EXAMINING BEST PRACTICES IN CURRICULUM DESIGN: INSIGHTS FOR ENGINEERING EDUCATION

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ABSTRACT

Higher education must be prepared for the ever-changing needs of the world to ensure that future engineers receive extensive training and are equipped to provide significant contributions to both the workforce and society. It is important for higher education leaders to be aware of the need for regularly reviewing curriculum and take part in development to ensure quality improvement. Engineering education needs to be up to date and driven by the need to prepare graduates for the challenges posed by rapidly changing technology, industry, and society. This paper specifically aims to identify best practices for curriculum design in engineering education. Data was collected through the exchange of engineering and business curricula among members participating in the DECART project (DECART 2022). The shared curricula underwent critical examination based on key features related to curriculum components. The analysis included reflection and feedback from project partners. The findings hold significance for engineering educators in various contexts, offering insights into curriculum transformation, agility, and resilience amidst increasingly Volatile, Uncertain, Complex, and Ambiguous (VUCA) environments, which continue to influence engineering education and higher education.

1 INTRODUCTION

1.1 Curriculum Design

Curriculum design holds a pivotal role in shaping the educational journey, ensuring its alignment with industry requisites, fostering critical thinking, and endowing students with the competencies requisite for success in their careers. According to Kumar and Rewari (2022), an outcome-based approach to curriculum is imperative, with clearly delineated program and course outcomes, in line with the demands of accrediting bodies and global benchmarks.

An important consideration is that of graduate employability and ensuring that the curriculum is of relevance for the labour market (Davey et al. 2018). Curriculum review and revision must be done on a regular basis, in response to changing needs of industry and to ensure innovation (Dopson and Tas 2004). A recommendation from the research of Davey et al. (2018) indicates that it is critical to provide support for designing new curricula as well as re-designing current curricula. It has been argued that diverse stakeholders, such as students, graduates, facilitators, staff, industry, and business, and even parents, should be involved in co-designing and co-delivering curricula (Plewa, Galán-Muros and Davey 2015; Kumar and Rewari 2022). It is important that the curriculum is accessible and can be adaptive and responsive (Prideaux 2003).

In the evolving landscape of the 21st century, the engineering domain finds itself immersed in a milieu characterised by volatility, uncertainty, complexity, and ambiguity, often referred to as VUCA (Bennett and Lemoine 2014; Panthalookaran 2022). The unprecedented pace of technological advancements, globalisation, and dynamic market demands has birthed challenges necessitating engineers equipped with a distinct skill set.

To prepare future engineers for the demands of the VUCA environment, curricula must evolve. By furnishing students with essential skills and knowledge, curricula endeavour to promote sustainability and address intricate engineering challenges within a VUCA framework (Rouvrais et al. 2018). In the ever-evolving realm of engineering, the acronym VUCA serves as a guiding framework to comprehend and navigate the challenges emerging in today's swiftly changing environment (Panthalookaran 2022; Bennett and Lemoine 2014). Understanding VUCA in engineering transcends mere acknowledgment; it serves as a clarion call for both professionals and higher education practitioners.

Engineers must foster resilience, agility, and a mindset of continuous learning to thrive in future VUCA environments. Educational programs need to surpass the imparting of technical skills, integrating experiential learning, collaborative projects, and exposure to real-world scenarios (Rouvrais et al. 2023). Latha and Christopher (2020) anticipate in their paper that with training, VUCA and its associated challenges will metamorphose into opportunities, fostering a dynamic culture propelling Engineering Education towards progress and productivity. Niemczyk (2023) underscores the necessity of adopting a mindset shift to address the challenges of the 21st century within the prevailing VUCA environment. Integrating VUCA principles into engineering curriculum design signifies a departure from traditional, inflexible educational models. Program leaders must ensure that the curriculum is structured and implemented with the ability to navigate a context of uncertain changes (Ciolacu et al. 2023).

