Curriculum Agility principles for transformative innovation in engineering education

Citation for the original published paper (version of record):
Brink, S., de Hei, M., Sjoer, E. et al (2024). Curriculum Agility principles for transformative innovation in engineering education. European Journal of Engineering Education. http://dx.doi.org/10.1080/03043797.2024.2398165

European Journal of Engineering Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ceee20

Curriculum Agility principles for transformative innovation in engineering education

Suzanne Cecilia Brink, Miranda de Hei, Ellen Sjoer, Carl Johan Carlsson, Fredrik Georgsson, Elizabeth Keller, Charles McCartan, Mikael Enelund, Reidar Lyng & Wilfried Admiraal

To cite this article: Suzanne Cecilia Brink, Miranda de Hei, Ellen Sjoer, Carl Johan Carlsson, Fredrik Georgsson, Elizabeth Keller, Charles McCartan, Mikael Enelund, Reidar Lyng & Wilfried Admiraal (04 Sep 2024): Curriculum Agility principles for transformative innovation in engineering education, European Journal of Engineering Education, DOI: 10.1080/03043797.2024.2398165

To link to this article: https://doi.org/10.1080/03043797.2024.2398165

Published online: 04 Sep 2024.

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
https://doi.org/10.1080/03043797.2024.2398165

Curriculum Agility principles for transformative innovation in engineering education

Suzanne Cecilia Brink [a,b], Miranda de Hei [c], Ellen Sjoer[c], Carl Johan Carlsson [d], Fredrik Georgsson [e], Elizabeth Keller [f], Charles McCartan [g], Mikael Enelund[h], Reidar Lyng [i] and Wilfried Admiraal [j]

[a]ICLONLeiden University Graduate School of Teaching, Leiden, the Netherlands; [b]Centre for Educational Development, Umeå University, Umeå, Sweden; [c]Research Group Sustainable Talent Development, The Hague University of Applied Sciences, Hague, The Netherlands; [d]Department of Communication and Learning in Science, Chalmers University of Technology, Gothenburg, Sweden; [e]Planning Office, Umeå University, Umeå, Sweden; [f]Department of Learning in Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden; [g]School of Mechanical & Aerospace Engineering, Queen's University Belfast, Belfast, Northern Ireland; [h]Department of Mechanics and Maritime Sciences, Chalmers University of Technology, Gothenburg, Sweden; [i]Center for Science & Engineering Education Development, NTNU Norwegian University of Science & Technology, Trondheim, Norway; [j]Centre for the Study of Professions, Oslo Metropolitan University, Kjeller, Norway

ABSTRACT

Transformative curriculum innovation is needed in engineering education programmes, to continuously keep up to date with developments in the professional and research disciplines, in society, technology and pedagogy, and in the characteristics and needs of its diverse students. To enable and facilitate such innovations, both the curriculum's design and its institutional organisation need to be easily adaptable. This paper introduces Curriculum Agility, a concept that has been developed between 2018 and 2023 in a series of focus group sessions with engineering education practitioners and experts. Throughout these co-creational and iterative sessions, Curriculum Agility was defined as a responsively organised education, with dynamic learning contents and flexible pedagogics and didactics, while all involved staff is continuously developing competency to deal with the necessary transitions. Ten principles of Curriculum Agility are presented to guide curriculum innovators at programme and course level towards continuous transformation that is desirable, feasible, and viable within their context.

ARTICLE HISTORY
Received 23 March 2023
Accepted 25 August 2024

KEYWORDS
Curriculum Agility; engineering education; curriculum innovation; transformative innovation; co-creation

Introduction

Since the 1990s, there has been an ongoing discourse in engineering education (EE) on how it needs to adapt to discipline-specific, technological and societal changes that lead to the need to teach students different and additional competencies for employability as well as competencies for sustainability (Kolmos, Hadgraft, and Egelund Holgaard 2016). Sheppard et al. (2008) examined EE on a large scale for several years and emphasise the need for a holistic view to meet these demands of the twenty-first century, with respect to diversity, quality, and rigour in curriculum adjustments. New educational paradigms are needed, rather than mere tweaking of curricula. Grasso and Burkins (2010) describe the resulting tension between the nineteenth-century design of Higher Engineering

CONTACT Suzanne Cecilia Brink suzanne.brink@umu.se linkedin.com/in/suzannececiliabrink

Education Institutions (HEEIs), the twentieth-century curriculum designs to teach engineering skills, and the twenty-first-century professional context after graduation. Therefore, they agree that there is a need for transformation rather than reformation in education, as only transformation into these new paradigms can address the challenges ahead due to disruptive technologies, globalisation, and demographic change.

Which knowledge, skills, and attitudes students need to learn to be able to work and function in this era, the employability competencies, has been studied abundantly (Dede 2010). Kamp (2016) summarises a kaleidoscope of learner attributes such as creativity, communication, lifelong learning, social relevance, interdisciplinary thinking, and entrepreneurship, for engineering students specifically. Martínez Bravo, Sádaba Chalezquer, and & Serrano-Puche (2021) summarise and capture a vast list of competencies belonging to digital literacy in their meta-study. The CDIO syllabus 3.0 development (Crawley et al. 2014; Malmqvist et al. 2022) shows a continuous refining of expected learning outcomes to underlie engineering course and programme design. This syllabus shows both competencies for employability and for sustainability. Many universities work with the Sustainable Development Goals (United Nations 2021) for students to contribute to a global sustainable society (Wiek, Withycombe, and Redman 2011). They add the competencies needed to promote sustainable development to their engineering curricula: understanding the role of culture, appreciating cultural diversity, and applying humanistic and holistic approaches to create a peaceful and equal world (UNESCO 2017).

Knight (2001) pronounces how the increasingly complex learning of engineering is best promoted by coherent curricula, with clear links and progression between courses of a programme. But this kind of coherence is not widespread. Kolmos, Hadgraft, and Egelund Holgaard (2016) discuss how universities more often choose minor revision strategies, adding on or integrating at course level, than the more complex and demanding redesign or transformation of their engineering programmes. With the example of social-emotional skills, Scheerens, van der Werf, and de Boer (2020) show how diverse the translations of such 'new' employability competencies are in higher education, resulting in numerous pedagogic and didactic formats of what and how to teach and assess. When students even need to be exposed to wicked sustainability problems that are complex, unstructured, and interconnected, to develop truly useful sustainability competency (Kopnina 2020; Malmqvist et al. 2022), the implementation requires even further-stretching changes that are not clear-cut (Hanstedt 2023).

Subsequently, we see many different translations, implementations, and operationalisations of distinctive employability and sustainability competencies in educational practice. How innovative these are, how much of a change compared to how it was before, depends on the context, culture, and (academic) traditions of the HEEI, varying from incremental (continuous improvement), sustaining (securing position), radical (breakthroughs to new targets), to disruptive curriculum innovations (altering the system) (Christensen 2000). Lindsay et al. (2023) take the context out of the equation and look at the maturity of a curriculum innovation. They state that when experience (branding and service), offering (systematic implementation) and configuration (networking, structure, profit) are all covered, a disruptive innovation is anchored to sustain. There are examples of successful radical and disruptive curriculum innovations on the programme level (Andrade 2020; De Beer and Van Niekerk 2017; Hallenga-Brink 2018; McCully and McDaniel 2007; Miller 2019; Willis & Anderson, 2013) but all show different approaches in this sense. They do have a reflective process in common and each has a shared vision underlying the innovation. Considering engineering education worldwide, differences in norms, values, and priorities in the global north and south and different academic traditions lead to different assessments of which and how much change is desirable and how it sticks (Escobar 2017; Nicholson 2022). It matters who does the innovation.

