physical opp. Next module requires the skills of the previous Interaction between departments Teacher training on CBL, modules, related-technologies, roles
Starting module development	Needs analysis Expert opinion Start with topic, LOs (content + competency) for each, challenge for each Start with challenge, topics Start with challenge, courses, topics Start with target learners, topics Start with competency domains, topics, instructional content (m/e)
Identifying module content	Video-taped lectures Review segment at the beginning Module quiz from pool of items Can re-do quiz three times with a threshold to get the credit Teacher observes assessment Modules to only include content necessary for challenge All related applications happen on campus Voluntary comprehension checks (elective exercises)

3.Results

Looking for similarities, the categories that emerged from the two methodology phases were merged into a single table. Table 3 shows the combined results summarized in three categories: a) thinking of overall course structure, b) starting module development, and c) identifying module content.

The final step was to update the CMODE design principles using the combined results. The resulting updated version is illustrated on Figure 3.

Table 3. Combined results

Categories	Codes
Thinking of overall course structure	Consider Algorithmic recommendation tool Consider interaction between departments Consider teacher training Flexibility is in 'when' Mandatory not sequenced Make a matrix of courses vs modules (mandatory(M) +elective(E)) E for (a) further study/support or to b) reach existing baseline Es as extra, assigned no credit List of pre-req. for each module Next module requires the skills of the previous
Starting module development	Start with topic, then LOs (content + competency) and challenge for each module challenge, then topics target learners, then topics competency domains, topics, instructional content (m/e) Needs analysis Q&a or general pre-assessment at the beginning Expert opinion at the beginning
Identifying module content	Threshold to get the credit, re-doing quiz multiple times Module for low-level learning objectives + classroom (application) for high-level learning objectives Knowledge modules better for earlier weeks (for cbl) Voluntary comprehension checks (for elective exercises)