1.2 Theoretical Importance

The field of curriculum studies involves examining different approaches to designing, implementing, and evaluating educational programs. These perspectives may include curriculum as a product, process, praxis, or cultural context, among others.

Van den Akker's (2003) work focuses on providing educators and researchers with frameworks to understand and navigate the complexities of curriculum development. He presents the ten components metaphorically as the supporting strings in a spiderweb with the rationale for the learning at the web´s centre. Figure 1 explains Akker's components in a spiderweb.

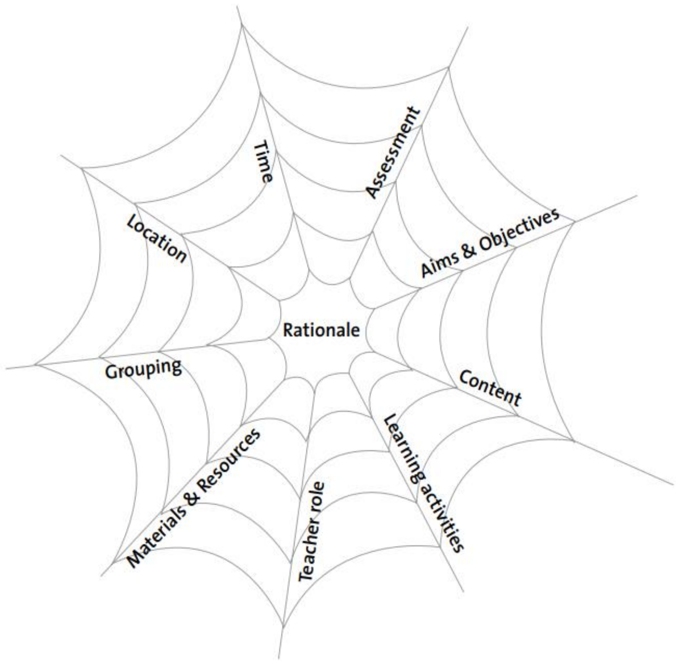

Fig. 1. Van den Akker's framework (Van den Akker, 2003:43)

Jonnaert et al. (2021) present a model that is valuable when transforming the curriculum and presents the curriculum as composed of three connected domains of educational policies of curriculum and of education practices. Figure 2 explains the components in Jonner's model.

