VUCA AND RESILIENCE IN ENGINEERING EDUCATION – LESSONS LEARNED

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ABSTRACT

As future system designers and decision-makers, engineering students should be trained to anticipate and navigate the unknown. These days, engineers often operate in professional, social and societal environments characterized by volatility, uncertainty, complexity and ambiguity (VUCA). Therefore, besides traditional engineering skills, educational programs must also provide students with future skills that are needed to address VUCA situations. This requires the competence and vision to design and manage systems that are resilient to unexpected, unstable and drastic events. This paper presents, compares and discusses teaching and learning activities addressing VUCA and resilience, occurring at different curriculum levels. Key lessons include the need to integrate VUCA and resilience training in a progressive manner, from freshman level to that of professional engineers. Recommendations are made for how engineering programs can better prepare graduates through the use of effective learning methods that are aligned with specific learning outcomes. Elements to extend an educational framework are suggested with curriculum integration based on examples of authentic experiences.

KEYWORDS

VUCA, Resilience, Teaching and Learning, Future Skills, Engineering Education, CDIO Standards: 1, 2, 3, 7, 8, 9, 11.

INTRODUCTION

Volatility, uncertainty, complexity and ambiguity (VUCA) characterize current and future challenges that engineers must face in their work, with "the shift from the traditional and simple situation of known knowns to the chaotic VUCA situation of the unknown unknowns" (Kamp, 2020, p. 13). Professional, social and societal environments, as the contexts and situations engineering teams have to operate within, as systems they design, are also strongly characterized by so-called VUCA characteristics. Raja (2021) makes a case for the relevance of VUCA in today's world, and further argues for a focus on leadership development as a way to deal with the disruptions associated with VUCA. The concept of VUCA, the origins of which can be traced back to the US Army (Clements, 2017), also has relevance in understanding the lack of stability and rapid changes witnessed in the business world (Lawrence, 2013). VUCA results in challenges for practitioners and leaders (Mueller, 2021). Resilience describes the ability, not only to quickly recover from and to respond to such events, but also to build adaptive capacity by learning from failure (National Research Council, 2012; Walker, 2020). Accordingly, resilience is crucial to address VUCA situations and characteristics (Rockley, 2022).

Therefore, besides traditional engineering skills, educational programs must also provide students and future leaders with the skills needed to face and tackle VUCA situations. Learning outcomes should echo the vision and competence to design systems that are resilient to utterly unstable and drastic events (Chester & Allenby, 2019; Clements, 2017; Martin et al., 2022). Implied are not only technical systems, but also engineering teams and their leaders. Those events may be society driven or may be a consequence of the inevitable more unstable and dynamic environment – like black swans appearing suddenly in the misty future. Future engineering practitioners and leaders should be trained on strategies which can help develop their ability to prepare for VUCA and to enhance resilience at different levels (Rimita et al., 2020), as resilience is a key competence and characteristic in dealing with the 'new normal' (Raja, 2021).

But how should resilience training in engineering education best be developed in order to, in the future, quickly recover systems and the teams that build them? This paper argues that VUCA and resilience training are connected and, as a premise, there is a need to reinforce students' abilities to work in VUCA situations. Drawing on four case studies from four countries, this paper compares and discusses teaching and learning (T&L) activities at different curriculum levels in higher educational institutions, and the extent to which they meet VUCA and resilience outcomes, mainly focusing on engineering education. With reference to both the diverse, interactive T&L methods and the aligned learning outcomes, this comparison enables insights into the challenges and opportunities of the respective approaches. The cases describe events where teams of engineering students have to tackle VUCA situations in real time early in their engineering curriculum in Iceland and France, students in their MSc program having to work on resilience strategies for diverse systems in Germany, and finally, students acquiring VUCA capabilities in the context of postgraduate and professional training in South Africa. The focus is on which T&L approaches are suitable to enable engineering students to design resilient systems in the context of a VUCA environment, and what competencies and learning outcomes are necessary to achieve this. Based on the experience of offering these different courses, the four approaches are analyzed in terms of similarities and differences, in order to integrate essentials within an educational framework for teaching resilience at different levels, and to examine how they are related to the CDIO educational framework. These elements are suggested to facilitate the rapid acquisition of VUCA and resilience skills.