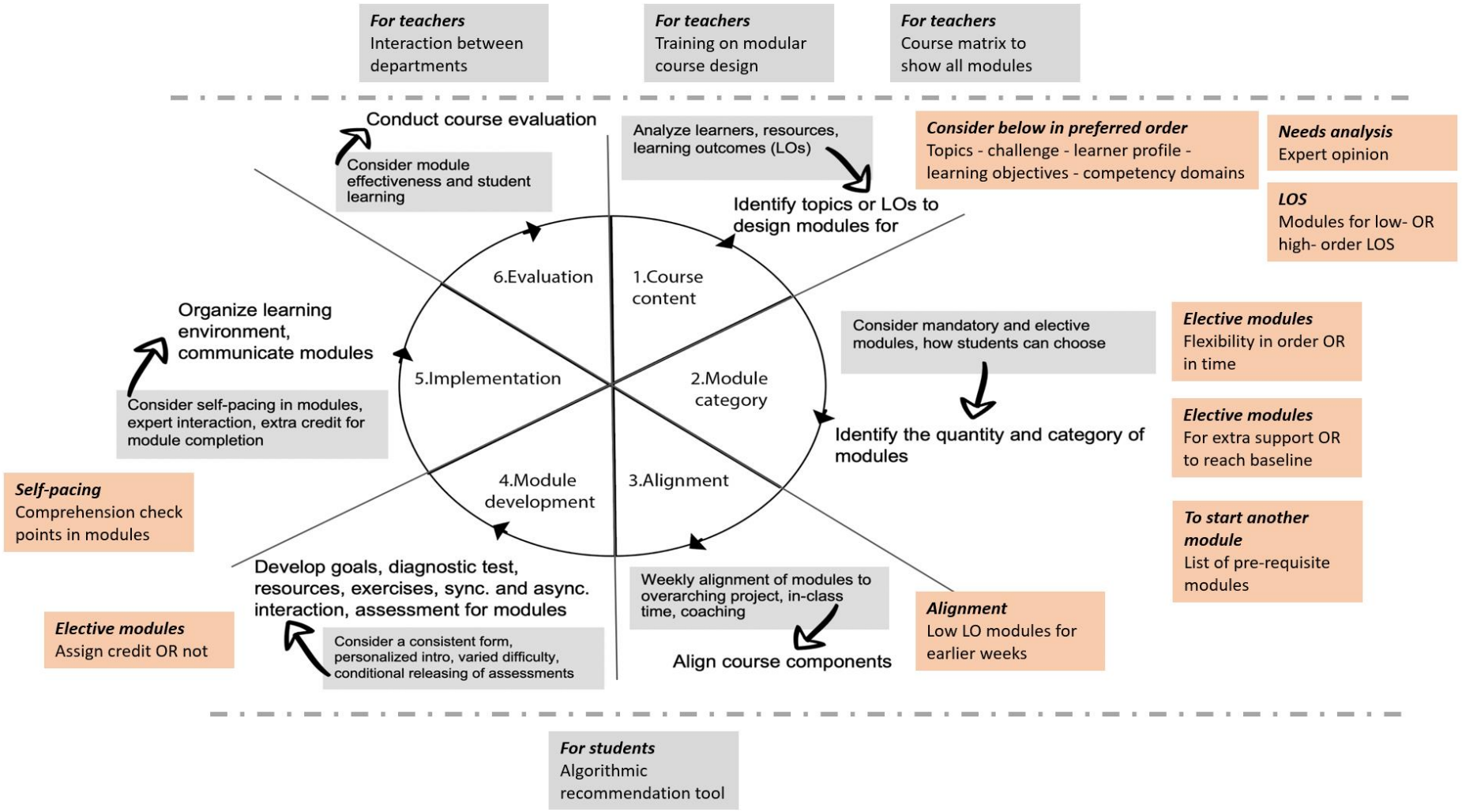

Figure 3. Revised design principles

4. Conclusion

The goal of CMODE-UP: Implementation was to deliver an improved practical tool that can support TU/e community in modular course design in engineering education. The product of the project is the improved design principles shown in Figure 3. 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 steps, using in-situ data from students and teachers.

Dissemination

CMODE-UP: Implementation findings are disseminated through:

- conference presentation; the 50th SEFI Annual Conference, September 19-22, 2022, Barcelona, Spain,
- conference presentation; the 49th SEFI Annual Conference, September 13-16, 2021, Technical University Berlin (virtual),
- research seminar at Innovation Space, May 12, 2022,
- presentation at TU/e CoP meeting, May 18, 2022,
- presentation at the 4TU Modularization event, December 9, 2021, and
- article under review in a peer-reviewed international journal.

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APPENDIX

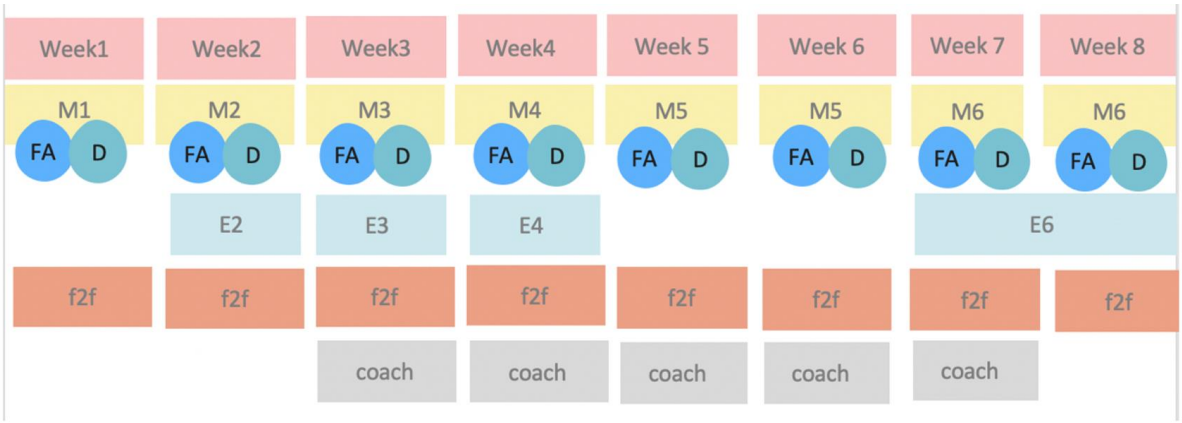
Table 1. Publications examined in the descriptive review

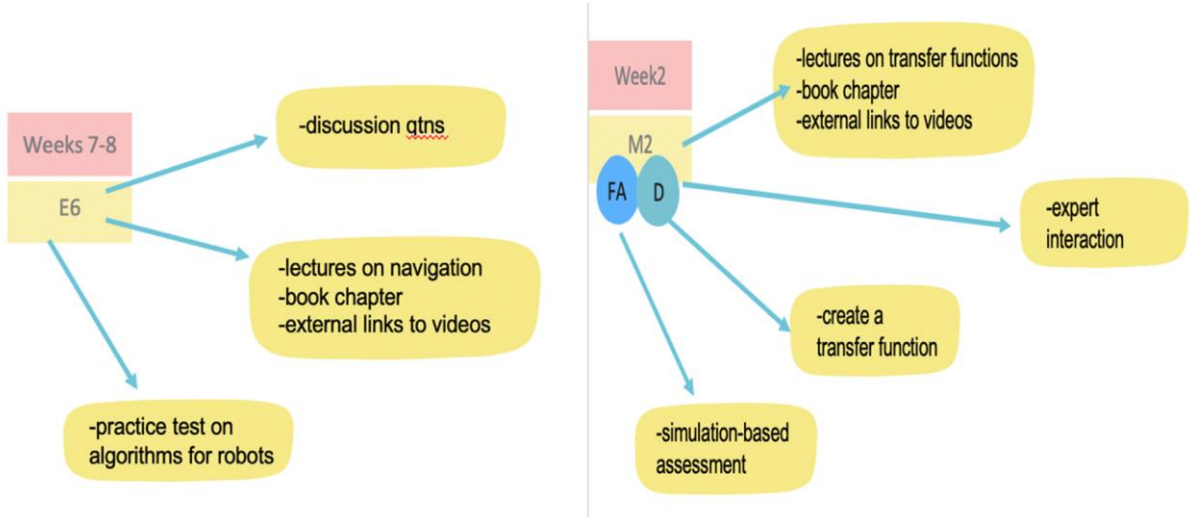
Publication type	Title	Year
Conference presentation	Towards a disruptive active learning engineering education	2018
Conference presentation	Challenge-based learning and traditional teaching in automatic control engineering courses: A comparative analysis	2020
Conference presentation	Challenge-Based Learning (CBL) in engineering: Which evaluation instruments are best suited to evaluate CBL experiences?	2020
Article	Challenge-based learning: An I-semester for experiential learning in Mechatronics Engineering	2019
Conference presentation	Integration of physics, mathematics and computer tools using challenge-based learning	2020
Conference presentation	Play lab: Creating social value through competency and challenge-based learning	2017
Conference presentation	Implementation of Educational Modules in a Biotechnology Course: A Challenge Based Education Approach	2002
Article	The practice of modularized curriculum in higher education institution: Active learning and continuous assessment in focus	2019
Article	Ensuring effective learning from modular courses: A cognitive	1997
Article	Modular instruction enhances learner autonomy	2017
Article	Development of challenge-based educational modules in the biotechnology domain	2007
Article	Replacing lecture with web-based course materials	2005
Article	Time and attention: Students, sessions, and tasks	2005
Article	The trifecta approach and more: Student perspectives on strategies for successful online lectures	2016
Conference presentation	Personalized education with the PERCEPOLIS PLATFORM	2011
Book chapter	Ontology-based recommendation algorithms for personalized education	2012