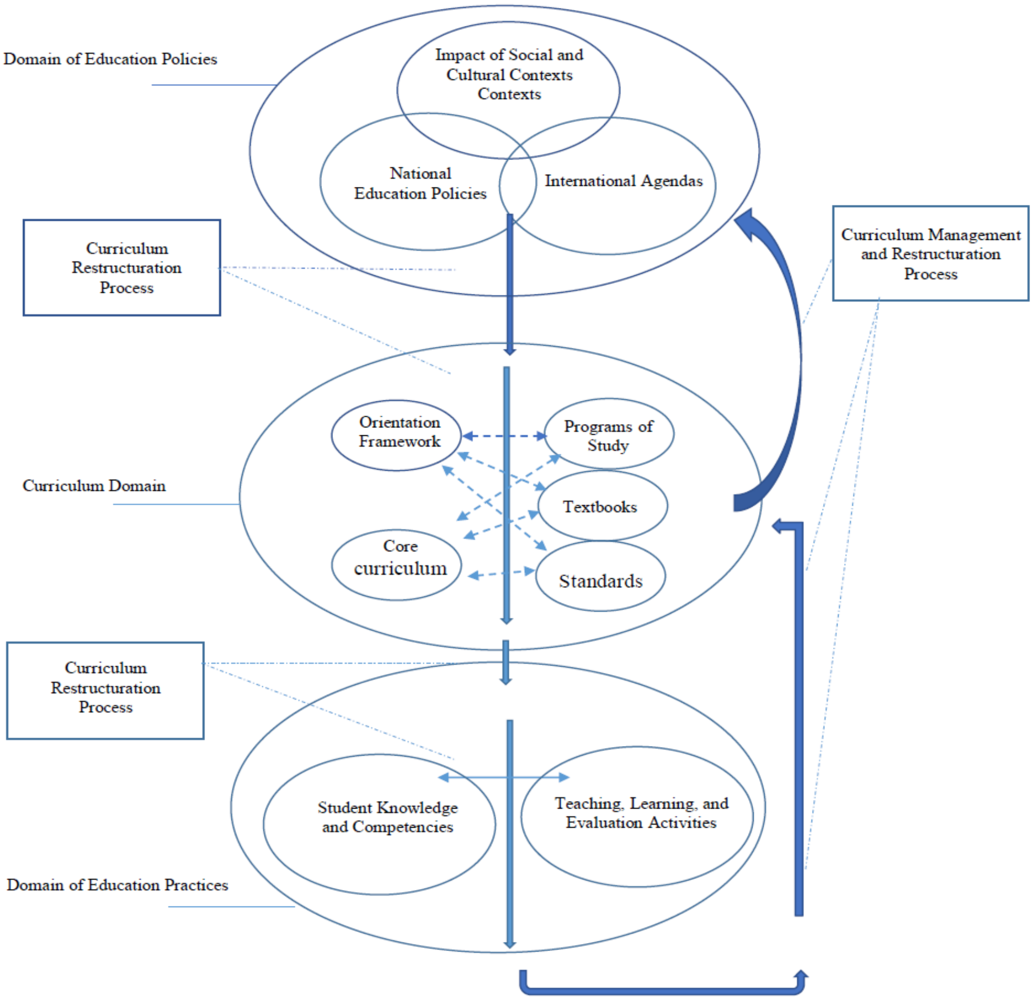

Fig. 2. The Jonnaert model (Jonnaert et al., 2021:11)

The CDIO (Conceiving, Designing, Implementing, Operating) model represents a framework for enhancing engineering education by focusing on a hands-on and project-based approach in an integrated manner with outcome-based education and a syllabus of learning outcomes (Crawley et al. 2014; Malmqvist et al. 2020). The twelve CDIO standards emphasise the integration of engineering fundamentals, personal and interpersonal skills, and real-world applications.

More recently, Brink et al. (2023) defined curriculum agility as an ability “to be responsive to changes in society’s, industry’s, and students’ characteristics and needs, by proactively and in a timely manner adapting the curriculum’s relevant organisational structures, learning outcomes, learning activities, and assessments” (27). In their perspective, ten principles of curriculum agility are defined, from educational vision to stakeholder involvement.

1.3 Question Addressed

The paper addresses the question of what best practices for curriculum design can be identified, based on actual and exemplary curricula in engineering education, reviewed by faculty from several countries and following the VUCA environment that we are navigating. Models from van den Akker (2003), Jonnaert (2021) and the CDIO standards (Crawley et al. 2014) formed the theoretical foundation in the analysis, which led to a specific new model with nine curriculum components (Audunsson et al. 2024). The results are from a study conducted in the DECART (Designing Higher Education Curricula for Agility, Resilience and Transformation) project (ERASMUS+ 2022-25). The project partners are from diverse higher educational institutions across three continents (Europe, Asia, and Africa), and are involved in Science, Technology, Engineering and Mathematics (STEM) and Management education.

1.4 Research Aim

The aim of this paper is to provide guidance to higher education leaders in STEM and Management education on curriculum design and sustainable resilient program transformation.

2 METHODOLOGY

The study primarily utilises reflective practices by faculty in Higher Education within the DECART project, specifically focusing on their roles as reflective educators. Consequently, the study aligns with the interpretivist paradigm. One of the DECART project's aims is to investigate curriculum design, which we approached through three phases of data collection and analysis.