TEACHING AND LEARNING APPROACHES

It is critical that 21st century T&L approaches include not only teaching the VUCA concept to students, but also assisting them to be well equipped for life in a VUCA world (Clements, 2017). This will allow individuals to develop intrapersonal capabilities, such as self-leadership, lifelong learning or resilience, but will also enable them to design and develop systems that are resilient in a VUCA environment. A VUCA context is quite unstable and unlikely to be deterministic. On the one hand, knowledge and know-how of dealing with complexity is inherent to most engineering programs, as required by accreditation bodies (e.g. ENAEE, ABET), where the learning process should enable graduates to demonstrate the ability to solve complex problems, so as to design, analyze and develop complex engineering products, processes and systems. On the other hand, VUCA environment training is more in the scope of competencies, is situation-oriented and relies on knowledge, skills and attitudes. Resilience, as the ability to adapt, withstand and recover within a VUCA environment, inherently requires system thinking (Mayar et al., 2022). Therefore, T&L approaches for a family of situations are needed, which foster competencies at higher complexity levels, such as systems or anticipatory thinking. Various T&L approaches in the context of active learning are adequate to meet VUCA and resilience development, e.g. those ranging from problem- and project-based learning, to experiential learning or professional work-based learning (Ban et al., 2015; Fazey, 2010). This section presents four case studies from different countries, and at different curriculum levels.

The four examples are in line with the spirit of the CDIO initiative. In particular, the ability to deal with resilience of a product, process and system may be considered as implicit in the CDIO Standard 1, which involves the context in engineering education. Moreover, the learning approaches in the four examples are all more or less based on experiential learning, which is explicitly referred to in CDIO Standard 8 as a core function of active learning. Experiential learning is also mentioned in CDIO Standard 7, which motivates for integration of VUCA learning experiences with the learning of disciplinary knowledge, and emphasizes the impact of these experiences.

Example 1: Disaster Days in Iceland (freshman engineer year)

The “Disaster Days” initiative at Reykjavik University was designed as an intensive two-day event that is mandatory for all engineering students early in their first semester in the program (e.g. CDIO Introduction to Engineering). The learning outcomes of the event were first to introduce the students to some unexpected, ambiguous situation that they had to confront in real time and second to realize the value of diversity within the teams. At the beginning of the event, students were briefly introduced to a disaster that was just about to unfold. Most of the information given was vague and ambiguous, and the event unraveled in the subsequent hours. In this way, the intention was to mimic a real time VUCA-like scenario that the students had to tackle. Typically, about 200 students took the course and worked in approximately forty teams of four to six students. Each team was asked to come up with recommendations to the local government on how to deal with the situation. The events were designed in such a way that the students had to analyze the situation and do some back-of-the-envelope calculations. Because the assignments were ill-posed, each team had to improvise in defining their approach. Events in the past have included a threatening volcanic eruption near the city of Reykjavik, an imminent tsunami, that Iceland has to host the Eurovision Song Contest with only a few days’ notice, and a severe pandemic (fall 2019). All the events were realistic and although unlikely to happen, could still have been possible. Faculty members were assigned to teams as facilitators, but the teams mostly worked on their own.

Introducing students to VUCA-like situations early on in their studies may provide them with some skills when confronted with ill-posed problems later in the progression of their degrees. Student feedback indicated that teamwork affected them the most and was considered a valuable experience. Teaming also opened doors to social networking. By far, most of the students liked the event because it was so different to what they were used to in their traditional courses of study, and enabled them to think ‘outside the box’, as some mentioned. A few students commented that the task given was too ambiguous, but most appreciated that it was so open. A detailed description of Disaster Days can be found in Audunsson et al. (2018).

Example 2: Man Overboard in France (sophomore engineer year)

In the context of a European project (www.dahoyproject.eu) at IMT Atlantique, an intensive one-week course for engineering sophomore-year students has been operated (Rouvrais et al., 2019). In real and authentic situations during two and a half days of the week, students are required to act in Man Overboard (MOB) sessions with progressive VUCA criticality levels. The learning is experienced on a sailing boat with around sixteen students inexperienced in the sea environment. Formally, the course permits students to develop and reinforce seven learner decision competencies, each in the context of VUCA characteristics: recognize and qualify; analyze; make a judgment; face the unknown; organize and implement actions; take responsibilities; and learn from experience. While one group is acting, the others observe. Up to fourteen incremental VUCA scenarios are used for MOB, all repeated twice for a team. In each scenario, after a first unexpected and unknown event, students have to define their own rescue procedure based on a short return on experience with the other observer group (reflective practice). A similar event is then repeated to implement the procedure, sometimes with less efficiency due to their procedural rules and new unknown external factors. The concept of meta-rules is thus presented to students after the sea experiences, as rules governing a set of lower-level rules.