HEEIs that work from a social innovation and ethical point of view on organisational educational changes and want to practice as they preach, benefit from inclusive co-creation within the curriculum design processes with multiple stakeholders (Baumber et al. 2020; O'Donnell 2016). But also HEEIs that operate more from an academic or market-driven mode than a hybrid (societal-values-

driven) one, have to move beyond the individual incremental course-based improvement based on student evaluations (Kolmos, Hadgraft, and Egelund Holgaard 2016), and need different stakeholders around the table. The more disruptive, the more stakeholders are impacted by a curriculum innovation. Lindsay et al. (2023) indicate that teaching staff is the most important stakeholder for acceptance, as they need a willingness to change. Merton et al. (2009) points out the importance of the role and advocacy of the leadership in the acceptance of a radical or disruptive curriculum innovation. Fullan and Ballew (2004) include moral purpose, coherence making, energy, enthusiasm, and hope as ingredients in their framework for leadership to reach commitment. But Coppoolse (2018) shows that making changes happen as an innovation manager, in a top-down way by running a temporary project, is suboptimal and risks premature termination or lack of adoption of initiatives. Walkington (2002) concludes that curriculum development is no longer the sole responsibility of one – any – single academic in a university, but instead requires a broader holistic approach that considers the needs of and impacts on students, teachers, institutions, employers, and governments. This study investigates such holistic approaches when co-creation (Brown 2008) with such stakeholders is considered.

Because the VUCA (Volatile, Uncertain, Complex, Ambiguous) world (Kamp 2016) unpredictably pushes the need for shifts and changes of curricula through time, HEEIs' needs can vary considerably, regarding to what extent to disrupt their curricula, which parts, at what point in time, and how often. Obstacles in the change processes are plenty, such as policies and laws, exam board approval, the need for developing staff competency and their willingness, lack of resources, and students' opinions (Brink et al. 2019), but are also highly context specific. Transformative curriculum innovation processes strive to create new value, reconciling tensions and dilemmas, and take responsibility to shape a better future (OECD 2017). They can include many bigger and smaller changes along the way. The question is then what can *enable* such continuous curriculum innovation, no matter in which direction it sets out to go, and whenever it is desirable in a certain context and moment.

The curriculum is the sum of learning vision, goals, content, resources, teaching, assessment, time, place, collaboration, and organisation (van den Akker, Kuiper, and Hameyer 2003) at both course and programme level. Considering all the diverse, continuous, multi-perspective, and multi-stakeholder curriculum innovations possibly needed in EE in a VUCA world, a certain *agility* is needed in the curriculum design. This agility refers to an ability to continuously adopt, respond, tweak, or change what is taught, how it is taught and how it is organised. Yet, this pressures the prevailing outcomes-lead curriculum designs and the outcome-oriented quality systems around them. This Curriculum Agility (CA) is what this study focuses on:

> What principles contribute to and help curriculum innovators to develop Curriculum Agility in higher engineering education to facilitate continuous transformative curriculum innovation processes?

The study is performed in the context of engineering education, but the findings can contribute to curriculum innovation in other profession-oriented disciplines as well. It includes all EEs' direct and indirect stakeholders, no matter where a university is located. The sought principles are directed to the people contributing to the actual curriculum transformations. Coppoolse (2018) uses the term innovation managers for those who lead the innovation, whether a project leader, consultant, or line manager. In this study, we use the term curriculum innovator, to embrace the holistic approach suggested in the literature review and include all practitioner-participants who are involved in the process, no matter their role and regardless of the position they hold within their university.

Method

Procedure and participants

Within educational design research, the first stage of research *for* intervention McKenney and Reeves (2018) seeks to contribute to theoretical understanding by focusing on the problem, the context in

all its complexity and the different stakeholder perspectives. This study aims to give insight into what is happening when working with continuous curriculum transformation in the increasingly complex context of engineering education worldwide. Therefore, it sought to involve those who are part of that complexity and working with curriculum innovation. International engineering education network meetings and conferences were chosen as the arena to get in contact with an international variety of curriculum innovators. Focus group sessions were planned for participants to discuss general assumptions in curriculum innovation and together synthesise pluralist principles in a co-learning agreement: gaining experience and expertise by participation through action and reflection by both researchers and practitioners within the group. Thus, the participants were co-creators of an – at the start of 2018 new – way of looking at the programme-level transformative curriculum innovation: by considering the agility of the curriculum design and organisation. By this, the study aimed to contribute to the development of transformative curriculum innovation theories at the crossroads of programme curriculum development and educational innovation theory.

McKenney and Reeves (2018) indicate that creativity within research *for* intervention is typical and essential to cater for the necessary flexibility and responsiveness within the development process of the answer to the research question. The sessions were a journey of which the end destination was yet unknown, and therefore needed this creativity. Therefore, co-creative research-through-design activities (Godin and Zahedi 2014) were planned in the focus group sessions to flexibly guide the research process towards answers captured in a certain tangible form. The activities were offered in the typically non-linear, iterative design thinking phases of empathising, defining, ideating, prototyping, and testing (Brown 2008): The empathise phase focused on brainstorms on the different needs, desires, challenges, obstacles, and motivations at play in curriculum innovation, to increase the relevance of the eventual results. By integrating user and expert experiences in the brainstorming sessions, change opportunities were identified (Gallagher and Thordarson 2020). In the defining phase, the vision, definition, scope, and constraints of CA were put into words based on the insights of the empathise activities and literature studies done by the focus group members. Techniques used were dot voting, and joint writing exercises. In ideation, the principles and the visual representation of the CA concept were imagined and re-imagined and, when relevant, added to, by fishbowl discussions, flow sketching, and reconfiguration exercises. This led to prototypes in visualisation and word of the concept of CA, the next phase. As tests, cognitive walkthrough activities were used (Lyon et al. 2021; Martin and Hanington 2019), to identify and assess aspects that may inhibit or facilitate the use of the prototype. All five design-thinking phases were iterated both during sessions and in between sessions, see column 4 in Table 1. The outcomes of each focus group session, plus the work shortly after, were used as input for the following session. Column 4 also shows the intermediate results that were worked on and revisited for validation and further development in the design thinking activities. Thus, the CA concept progressively developed to its current tangible form of a definition, characteristics, principles, rationales, and a visualisation of the concept.

Eleven interactive sessions were held between 2018 and 2023 at international engineering education conferences and meetings, such as the Worldwide CDIO Conferences and the Frontiers in Education Conference, see Table 1. The sessions were one to three hours long, except for the working group days (sessions 3, 8, and 11), which were six- to eight-hour sessions. The concept of CA was constructed by an internationally diverse group of participants (column 3 in Table 1). Their individual cause for participation was to gain insights into a capacity for sustaining transformative curriculum innovation and translate it to their own context. They were aware of the research project and able to withdraw their input or participation at any moment. Therefore, there were sometimes more participants than co-creators in a session. All participants were EE practitioners, with an interest and experience in curriculum development, and specifically innovation. Their position within their university varied from faculty deans to middle managers, professors to lecturers, and workshop technicians to PhD students. Ages varied between 25 and 65

Table 1. The focus group session series and the co-creating participants.