In Phase 1, beginning in 2023, six project partners shared the curricula they were involved with, as well as other innovative and exemplary curricula they knew of. The shared curricula were mainly from Engineering and Management, reflecting the nature and objectives of the DECART project. Phase 2 involved a critical examination of these diverse curricula by the six project partners, focusing on key features related to the curriculum. The components identified in Phases 1 and 2 were discussed and analysed, resulting in the identification of nine components (see Results and discussion). The identified components may not be exhaustive and do not encompass all elements from the curriculum development literature. In Phase 3, all project partners (a total of 17 individuals related to the project) reflected on and engaged with the received feedback to identify best practices for curriculum design components. This analysis is presented below, in Results and discussion.

3 RESULTS AND DISCUSSION

The components that the partners identified are 1) learning outcomes, 2) entry requirements, 3) structure of program, 4) teaching methods, 5) location of teaching and learning, 6) teaching of interpersonal skills, 7) assessment methods, 8) language, and 9) ethno- and sociographic aspects. The following section thus presents the key points which were noted by project partners in terms of identifying best practices within the context of curriculum design.

3.1 Learning outcomes

It was indicated that learning outcomes or goals should promote co-building of knowledge, autonomy, communication, theoretical engagement, and intellectual independence. Also important is a good structure of the learning outcomes. The learning outcomes should have been explained in the module or course outline. Students should thus be aware of the goals or learning outcomes and should be able to know how to apply the knowledge that they gained to solve real world problems. It is also important that general and specific skills, knowledge, and attitudes are clearly outlined. The curriculum should also be practical, involving real-world implications and not just theory. It was considered important that the goals and learning outcomes have a direct impact in terms of leading to the training and education of graduates who can contribute to the development of society, enhance existing knowledge, address complex problems, and ultimately be responsible citizens.

Within the business context, it was noted that goals or learning outcomes should be more applied, and would typically be relevant for business stakeholders, which would include the students, who are often working. Goals and learning outcomes should thus be adapted to the context. It was also noted that goals or learning outcomes should incorporate national values.

3.2 Entry requirements

It was noted that entry requirements for students should be clearly outlined and should be detailed and understandable. There should be a link to national requirements, and these should be coherent with learning outcomes.

It was argued that entry requirements typically focused on the basic educational requirements, such as matric or similar, or a maths background for STEM subjects. Some degrees may also have specific requirements in terms of grades, language, and possibly practical work experience and a minimum age.

3.3 Structure of the program

The structure of the program should clearly indicate the academic timelines and schedules, and indicate the semesters, terms, and breaks. The duration of the programme and modules should be clear, with all compulsory and elective modules outlined. Learning pathways are explicit, as well as the hours, credits, format, location, and whether there are internships.

3.4 Teaching methods

It was noted that there should be diverse teaching methods. The learning methods typically include lectures, group work, projects, and case studies. There may also be guest lectures or presentations from industry professionals. The student experience is critical. Teaching methods should be coherent with entry requirements and learning goals. It was also noted that there is great value in incorporating a problem-based approach, flipped learning, and ensuring a student and faculty-friendly learning management system.

Key aspects to consider is to record the lectures, which became a critical practice during the Covid-19 pandemic. The level of the programme and the student must be considered. For example, Business School students are usually more mature, and often have a job. Adult learning principles and the integration of work and life experience of the student is thus incorporated.

3.5 Location of teaching and learning

The location of teaching and learning is important, especially in considering that there may be online teaching and learning. Students may also spend a semester abroad or be based in a company. It should be clearly outlined if the learning location may not only be confined to campus.

3.6 Teaching of interpersonal skills

The value of having diverse interpersonal skills was noted as critical for the development of students, especially to ensure that they were ready for the world of work, but also to empower them during their years of studying. The skills should be visible in the diverse modules. Various interactive and collaborative learning activities should be designed and integrated into the curriculum to enhance students' interpersonal skills.