The optional course is located in the middle of a curriculum when students are already aware of complex situations they may have to handle as engineers, but still have room to discover new characteristics inherent to VUCA situations. Learning assessment is formative, aligned with the seven learning outcomes. Attitudes and emotional competencies linked to teamwork and leadership are solicited in action but are not assessed (e.g. cases of leadership friction, empathy, anxiety). An interpersonal characteristic was added to extend the VUCA model. In triggering judgment and decision-making skills, this course permits students to develop higher confidence in their ability to grasp VUCA situations, and allowed them to adapt dynamically to unexpected circumstances and unstable contexts. Nevertheless, the VUCA precise characteristics of a situation took time to appropriate in a week only and the letter semantics tend to also be ambiguous. Description of some student feedback can be found in Rouvrais and Gaultier Le Bris (2018).

Example 3: Resilient System Design in Germany (senior engineer year)

As an elective master’s course, the seminar “Resilience and socio-technical systems” takes place annually over a period of five months and targets engineering students from civil, environmental and industrial engineering at RWTH Aachen University. After completing the course, students should not only have sound knowledge and understanding of the concept of resilience, but should also be able to apply resilience and system thinking to different contexts and be able to analyze and evaluate existing crisis management approaches with regard to resilience. The teaching approach consists of several elements in the context of active learning, such as problem- and case-based learning as well as collaborative learning, and is described in detail in Winkens and Leicht-Scholten (2022). By working in groups during the semester, students elaborate a real-world case study on socio-technical systems in reference to resilient system design. The design of the case has been varied in the last years. In one semester, students were given a case on COVID-19, in which they had to take the perspective of a resilience consultant to advise local politics. In another semester, students were able to choose their own case. In both instances, the resilient system design did not only include technical artifacts, instead students had to critically reflect on failures, possible future state, system boundaries and interactions as well as on different stakeholder perspectives.

Moreover, several unknowns were given in the context of which the students had to conduct a scenario analysis. By dealing with an ill-defined problem, students should acquire VUCA-related competencies by learning to deal with uncertainty and complexity, and learning from failure, and should also enhance their anticipatory and system thinking competencies. The course results showed that students developed, in particular, the competencies with higher levels of complexity (e.g. analyze, evaluate, create) during the course. At the same time, these competencies were hardly pronounced before the course. Evaluations and feedback sessions with the students revealed that the task was challenging for them, as they had no previous exposure to resilience or VUCA contexts.

Example 4: Leadership Training in South Africa (postgrads and professionals)

The context in this fourth case is that of a leadership course taught to postgraduate adult learners in the Business School of the University of KwaZulu-Natal (UKZN). The majority of the participants are working students based in the public and private sectors in South Africa. The students emanate from diverse educational backgrounds and hence also workplaces, including the engineering sector. As an academic teaching leadership to adult learners in the Business School, it is critical to draw on the diverse, rich experience that the students bring with them to the classroom. The classes are highly interactive with an emphasis on individual and collective learning, solidified by student-centered approaches, facilitation, and experiential learning. As Business School students possess different qualifications, engineering being among these, it is not possible in most cases to say whether they have had formal VUCA or resilience training in their previous qualifications. However, the students do have valuable life and work experience, which may have already exposed them to VUCA situations and the importance of resilience. The course offered by the Business School thus provides a formal language and skills to assist these diverse students in their leadership development.

There are many challenges facing South Africa, and thus it is crucial that leaders and managers are equipped with the necessary skills to navigate the complexity faced in their workplaces. This is in line with principles of adult learning, where it is argued that these students should learn subjects relevant to their work and personal lives. The classes at the Business School commence with an introduction to VUCA, which inevitably most students have never heard of, but most are impressed with. Time is taken to allow the students to examine the leadership challenges that they face within the context of constant change, and to be able to develop a mindset which is not resistant to change, but rather embraces it and is proactive, thus enabling students to rapidly respond to disruptions. Herein, students gain rich insights as they get to hear about the experiences of fellow students in their work and personal contexts. Many students in the course evaluations often highlight the value of 'realizing that they are not the only ones feeling that way'. The VUCA context then paves the way to allow learners to reflect on what leadership entails, especially in light of the view that their leadership roles should not be focused on being about a position or title, but should rather be understood as an influential relationship amongst leaders and followers who intend real changes. An understanding of VUCA helps the students to understand how they, as leaders and managers, need to have the skills to operate in dynamic, non-linear contexts, where there are high levels of unpredictability (Cartier, 2022). They are able to gain awareness of how they need to conduct themselves in their leadership roles, embrace change, and become adaptable and resilient to deal with the constant changes that define the complex systems that they form part of (Folan, 2021). Emphasis is also placed on gaining self-awareness and personal mastery, but also being able to lead a team and deal with organizational change and culture.