Session date	Session format Occasion Location	Actual co-creators of all session participants Gender Nationalities	Design thinking activities (during and shortly after the session) outcomes
1. July 2018	Workshop • Worldwide EE conference • Kanazawa Institute of Technology, Japan	18 co-creators: • 7 women, 11 men • From Australia, Canada, Denmark, France, Ireland, Japan, the Netherlands, Norway, Russia, Sweden, UK, USA	• Empathising, ideation, defining, empathising • The name of CA, 1st prototype, characteristics of CA, lists of obstacles for curriculum innovation
2. January 2019	Working lunch • EU&UK regional EE meeting • CESI Graduate School of Engineering La Rochelle, France	20 co-creators: • 8 women, 12 men • From Denmark, France, Iceland, The Netherlands, Russia, Sweden, Tunisia, UK	• Developmental evaluation, empathising, ideation, defining • Important elements of CA, obstacles, good practices
3. June 2019	Working group day • Worldwide EE Conference, • Aarhus University, Denmark	8 co-creators: • Of 11 participants in total • 4 women, 7 men • From Indonesia, UK, Norway, the Netherlands, Sweden	• Empathising, defining, developmental evaluation • Refined definition CA, rationale for CA, 2nd prototype
4. January 2021	Online workshop • EU & UK regional EE meeting • Norwegian University of Science and Technology Trondheim, Norway	14–25 co-creators: • Of 29 participants in total • 9 women, 20 men • From Denmark, the Netherlands, Norway, Sweden, Switzerland	• Developmental evaluation, testing • 3rd prototype, culture of change principle, CA pandemic stress test, conference paper on the 7 principles of CA
5. June 2021	Online roundtable • Worldwide EE Conference • Chulalongkorn University Bangkok, Thailand	19 co-creators: • 7 women, 12 men • From France, Japan, Tunisia, The Netherlands, UK, Norway, Singapore, Spain, Sweden, Thailand	• Empathising, defining, testing, ideation • 4th prototype, validation of 7 principles, stakeholder insights
6. October 2021	Hybrid special session • Worldwide EE conference • University of Nebraska – Lincoln • College of Engineering, USA	8–10 co-creators: • Of 13 participants in total • 4 women, 9 men • From Canada, The Netherlands, USA, Sweden	• Empathising, developmental evaluation, testing, defining • Refined principles, 8th principle added
7. October 2021	Online interactive keynote • Asian regional EE meeting • Australian College of Kuwait, Kuwait	21–25 co-creators: • Of 107 participants in total • Male-female division unknown • From the Middle East and the whole of Asia, plus Australia	• Empathising, defining • 6th prototype, validation principles in another region, 9th principle added
8. June 2022	Working group day • Worldwide EE Conference • Reykjavik University, Iceland	16 co-creators: • 9 women, 7 men • From Sweden, Norway, UK, The Netherlands, Estonia, France	• Developmental evaluation, empathising, ideation, prototyping • 7th prototype, 10th principle, 4th addition to characteristics
9. November 2022	Fall meeting workshop • EE Fall Working Meeting • TUAS, Turku, Finland	9 co-creators: • 4 women, 5 men • From Sweden, Norway, the Netherlands, Finland, Singapore	• Developmental evaluation, defining, ideation • 8th prototype with different configuration of principles

(*Continued*)

Table 1. Continued.

Session date	Session format Occasion Location	Actual co-creators of all session participants Gender Nationalities	Design thinking activities (during and shortly after the session) outcomes
10. January 2023	Working group session • EU&UK regional EE meeting • Canterbury Christ Church University, UK	11 co-creators: • 3 women, 8 men • From UK, Ireland, the Netherlands, Sweden, Norway, Finland	• Developmental evaluation, ideation, defining • New visualisation of CA concept, 9th prototype, validation of principles
11. June 2023	Working group day • Worldwide EE Conference • Norwegian University of Science and Technology Trondheim, Norway	15 co-creators: • 8 women, 7 men • From Sweden, the Netherlands, India, Canada, UK, France, UK, Finland	• Developmental evaluation, ideation, defining • 10th prototype of CA, new categorisation of principles, validation

years. Some attended multiple sessions, others came in only once or twice. A core group of eight co-creators formed voluntarily around the lead researcher. They attended frequently and collaborated more intensively in between sessions as well.

Data analysis

The data analysis was a systematic thematic analysis, with transcription, keywords, coding, theme development, conceptualisation, and modelling as the main stages (Naeem et al. 2023). The core group of co-creators together with the lead researcher carried out this thematic analysis to increase intersubjectivity and limit potential bias. They used the 'developmental evaluation' approach of Leonard, Fitzgerald, and Riordan (2016) for each phase of the thematic analysis to analyse, interpret, report, reflect, and validate iteratively (see Table 1, rightmost column). This approach is particularly helpful to evaluate research results that are in a continuous state of change, by not asking evaluators to simply appraise a final outcome but to iteratively co-create and prototype. Within the thematic analysis, this interactive approach supported the core group of practitioners to form multi-perspective narratives for each principle based on the data, in line with Lainson, Braun, and Clarke (2020).

Thus, the data analysis and validation became built-in steps of the co-creative design process both in and between the sessions. The empathise and ideation activities in each session were transcribed on sticky notes and the workshop worksheets provided and were photographed. Co-creators selected keywords while working with the sticky notes and worksheets in the defining activities. Coding these keywords in the ideation activities formed the basis for the characteristics and principles of CA. In the theme development stage, rationales behind each principle were formed by evaluating them in cognitive walkthroughs, using the participants' expertise. The tweaks on the CA definition, characteristics, principles, and categorisation by different groups of participants in the developmental evaluation activities formed the conceptualisation stage. Finally, through all its different visualisations (prototypes) the concept of CA developed into the model as presented here.

The thematic analysis stages that happened during sessions continued between sessions, in preparation for the next. Session outcomes were merged into the newest version of the prototype of the concept. Members of the co-creator core group gathered online to discuss and evaluate the progress of the CA concept so far. By this developmental evaluation activity, the purpose and needed activities of the next session could be agreed upon in a flexible, responsive way. This resulted on three

occasions in a conference proceedings publication (Brink et al. 2020; Brink et al. 2021; Brink et al. 2023). On other occasions, a session description was sent out beforehand to invite attendees of the meeting to participate. The last column in Table 1 shows the non-linear occurrence of the iterations of the design thinking and thematic analysis activities as they were thus executed for each focus group session.

Results

All along the process, including the writing of this publication, the co-creators challenged and negotiated different parts of the CA concept, based on their knowledge and experiences, challenges they were confronted with in practice, best practices they shared, and future developments they deemed important.

From the first session onwards, CA became the short answer to what is needed for a university to be able to do transformative curriculum innovation, continuously evaluating and adjusting EE to its quickly developing context. The term agility was chosen for its meaning of 'the ability to move quickly and easily'. The term gave the co-creators associations with short reaction time in direction changes, smooth and swift performance, and fitness. In a number of iterations, of which the most important one was during Session 3 (see Table 1), agreement was reached on the definition:

> Curriculum Agility is to be responsive to changes in society, industry 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.