Publication type	Title	Year
Conference presentation	Algorithmic support for personalized course selection and scheduling	2020
Article	Faculty performance in the delivery of modular teaching during the CoViD-19 pandemic	2021
Article	Development and validation of instructional modules on rational expressions and variations	2017
Conference presentation	Design and development of a modular maker education course for diverse education students	2019

APPENDIX
Example Course-1

Challenge:	Design a real-time controller for a pick-and-place robot.
10 modules	*Topics of Course:* "Robot Mechanics"
M	1.Basic aspects of robotics
M and E	2.Transfer functions
M and E	3.Frequency response methods
M and E	4.Kinematics and dynamics of robots
M	5.Feedback controller
M and E	6.Different methods for navigation





APPENDIX
Example Course-2

Student Characteristics:

- The 2nd year master-level course includes 16 students.
- The students submitted **a motivation letter** to take this course to also experience modular approach.
- Some of the students have **experience with using mandatory/sequenced modules** in project-based courses.
- The students **did not take a course with elective modules** before.
- **Half of the students** designed a proposal for educational research before.

Title of Course: Research Methods in Education

Learning Outcomes:
LO1. Explain the basic concepts of education research
LO2. Analyse the fundamental characteristics of main research designs
LO3. Design a research proposal to facilitate development of educational theory and practice

Course Assessment:

- *Formative assessment:* Each mandatory module
- *Summative assessment:* A written research proposal

Learning Outcomes	Modules	Category of Modules
LO1. Explain the basic concepts of education research	**Module1**-Introduction to education research-I **Module2**-Ethics in education research	Module1 (mandatory) Module 2 (elective)
LO2. Analyse the fundamental characteristics of main research designs	**Module3**-Main research designs in education-I **Module4**-Main research designs in education-II	Module 3 (mandatory) Module 4 (elective)
LO3. Design a research proposal to facilitate development of educational theory and practice.	**Module5**-Creating a research proposal **Module6**-Conducting a literature review **Module7**-Formulating research questions **Module8**-Identifying the research design and data collection strategies	Module 5 (elective) Module 6 (mandatory) Module 7 (mandatory) Module 8 (mandatory)

Modules	Personalized video	Diagnostic test	Theory	Application	Interaction	Assessment (100%)
M1: Introduction to education research-I	-	●	●	●	Asynchronous-Pose one question on the discussion board referring to the book chapter	Respond to test with open-ended qtns. (5%)
E2: Ethics in education research	-	●	●		Asynchronous-Pose one question on the discussion board referring to the video you watched and respond to a question asked by one of your peers	-
M3: Main research designs and data collection-I	-	●	●		Synchronous-Join check-in session to explain your proposal topic and get feedback	Respond to multiple choice qtns. (5%)
E4: Main research designs and data collection-II	-	●	●	●	Synchronous-Join brainstorming session to reflect on and decide on your proposal topics	-
E5: Creating a research proposal	-	●	●	●	Synchronous-Using the Miroboard provided, create research questions and research designs for given topic with your assigned teammates	-
M6: Conducting a literature review	●	●	●	●	Synchronous-Join webinar to discuss issues with literature review	Upload results of a short literature review (10%)
M7: Formulating research questions	●	●	●	●	Synchronous-Join webinar to discuss issues with formulating research questions	Create research questions based on a given case (10%)
M8: Identifying the research design and data collection strategies	●	●	●	●	Synchronous webinar to discuss issues with your methodology	Upload an example research methodology considering a given case (10%)
	Summative assessment: A research proposal with literature review, research questions and methodology around the topic of inclusive education. (60%)					