Overview

Table 1 provides an overview of the four T&L examples, as well as their main pedagogical aspects. Thereafter, Table 2 outlines the intended learning outcomes of each example. Based on the outlines provided in Tables 1 and 2, the following section discusses similarities, differences as well as challenges and opportunities of progressive reinforcement of students' skills in the scope of VUCA and resilience.

Table 1. Overview of Four Examples for Teaching VUCA Characteristics

Example	**#1 Disaster Days in Iceland** (Reykjavik University)	**#2 Man Over Board in France** (IMT Atlantique)	**#3 Resilient System Design in Germany** (RWTH Aachen University)	**#4 Leadership Training in South Africa** (UKZN)
Students	First year engineering	Bachelor's & Master's + Erasmus	Master's	Postgraduates
Fields of Study	All students in engineering	IT Engineering	Civil, Environmental, Industrial Engineering	Leadership (diverse student body, including engineers)
Size	200 students, in groups of 5	16 students, in groups of 4	25 students, in groups of 5	15–20 students, in groups of 4 to 5
Part of Curriculum	Mandatory	Elective	Elective	Mandatory
ECTS	1	2	4	6 (equivalent)
Interval / Duration	2 days in the fourth week of semester	Full week between 2 semesters	1 Semester	Block release (2 weeks)
T&L Approach	Experiential learning; PBL; Open ended task	Experiential learning; Peer-learning with reflective debriefings	PBL; Case-based learning; Peer-learning	Experiential learning; Adult learning; Collective learning
Assessment	Team presentations	VUCA field practice; Peer-assessment	Group presentations and reports; Reflective Diaries; Peer-assessment	Reflective assignments
Content/Keywords	VUCA; teamwork; quick decision by a team; multiple disruptions	VUCA progressive scenarios; teamwork; leadership; snap decision	VUCA; resilience assessment methods; scenario planning; system thinking; disasters, learning from failure	VUCA; multiple disruptions; change; leadership; self-awareness; personal mastery; system thinking; team leadership; organizational culture

Table 2. Learning Outcomes and Experience of the Four Examples discussed

Course	Learning Outcomes and Experience
#1 Disaster Days in Iceland (Reykjavik University) 1 ECTS	After completing the course, students are able to: - experience teamwork and understand the importance of cooperation and diversity in a group; - are introduced to diverse ways in presenting solutions; - experience a situation where decisions and planning are based on uncertain information.
#2 Man Over Board in France (IMT Atlantique) 2 ECTS	After completing the course, students are able to: - recognize and qualify the VUCA characteristics of situations; - analyze VUCA situations; - make judgment in VUCA situations and face VUCA characteristics of situations; - organize and implement actions in VUCA situations; - take responsibilities of the decision process in VUCA situations; - learn from VUCA experiences.
#3 Resilient System Design in Germany	After completing the course, students are able to: - develop local resilience-based approaches with regard to the COVID-19 pandemic; - reflect on resilience-oriented approaches and ways of thinking in their future work as engineers. Moreover, they reflect on the relevance of resilience-oriented approaches to local and global crises;

(RWTH Aachen University) 4 ECTS	- analyze different scenarios with regard to their resilience effects. They assess existing crisis management approaches regarding their resilience potential; - apply resilience-oriented approaches to practice-related decisions; - outline, compare and contrast different interdisciplinary discourses regarding the concept of resilience. They understand the relevance of crises in the 21st century; - define resilience with its various conceptions.
#4 Leadership Training in South Africa (UKZN) 6 ECTS	After completing the course, students are able to: - develop leadership capabilities to assist in navigating through disruptive times; - develop self-awareness, personal mastery, team leadership, and gain insights into organizational culture and organizational change; - recognize how the inner aspects of leadership play a role in how they lead self and others; - analyze, reflect on, compare and critique leadership approaches and challenges in diverse work contexts; - develop critical perspectives on leadership theories and practices, and understand the application thereof to their professional and personal lives, especially in a VUCA world.

DISCUSSION

Challenges and Opportunities

A comparative analysis of the presented T&L approaches resulted in the identification of both similarities and differences. A VUCA context is based on high levels of ‘unknown unknowns’ and students thus need the opportunity to learn to deal with this uncertainty. Accordingly, they need to be actively engaged on problems or cases which are ill-defined, but which also represent real-world problems (e.g. volcanic eruption, men over board, pandemic or leadership challenges). All presented approaches include active learning by providing a learning environment that enables engineering students to reflectively work on topics of resilience or VUCA. Notably, in all courses, students work collaboratively and are thereby gaining communication and teamwork skills. The students also develop decision-making and crisis-management skills, which are valuable in navigating the VUCA world. The assessment methods include group presentations and reports, and in some cases, peer-assessment and reflective tasks. The analysis of the four T&L approaches also illustrates the responsibility of academics to teach students to be well-equipped for an uncertain future, and not only to impart content knowledge in a way which may create a potentially false impression of a simple rather than VUCA world. The various approaches also demonstrate how to factor in system thinking and complexity into the curriculum.