Four main characteristics describe the innovation space of CA: flexible pedagogy and didactics, responsiveness of the organisation and management, dynamic contents of learning, and continuous development of all (not just teaching) staff involved in the curriculum/programme, see Figure 1. The arrows indicate that not one of these characteristics is 'the first' or most important. That completely depends on the context of the university that works on its CA, its aims and possibilities for development, and its perspectives on good education.

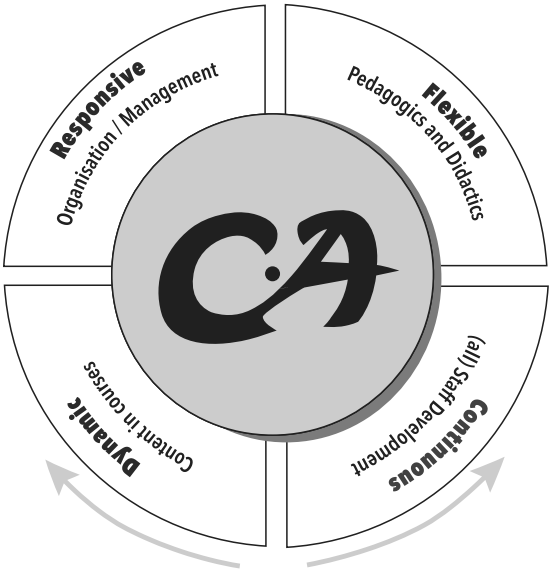

Figure 1. Curriculum Agility and its four characteristics.

Note: Visualisation of the four characteristics of Curriculum Agility: flexible pedagogics and didactics, dynamic content in courses, responsive organisation and management, and continuous development of all staff. The characteristics are centred on a pinwheel, as any of the four can be most important 'on top', depending on the context of the institution.

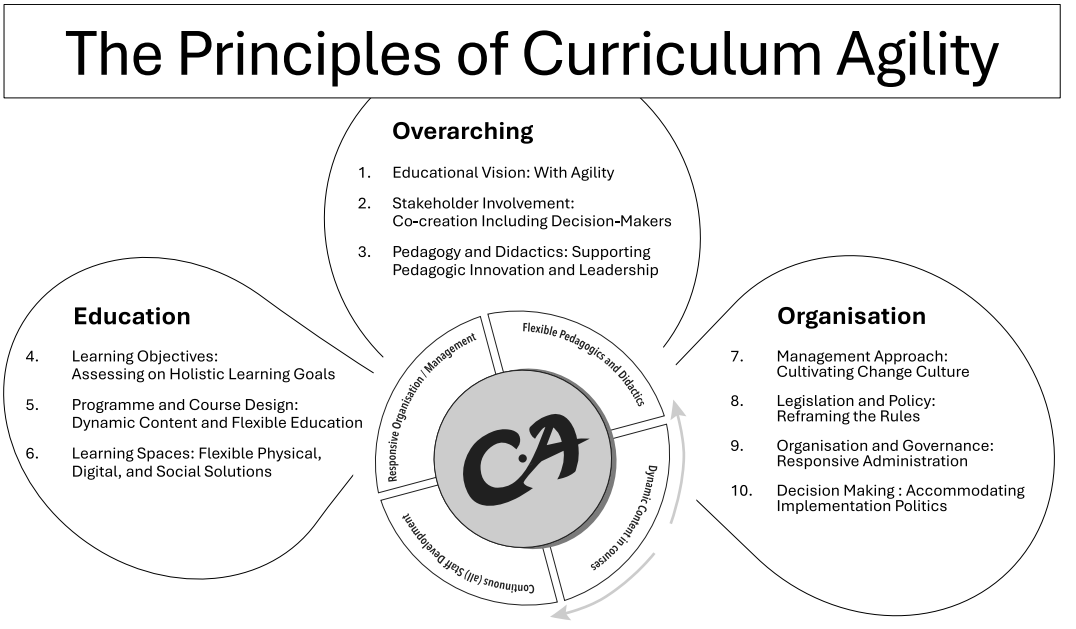

Figure 2. The Principles of Curriculum Agility, as co-formulated in 2018–2023 by engineering education experts and practitioners in a series of eleven co-creational sessions.

Note: Visualisation of the Principles of Curriculum Agility with the educational principles to the left, organisational principles to the right, and overarching principles on the top. The characteristics of Curriculum Agility are centred on a pinwheel in the middle, as any of the four can be most important 'on top', depending what the institution decides to work on.

Ten principles to enable transformative curriculum innovations were formulated around the characteristics, clustered in organisational, educational, and overarching principles, see Figure 2. In addition, an idea is given of which stakeholders can be included in the transformative curriculum innovation processes. Universities are organised differently worldwide and can even have different organisational models locally, so relevant stakeholders in the list can vary per context.

The ten principles of Curriculum Agility

1. **Educational Vision: With Agility**
   Encouraging initiatives and innovations that promote education that is responsive to change, dynamic in content, and flexible in didactics in order to be prepared for societal and technological changes.

There is a shared vision in all layers of the institution to proactively recognise the needs and answer the external (including governmental) expectations for transformational curriculum innovation. This translates into encouraging and allowing more room for new initiatives and explorations in adjusting education, regarding content, teaching and learning, and organisation. The vision helps education to become more agile by improving the responsiveness of the system, the dynamics of the content, the personalisation of student learning, and continuous staff development for all involved.

2. **Stakeholder Involvement: Co-creation Including Decision-Makers**
   Involving both external and internal stakeholders in curriculum transformation and establishing structures and procedures for identifying, prioritizing, and fulfilling stakeholders' (changing) needs continuously.

This principle focuses on how and by whom curriculum innovation is done. Input from relevant direct and indirect stakeholders is gathered and applied to maintain and develop the quality of the curriculum and its organisation. Within the university, the involved stakeholders come from different levels and actively participate in relevant co-creational phases throughout the curriculum innovation process. Mutual understanding and inclusion of the different strategic stakes are thus safeguarded by allowing for a timely exchange of perspectives, reciprocal learning, and negotiation.

Beyond co-creating with students and industry, many other stakeholders take part depending on the context and disruptiveness of the innovation: academic staff such as professors, lecturers, technicians, assistants, heads of program, directors of education, other departments, partner universities, (inter)national networks, research centres etc. Other relevant stakeholders within the university can be direct management, higher management, university leadership, administrative staff in the facility, scheduling, grade administration, IT services etc. Outside the university, alumni and prospective students can be included, as well as local entrepreneurs, governmental and non-governmental partner organisations, industry advisory boards, clients, users, patients etc.

3. **Pedagogy and Didactics: Supporting Pedagogic Innovation and Leadership**
   Having structures for supporting new developmental needs of teachers, by promoting scholarship of teaching and learning, facilitating pedagogic unit support, and collegial teaching teams. Incorporating innovative pedagogies in traditional teaching cultures, facilitating continuous support in its implementations.

Scholarship of teaching and learning (SoTL) stresses the importance for teachers to make informed choices regarding suitable pedagogical and didactic approaches and methods for flexible and dynamic education. Teaching staff is encouraged to contribute to sharpening established teaching methods for a diverse and fast-changing student body. Collaboration and co-creation in teaching teams is also encouraged as a way of competency development at the institutional level for implementing educational innovations.