The importance of developing soft skills for students was highlighted. These include teamwork, communication, leadership, decision-making, dialogue, conflict management, emotional intelligence, responsibility, time management, intercultural, and being able to work effectively individually as well as with others. Students should also be able to manage their own career development.

3.7 Assessment methods

It was noted that there should be diverse types of assessment. In certain instances, companies and/or other industry professionals may be involved. The value of continuous assessment was noted. Rubrics should be provided.

3.8 Language

It was highlighted that there is value in having instruction be provided in more than one language, especially where there are national languages. There is also value in having materials, module outlines, and assessments available in the relevant national languages. It is however important that necessary resources are provided, as this would have implications for various aspects related to teaching and learning.

3.9 Ethno- and sociographic aspects

Ethno-/sociographic components need to be well specified. It was noted that diversity is critical, especially with respect to the diverse backgrounds of students, as well as diverse educational backgrounds. It is also important to consider the culture and specific needs that international students may have. Related to this is the need to focus on communities, society, partnerships, collaboration, and values. Other important considerations include female representation and industry collaboration.

4 SUMMARY AND CONCLUSION

If we compare our 9 components to the models described in Section 1.3, we see that van den Akker’s framework (2003) provides a comprehensive view by integrating these components into a coherent system that emphasises the interrelationships between curriculum elements. It highlights the importance of considering the socio-cultural context, adaptability, and the alignment of learning activities and assessment methods with the intended learning outcomes. This alignment ensures a holistic and effective approach to curriculum design and implementation. The Jonnaert model (2021) integrates its components within a competency-based framework. Both our list and the CDIO standards (Malmqvist et al. 2020) emphasise crucial aspects of curriculum design. The CDIO standards provide a structured and integrated approach focused on producing graduates who can conceive, design, implement, and operate complex systems. They highlight the importance of active learning, integrated curriculum, and competency-based assessment, aligning closely with many components from our list, such as learning outcomes, teaching methods, and assessment methods. The CDIO framework, however, places a stronger emphasis on engineering-specific contexts and hands-on learning environments. Our framework highlights the importance of developing and accessing competencies in real-world contexts, promoting a more holistic and flexible approach to education that is responsive to the needs and backgrounds of all learners.

Although the structure from van den Akker (2003) and the above nine components appear comprehensive in describing a curriculum, it is important to ensure that the curriculum has the inherent property of flexibility to be able to readily respond to different VUCA situations. This was especially evident during the COVID-19 pandemic.

In summary, best practices in curriculum design for engineering education are multifaceted, encompassing industry relevance, active learning, interdisciplinary approaches, and a focus on soft skills development. A curriculum that adeptly integrates these elements not only equips students with technical knowledge but also cultivates the adaptability and versatility necessary for a successful engineering career. As technology advances and societal needs evolve, engineering education must remain at the vanguard of innovation to produce graduates capable of tackling future challenges.

We would like to conclude by underlining the importance of the findings and recommendations for a wide array of stakeholders, including educators, curriculum leaders, quality assurance and accreditation bodies, students, and industry players. These insights have the potential to drive curriculum transformation, agility, and resilience in the face of VUCA contexts. The paper accentuates the potential impact on curriculum and course development, engineering projects, student preparation, and engagement. The study findings hold valuable insights for engineering educators across various contexts, particularly as they were derived from real curricula and evaluated by faculty involved in curriculum design or reflective educators who grappled with swiftly responding to the challenges posed by VUCA conditions in Higher Education. The recommendations carry implications for curriculum development, enhancing student engagement and preparing engineering students for the future.

The study limitation, which is also its strength, is that it builds on the work of a small, closed group of DECART project partners. Nonetheless, all partners are experienced teachers who are deeply involved in curriculum design. The study limitations also include time constraints, and that the study drew on limited methods. This study is part of the DECART project, an EU funded Erasmus+, n 2022-1-FR01-KA220-HED-000087657 (DECART, 2022).

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