4. **Learning Objectives: Assessing Holistic Learning Goals**
   Formulating holistic learning outcomes on programme level, with flexible, replaceable objectives and indicators to support dynamic teaching content and flexibility in the programme's curriculum. Maintaining a holistic character of criteria in assessment within the programme and courses.

At the basis of flexible education and dynamic contents of teaching lie learning outcomes that guarantee the quality of the degree without limiting necessary, swift alterations in what is offered to students to learn. These holistic goals contain relevant, stable elements of the discipline, integrated with transcending elements for interdisciplinary and twenty-first-century competency; they are a unification of knowledge, skill, and attitudes.

5. **Programme and Course Design: Dynamic Content and Flexible Education**
   Adjusting learning content to newest developments in the discipline. Creating pedagogic and didactic flexibility: course choices, adjustable and customizable projects, opportunities for students to build their own professional identity and study profile.

The curriculum and courses in existing and new programmes are designed and developed to address disciplinary and social changes, as well as changes in students' characteristics and learning needs, in a timely manner. Dynamic disciplinary and professional learning content as well as flexible pedagogy matter. Permitting individual flexibility and ownership of learning becomes ever more important as the student body grows and changes under efforts on lifelong-learning, diversity, equality, and inclusion.

6. **Learning Spaces: Flexible Physical, Digital, and Social Solutions**
   Utilizing blended and hybrid social, physical, and digital learning environments, allowing for flexibility of teaching and learning, in format, place, and time.

Learning spaces respond to changing needs and demands in the learning environment, and the contextualisation of where the learning takes place, under the influence of digitalisation, lifelong learning structures, and unforeseen events (such as a pandemic). Attention is paid to the social learning environment in all configurations, including its future value in the university as a physical institution. Lifelong learning and the ever-growing diversity of students ask for standardised but flexible solutions, with added value from a personalised approach.

7. **Management Approach: Cultivating Change Culture**
   Ensuring and maintaining a culture rather than a "one-person engagement" for change and innovation through entrepreneurial change management: being initiative-driven, and proactive rather than reactive.

The management establishes and maintains an approach to change as a natural and continuous part of curriculum design throughout the institution. It encourages and facilitates entrepreneurial thinking for curriculum development. It promotes a willingness to act on new and changing needs in society and facilitating it in the organisation. The willingness to change should not depend on individuals as single drivers for change.

8. **Legislation and Policy: Reframing the Rules**
   Finding the space for innovation within the interpretation space that legislation and policies hold, within collaborations on reform and reformulation moments, and being prepared to make concessions where needed in the details or framing of the changes, there were one is in control.

Existing rules, regulations and laws steer or even dictate actions and decisions, as well as estimations of what is feasible. Sometimes perceptions of these rules and regulations lead their own life, unquestioned. There is often space for interpretation, not in the least in how laws and regulations are operationalised and by whom. An attitude of critical thinking, by questioning the status quo and patterns, making time for dialogue and argumentation, and investigating reframing opportunities and possibilities, is needed to make innovation possible in a highly regulated organisation such as a university.

9. **Organisation and Governance: Responsive Administration**
   Empowering an organizational structure where people effectively address and guide the administrative system and its internal and external regulations, in order to guarantee implementation and support maintenance of the curriculum changes while safeguarding the quality.

The organisation of the institution needs to be such that its educational programmes and curricula can be responsive to (rapid) changes in their domains. This means that the systems and process flows must give room and resources for customisation, interdepartmental collaborations, informed adjustments of university rules, and (financial) interdepartmental agreements. It also entails systematic facilitation of, and support for, implementation, e.g. by professionalisation, guidance, and reward.

10. **Decision Making: Accommodating Implementation**
    Having transparent, efficient curriculum and course approval and adjustment processes: timeframes, steps required, number of persons involved, communication channels.

Decision-making procedures for curriculum development are effective, efficient, quality insuring processes. Procedures regarding the roles involved (including chain of command), and how, when and by whom the processes and decisions are executed and communicated for impact in the organisation are lean and transparent. Political structures are transparent and accommodate improvement. The principle covers starting new programmes or courses, making changes in existing programmes and courses, as well as decommissioning programmes and courses.

Discussion

Strengths and limitations

This focus group study for educational design research *for* intervention used design-thinking, co-creational, and reflective praxis approaches and thus resulted in original work aimed to have practical value, as is often seen in these kinds of processes (Godin and Zahedi 2014). The design thinking activities in the focus groups comprised both synthesis and analysis. The co-creators during and in between the session were a varying international mix of experts and practitioners in curriculum innovation and brought theoretical insights along as well (McKenney and Reeves 2018). The results of their work, the concept of CA with its ten principles, underwent ten prototyping rounds over the five years of the study, concentrically coming closer to the answer on how transformative curriculum innovation can be facilitated by CA.

The principles for CA and their narratives became consistent over time by the thematic analysis iterations that were integrated in the design-thinking approach of the study. As lead researcher, the first author was consistently involved to guarantee consistency and the necessary flexibility throughout the process. But to prevent single-perspective personal bias in the thematic analysis, different members of the core group were included in the systematic preparation, facilitation, data analysis, prototyping, and validations between different sessions, by using the co-creative developmental evaluation approach. All co-creators, from workshop technicians to heads of schools, were involved in coding as well as conceptualising activities. The changing configuration and cultural variety of the participants increased the intersubjectivity of the validation and decreased the dominance effect (Nyumba et al. 2018). The study included both the global north and global south perspectives. Table 1 shows that participants came from Europe, Asia, the Middle East, upper Africa, Australia, and North America, but none from South America.

This inclusive approach to the method resulted in a safeguarding of the holistic character of the principles as well as their pluralist character. The study was performed in line with the critical realist perspective (O'Donnell 2016) including multiple levels of reality, norms and values on the empirical and actual levels, by working in a co-creational, dynamic way with different experts and practitioners from different positions and cultural backgrounds within the context of EE. By the hybrid approach to thematic analysis (Lainson, Braun, and Clarke 2020), the practioner's' knowledge in the research context of engineering education was included in a collaborative, intersubjective way. As a result, the CA concept does not advocate for one type of flexible pedagogy, or the newest trend in learning space technology and design. Instead, it spotlights the areas in which HEEIs can find helpful innovations, without telling what is right or wrong from a certain cultural, single-angle, or time-specific perspective.

As the co-creators brought not only their experience, but also their theoretical knowledge in engineering education with them, the principles that were generated are partly embedded in existing literature, partly built on ideas in literature that have not yet come to be, and partly based on practical experiences. Principle 1 on a shared vision can be related to the studied successful innovation cases mentioned in the introduction, which all had that in common. Principle 2 matches the dynamic, multi-actor perspective in curriculum innovation which increases the chance of continuation of innovation as described in (Coppoolse 2018; Lindsay et al. 2023). It also guarantees transdisciplinary perspectives and pluralist inclusion in the collaborative partnerships of stakeholders in the curriculum innovation process (Baumber et al. 2020). The CA concept

inherently facilitates joint reflection by including the culture of change as principle 7 for sustaining transformation (Fullan and Ballew 2004). The CA concept suggest with principle 10 to include decision-makers as co-creators in the curriculum innovation process. This is in line with the recommendations of Leonard, Fitzgerald, and Riordan (2016), who developed the developmental evaluation method used in this study to include Course Advisory Groups in co-prototyping and co-evaluating activities. This way, curriculum innovations would not get lost in translation. For the same reasons, considering more complex programme curriculum innovation, CA principles 9 suggest an even wider organisational involvement in the co-creation of curriculum innovation, including management and administration.

The CA principles in the educational cluster match turn-of-the-century literature on curriculum innovation. Walkington (2002) indicated how curriculum change is non-linear and uncertain, requires both top-down and bottom-up strategies, and needs wide community connection for sustained effects. These are important elements underlying the CA concept. Knight (2001) emphasised the importance of coherent programme curricula, with clear links and progression between courses, and this can be seen back in principles 4, 5 and 6 with holistic programme learning goals, social learning spaces, and dynamic learning content and formats directed at integration and transformation. These principles are directed to the approaches that Kolmos, Hadgraft, and Egelund Holgaard (2016) see are needed but still underrepresented in curriculum innovation. Throughout the study, it became clear that part of the complexity of transformative curriculum innovation lies in a lack of curriculum agility in the structures and institutional organisation.

In between Sessions 4 and 7 (Table 1), the Covid-19 pandemic affected data collection. Conferences and meetings were held online and later in hybrid formats, which demanded different interactive session formats. At the same time, as HEEIs saw themselves forced to change their teaching practices overnight, CA and especially principle 8 of reframing the rules became even more relevant to all involved in the study. In that sense, the pandemic served as a stress test for the CA concept, resulting in added and sharpened principles.

Suggestions for further research

The CA concept contributes to successful transformative curriculum innovation specifically by involving stakeholders beyond a project group actively in the process as co-creators. They collaborate and negotiate towards mutual understanding and shared vision, bringing their own values and agendas to the table. Further research into these personal educational values is an important next step. Likewise, the influence of provoked agency roles in these educational change processes can be included. Annala et al. (2023) describe different themes in the agency of academic staff working on curriculum innovations, and the roles that intentions and power relations play in that. This can be considered for all involved stakeholders in a co-creation approach. A third direction is to map the complexity that underlies co-creational transformative innovation for increased insights into the challenges of its non-linear process by participatory case studies over a longer span of time.

Practical implications

A case study has been conducted in which CA was assessed at a Swedish university (Brink et al. 2022) and four Dutch, Swedish and Finnish universities (Brink et al. 2024). In those studies, it was shown that all principles were deemed important by lecturers, programme managers, and faculty or school managers alike. Co-evaluation of CA throughout the layers of the university helped pinpoint bottlenecks and increased understanding. Depending on their context and transformation goals, certain principles were prioritised. But the dialogue that started was appreciated most. Therefore, the next step in the development of the CA concept is to proceed with developing a self-mapping process for all HEEIs and making it readily available for all to use.

Many of the co-creators were CDIO members, and a connection can be made between the Principles of CA and the worldwide CDIO Standards of good EE (Crawley et al. 2014). Therefore, a closer connection will be sought to the CDIO framework for dissemination of the CA concept (Brink et al. 2023).

However, the concept of CA does not need to be limited to EE. The generalisability of the results to other professional disciplines with equally swiftly changing disciplines is worth exploring, as well as other disciplines less impacted by rapid developments, but still affected by changing student populations, new (educational) technologies, and disruptive societal events such as a pandemic or war.

Conclusions

To have Curriculum Agility (CA) as a Higher Engineering Education Institution (HEEI) is to be responsive to changes in society, industry and students' characteristics and needs, by proactively and in a timely manner adapting their engineering programmes' relevant organisational structures, learning outcomes, learning activities, and assessments.

The characteristics of CA stretch from flexible pedagogics and didactics and dynamic contents of learning to a responsive organisation and continuous scaffolding of all staff's development, in line with what the new curriculum demands of them. Which characteristics are in focus in curriculum innovation depends on the goals, current curricula, staff characteristics, and resources that together form the specific context of a HEEI. The same is true for the disruptive extent of the transformative curriculum innovation.

Ten principles of CA were formulated in this study. Their numbering is meant for identifying purposes only and does not indicate a specific order or gradient of importance. Their full descriptions can be read in the results section. In summary, to achieve transformative curriculum change, a holistic approach is needed, involving relevant stakeholders on different hierarchical levels within and outside the HEEI in engaging, informative, and constructive steps along the process (Principle 2, Stakeholder Involvement: Co-creation Including Decision-Makers). A shared vision of agility within the HEEI should underlie curricular change, stimulating initiatives and reserving resources for such proactive quality enhancement of its education (Principle 1, Educational Vision: with Agility). A prevalent change culture will support such initiatives, ensuring sustainable thoroughfare of ideas, as the willingness to change should not depend on single drivers (Principles 7, Management Approach: Cultivating Change Culture). Obstacles in policies and rules need reframing and co-evaluation to become opportunities for quality improvement on a bigger scale within the HEEI (Principle 8, Legislation and Policies: Reframing the Rules). Sometimes only the perception of the rules needs readjusting. Administration needs to be willing to respond and take a lead in the necessary transformative changes (Principle 9, Organisation and Governance: Responsive Administration). Decision-making processes for new programmes, adjustments, and decommissioning need to be lean and transparent (Principle 10, Decision Making: Accommodating Implementation).

Apart from these organisational principles, there are also educational principles of CA. Holistic learning outcomes on the programme-level safeguard the agility needed to deal with teaching content that is dynamically changing over time (Principle 4, Learning Objectives: Assessing on Holistic Learning Goals). With an increasingly varied student body, flexibility in education becomes important, with room for choice, profiling, and transdisciplinary specialisations (Principle 5, Programme and Course Design: Dynamic Content and Flexible Education). With both dynamic content and flexible education, more flexibility is also asked of the learning spaces that universities offer (Principle 6, Learning Spaces: Flexible Physical, Digital, and Social Solutions). And to be able to work with and in such shifting and uncertain conditions, all involved staff members need to continuously develop and learn (Principle 3, Pedagogy and Didactics: Supporting Pedagogic Innovation and Leadership).

That all staff is on par with, and stimulated to show leadership in, pedagogic innovation is both an important demand as well as a result of CA. With CA included in the vision, continuous and reciprocal

learning can occur in the multi-stakeholder co-creation, and lifelong learning processes thus become inherent to the way of working. This way, transformational curriculum innovation becomes feasible, which is something we need in EE in this fast-changing, VUCA world.

Acknowledgments

The authors would like to thank all co-creators in the focus group sessions for their time, engagement, and input to make Curriculum Agility what it is today.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethical statement

This project has been approved by the ICLON Research Ethics Committee, Leiden University, the Netherlands, under number IREC_ICLON 2021-09.

Notes on contributors

Suzanne Brink is an associate professor in Higher Education Pedagogics and Distinghuised Teacher at the Centre for Educational Development at Umeå University. With her interdisciplinary background in Industrial Design Engineering and Educational Sciences, she advices in a broad variety of higher education curriculum development processes. Her doctoral research at ICLON, Leiden University, focuses on Curriculum Innovation, Curriculum Agility, and Curriculum Perspectives in the co-creation of higher education.

Miranda de Hei is a senior researcher at the Hague University of Applied Sciences. She leads the research group on Co-creation and is a senior lecturer at the Human Resource Management bachelor programme. She obtained her PhD degree in Educational Sciences at Leiden University. Her PhD thesis (2016) is entitled: Collaborative learning in higher education: design, implementation and evaluation of group learning activities. Her expertise beholds research on co-creation, learning communities, educational design, and lifelong learning.

Ellen Sjoer currently heads the Research Group Sustainable Talent Development at The Hague University of Applied Sciences. The first research group she headed was Knowledge Infrastructure for Science and Technology and she has worked at the Faculty of Technology, Policy and Management at Delft University of Technology in the past. Ellen participates in various EU projects and networks such as the Stichting HRM Lectorennetwerk Nederland and the board of the IACEE (International Association for Continuing Engineering Education) and has led various research projects about e-learning and information management in higher education and at companies.

Carl Johan Carlsson is a senior lecturer and assistant head of education at the Dept. of Communication and Learning in Science at Chalmers University of Technology. His teaching focuses on disciplinary and interdisciplinary communication. His main interests include writing in higher education, integrated and cross-disciplinary learning, disciplinary socialisation, pedagogical development work and curriculum design.

Fredrik Georgsson is an associate professor in Computing Science at the University of Umeå and currently works as a quality developer at the university level with education and research quality management, digitalisation and life-long learning. He holds a PhD in image analysis, is appointed an Excellent Teacher and has experience as being Program Director as well as a Faculty program Director of Engineering Programmes.

Elizabeth Keller is a lecturer at the Department of Learning in Engineering Sciences at the KTH Royal Institute of Technology, Stockholm. She has been involved in the pedagogical development of young engineering faculty. In addition, her interests involve intercultural communication and the use of digital tools in higher education.

Charles McCartan is a reader (Education) in the School of Mechanical and Aerospace Engineering at Queen's University Belfast. He is the Director of Education for postgrad taught programmes. His scholarly interests include developing, applying, and evaluating (inter)active learning methods, assessment strategies, and the transition to university and programme evaluation.

Mikael Enelund is a professor in Structural Dynamics and Dean of Education at Chalmers University of Technology. Currently, he is the leader of Chalmers's ten-year initiative Tracks to develop education to become more flexible and responsive to changes in society.

Reidar Lyng is an associate professor at The Dept. of Physics NTNU, presently residing expert on Education Development at the Centre for Science and Engineering Education Development at NTNU, with more than 30 years' experience in education development from NTNU and several Swedish universities. His R&D interests include the systemic interplay between teachers, students, and learning spaces, and how regulatory frameworks hinder or facilitate Curriculum Agility.

Wilfried Admiraal is a full-time professor of Educational Sciences with a focus on Technology Enhanced Teaching and Learning. His research interest combines the areas of teaching, technology and social psychology in secondary and higher education. Current projects relate to simulations and virtual reality in higher education. He is also involved in research on how to increase the retention of young professionals and the role of higher education in this. More information on projects and publications on his personal homepage: https://sites.google.com/site/wilfriedadmiraal/.

ORCID

Suzanne Cecilia Brink http://orcid.org/0000-0002-2622-5764
Carl Johan Carlsson http://orcid.org/0000-0002-3945-8276
Miranda de Hei http://orcid.org/0000-0002-4018-0427
Fredrik Georgsson http://orcid.org/0009-0008-5200-9417
Elizabeth Keller http://orcid.org/0000-0002-1701-843X
Charles McCartan http://orcid.org/0000-0003-4079-6843
Reidar Lyng http://orcid.org/0000-0003-1788-823X
Wilfried Admiraal http://orcid.org/0000-0002-1627-3420

References

Annala, J., J. Lindén, M. Mäkinen, and J. Henriksson. 2023. "Understanding Academic Agency in Curriculum Change in Higher Education." *Teaching in Higher Education* 28 (6): 1310–1327. https://doi.org/10.1080/13562517.2021.1881772.

Baumber, A., G. Kligyte, M. van der Bijl-Brouwer, and S. Pratt. 2020. "Learning Together: A Transdisciplinary Approach to Student–Staff Partnerships in Higher Education." *Higher Education Research & Development* 39 (3): 395–410. https://doi.org/10.1080/07294360.2019.1684454.

Brink, S. C., C. J. Carlsson, M. Enelund, K. Edström, E. Keller, R. Lyng, and C. McCartan. 2023, June. "Curriculum Agility as Optional CDIO Standard." Proceedings of the 19th International CDIO Conference. The 19th International CDIO Conference, NTNU, Trondheim, Norway.

Brink, S. C., C. J. Carlsson, M. Enelund, F. Georgsson, E. Keller, R. Lyng, and C. McCartan. 2020. "Assessing Curriculum Agility in a CDIO Engineering Education." Proceedings of the 16th International CDIO Conference, 1(2), 13.

Brink, S. C., C. J. Carlsson, M. Enelund, F. Georgsson, E. Keller, R. Lyng, and C. McCartan. 2021. "Curriculum Agility: Responsive Organization, Dynamic Content, and Flexible Education." *FIE: Envisioning Convergence in Engineering Education* 2021.

Brink, S. C., F. Georgsson, G. Thomson, M. S. A. de Hei, E. Sjoer, and W. F. Admiraal. 2019. Mapping Current Curricular Changes in European Engineering Education. Complexity Is the New Normality. 47th Annual SEFI Conference, Budapest.

Brink, S.C., Gomez Puente, S.M., Rooij, R., Aalbers, K., Carlsson, C.J., Enelund, M., & Lehtinen, L. (2024). "Experiences with Self-Mapping Curriculum Agility." In Proceedings of the 20th International CDIO Conference, Ecole Supérieure Privée d'Ingénierie et de Technologies (ESPRIT) Tunis, Tunisia.

Brink, S. C., S. Vikström, S. Schedin, T. Mejtoft, and E. Sjoer. 2022. "Curriculum Agility at Faculty, Department, Program, and Course Level. Towards a New Future in Engineering Education." 50th Annual Conference of The European Society for Engineering Education, Barcelona.

Brown, T. 2008. "Design Thinking." *Harvard Business Review* 86 (6): 84–141.

Christensen, C. M. 2000. *The Innovator's Dilemma [Updated ed.]*. HarperBusiness.

Coppoolse, R. 2018. "Werkregels voor innovatiemanagers: Vernieuwing in het hoger beroepsonderwijs in een versnelling." Thesis, Universiteit Utrecht.

Crawley, E. F., J. Malmqvist, S. Östlund, D. R. Brodeur, and K. Edström. 2014. *Rethinking Engineering Education*. Springer International Publishing.

De Beer, S. F., and A. S. Van Niekerk. 2017. "Transforming Curricula Into the Next Century: Doing Theology Collaboratively with Local Communities." *Verbum et Ecclesia* 38 (4): 213–302. https://doi.org/10.4102/ve.v38i4.1683.

Dede, C. 2010. "Comparing Frameworks for 21st Century Skills." In *21st Century Skills: Rethinking how Students Learn*, edited by J. Bellanca, and R. Brandt, 51–76. Solution Tree Press.

Escobar, A. 2017. "Response: Design for/by [and from] the 'Global South.'." *Design Philosophy Papers* 15 (1): 39–49. https://doi.org/10.1080/14487136.2017.1301016.

Fullan, M., and A. C. Ballew. 2004. *Leading in a Culture of Change: Personal Action Guide and Workbook*. . 1st ed. San Francisco, CA: Jossey-Bass.

Gallagher, A., & Thordarson, K. (2020). *Design Thinking in Play: An Action Guide for Educators*. ASCD.

Godin, D., and M. Zahedi. 2014, June 16. Aspects of Research through Design: A Literature Review. Design's Big Debates. DRS International Conference, Umeå, Sweden.

Grasso, D., and M. B. Burkins. 2010. "Beyond Technology: The Holistic Advantage." In *Holistic Engineering Education: Beyond Technology*, edited by D. Grasso, and M. B. Burkins, 1–10. Springer.

Hallenga-Brink, S. C. 2018. "Designing an Integrated, Futureproof, and Flexible Curriculum." In *Inspired to Change: A Kaleidoscope of Transitions in Higher Education. - Chapter 10*, edited by Frans Jacobs, and Ellen Sjoer, 116–128. De Haagse Hogeschool.

Hanstedt, P. 2023. *Creating Wicked Students: Designing Courses for a Complex World*. Sterling, Virginia: Routledge.

Kamp, A. (2016). *Engineering Education in the Rapidly Changing World: Rethinking the Vision for Higher Engineering Education*. TU Delft: Faculty of Aerospace Engineering.

Knight, P. T. 2001. "Complexity and Curriculum: A Process Approach to Curriculum-Making." *Teaching in Higher Education* 6 (3): 369–381. https://doi.org/10.1080/13562510120061223.

Kolmos, A., R. G. Hadgraft, and J. Egelund Holgaard. 2016. "Response Strategies for Curriculum Change in Engineering." *International Journal of Technology and Design Education* 26 (3): 391–411. https://doi.org/10.1007/s10798-015-9319-y.

Kopnina, H. 2020. "Education for the Future? Critical Evaluation of Education for Sustainable Development Goals." *The Journal of Environmental Education* 51 (4): 280–291. https://doi.org/10.1080/00958964.2019.1710444.

Lainson, K., V. Braun, and V. Clarke. 2020, Jan 21. "Being Both Narrative Practitioner and Academic Researcher: A Reflection on What Thematic Analysis has to Offer Narratively Informed Research." *The Economist* 434:86–98.

Leonard, S. N., R. N. Fitzgerald, and G. Riordan. 2016. "Using Developmental Evaluation as a Design Thinking Tool for Curriculum Innovation in Professional Higher Education." *Higher Education Research & Development* 35 (2): 309–321. https://doi.org/10.1080/07294360.2015.1087386.

Lindsay, E. D., R. G. Hadgraft, F. Boyle, and R. Ulseth. 2023. *'Disrupting Engineering Education'*. Routledge.

Lyon, A. R., J. Coifman, H. Cook, E. McRee, F. F. Liu, K. Ludwig, S. Dorsey, K. Koerner, S. A. Munson, and E. McCauley. 2021. "The Cognitive Walkthrough for Implementation Strategies (CWIS): A Pragmatic Method for Assessing Implementation Strategy Usability." *Implementation Science Communications* 2 (1): 78–78. https://doi.org/10.1186/s43058-021-00183-0.

Malmqvist, J., U. Lundqvist, A. Rosén, K. Edström, R. Gupta, H. Leong, S. M. Cheah, et al. 2022. The CDIO Syllabus 3.0—An updated statement of goals. Proceedings of the 18th International CDIO Conference, Reykjavik University. 18th International CDIO Conference, Reykjavik, Iceland.

Martin, Bella, and Bruce Hanington. 2019. *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions* (2nd ed.) Rockport Publishers.

Martínez Bravo, M. C., C. Sádaba Chalezquer, and J. & Serrano-Puche. 2021. "Meta-marco de la alfabetización digital: Análisis comparado de marcos de competencias del Siglo XXI." *Revista Latina de Comunicación Social* 79:76. https://doi.org/10.4185/RLCS-2021-1508.

McCully, M. S., and E. A. McDaniel. 2007. "College Transformation Through Enabling Agility." *Issues in Informing Science and Information Technology* 4:703–712. https://doi.org/10.28945/981.

McKenney, S., and T. C. Reeves. 2018. *Conducting Educational Design Research* (2nd ed.) Routledge.

Merton, P., J. E. Froyd, M. C. Clark, and J. Richardson. 2009. "A Case Study of Relationships Between Organizational Culture and Curricular Change in Engineering Education." *Innovative Higher Education* 34 (4): 219–233. https://doi.org/10.1007/s10755-009-9114-3.

Miller, R. K. 2019. "Lessons from the Olin College Experiment." *Issues in Science and Technology* 35 (2): 73–75.

Naeem, M., W. Ozuem, K. Howell, and S. Ranfagni. 2023. "A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research." *International Journal of Qualitative Methods* 22 (3): 1–18.

Nicholson, D. 2022. "De-colonising Higher Education Curricula: Authentic Guiding Narratives From Academic and Learner Communities." European Conference of the Scholarship of Teaching and Learning. European Conference of the Scholarship of Teaching and Learning, Manchester.

Nyumba, O. T., K. Wilson, C. J. Derrick, and N. Mukherjee. 2018. "The Use of Focus Group Discussion Methodology: Insights from Two Decades of Application in Conservation." *Methods in Ecology and Evolution* 9 (1): 20–32. https://doi.org/10.1111/2041-210X.12860.

O'Donnell, V. L. 2016. "Organisational Change and Development Towards Inclusive Higher Education." *Journal of Applied Research in Higher Education* 8 (1): 101–118. https://doi.org/10.1108/JARHE-04-2014-0051.

OECD. 2017. Education 2030—Conceptual learning framework: Background Papers." Background Papers EDU/EDPC (2017)25/ANN3. Directorate for Education and Skills Education Policy Committee.

Scheerens, J., G. van der Werf, and H. de Boer. 2020. *Soft Skills in Education: Putting the Evidence in Perspective*. Springer International Publishing, part of Springer Nature 2019.

Sheppard, S. D., K. Macatangay, A. Colby, and W. M. Sullivan. 2008. *Educating Engineers: Designing for the Future of the Field*. Stanford, CA: Carnegie Foundation for the Advancement of Teaching.

Snow-Andrade, M.. 2020. "A Responsive Higher Education Curriculum: Change and Disruptive Innovation." In *Innovations in Higher Education - Cases on Transforming and Advancing Practice*. IntechOpen.

UNESCO. 2017. *Education for Sustainable Development Goals: Learning Objectives*. Paris: UNESCO.

United Nations. 2021. *The Sustainability Development Goals Report 2021*, 64. New York: United Nations.

van den Akker, J., W. Kuiper, and U. Hameyer. 2003. *Curriculum Landscapes and Trends*. Dordrecht: Kluwer Academic Publishers.

Walkington, J. 2002. "A Process for Curriculum Change in Engineering Education." *European Journal of Engineering Education* 27 (2): 133–148. https://doi.org/10.1080/03043790210129603.

Wiek, A., L. Withycombe, and C. L. Redman. 2011. "Key Competencies in Sustainability: A Reference Framework for Academic Program Development." *Sustainability Science* 6 (2): 203–218. https://doi.org/10.1007/s11625-011-0132-6.

Willis, H., & Anderson, S. (2013). Speculative Design and Curriculum Development: Using Worldbuilding to Imagine a New Major in a Post-Course Era. The Journal of Media Literacy Education, 5(2), 378.