Despite the similarities noted above, the four approaches also have differences. First there is the structural difference, which means that the courses are located at different stages in the curricula. Second, there are large classes with around 200 students in some locations, as well as very small classes in others. Furthermore, the courses can be distinguished as either elective or obligatory courses. There appears to be value in incorporating VUCA and resilience topics throughout the curriculum. Early exposure in the curriculum to these valuable concepts may have a wide-spread significant impact on the students’ abilities to navigate complexity. A focus on postgraduates and working students also has tremendous value, by incorporating their work and real-world experience. In terms of the complexity level of learning outcomes apparent in each of the four courses, example 1 is closer to “Remembering” level (have experienced), example 2 at “Analyzing” level, example 3 more at “Creating” level (develop), and example 4 closer to “Evaluating” (critique and challenge).

Example 1 takes place very early in the first semester. In contrast, examples 3 and 4 refer to either master’s students or postgraduates, whereas example 2 targets both bachelor and master’s students. The timing at which students (can) take the courses has an impact on student outcomes, as evaluations or feedback sessions with students have shown. For example, the mandatory course in example 1 showed that students value thinking and working out of the box so early on in their degrees. They also appreciated the teamwork experience.

These experiences can be valuable for students' further study progress by being introduced to VUCA contexts quite early and therefore, promoting the development of skills very early on to enable them to deal with complexity and uncertainty in their roles as future engineers. Example 2 shows how a course can benefit from being located in the middle of the curriculum, based on students' prior knowledge and awareness of complex situations. However, this is only suitable if the students do indeed have prior knowledge and experiences in VUCA environments, which is not always the case. Students took long time to clarify the semantic of the four VUCA dimensions. In contrast, in the elective master's course in example 3, students noted that they had significant problems with the level of uncertainty and complexity, because they had not learned to deal with it before. Furthermore, they had hardly any prior knowledge about resilience-related issues. Finally, this is also illustrated by the fourth example, in which postgraduates initially reflect on their roles as leaders and what leadership entails in an uncertain and ambiguous environment. Leaders who are able to navigate VUCA are critical, given the multiple disruptions that are experienced, and how difficult it is to predict the future (Cole, 2022). The four – partly strongly contrasting – examples illustrate the relevance for a holistic and systematic curriculum approach, as represented by the CDIO educational framework.

VUCA situations can also now be a context of engineering education through which skills are taught, practiced and developed, and where students are exposed progressively from well-defined problems to ill-defined VUCA problems and situations.

Educational Framework Integration

The CDIO syllabus evolves, and revisions are implemented in tandem with changes in society and the expected working environment of future engineers. In the recent update of the syllabus, Malmqvist et al. (2022) stated that there are mainly three external drivers that motivated the changes in the most recent upgrade: sustainability, digitalization, and acceleration. Both VUCA and resilience as discussed in this paper are in the realm of acceleration and one may argue that resilience is an implicit factor in sustainability. Targeted teaching of resilience can contribute to sustainable development (Fazey, 2010).

Thus, specific learning outcomes may help to ensure that students acquire the appropriate foundation for their future to become lifelong learners, a foundation which includes VUCA capabilities and resilience. In the recent 3.0 version of the CDIO syllabus in particular, some categories and topics address resilience-related aspects (Winkens et al., 2023, under review), such as 2.3.2 on emergence and interactions of systems, or 4.1.6 on visions of the future. Moreover, the CDIO syllabus proposes learning outcomes such as initiative and willingness to make decisions in the face of uncertainty (LO 2.4.1) and analysis with uncertainty (LO 2.1.4), uncertainty being just one facet of VUCA situations. Table 2 presents further learning outcomes, for instance, analysis, team leadership, and reflective skills as VUCA-abilities and system resilience.

VUCA and resilience outcomes are transversal to curricula. Related competencies include skills and attributes developed by students when they are placed in VUCA contexts. As stated in the CDIO Integrated Curriculum Standard, "the integration of skills and multidisciplinary connections are to be made, for example, by mapping the specified learning outcomes to courses and co-curricular activities that make up the curriculum" (Malmqvist et al., 2020). To meet dedicated learning outcomes, within the context of simple problems to progressive high VUCA contexts, T&L activities may reach individuals, organizations, and communities, as the sociotechnical systems to be built. The CDIO Integrated Learning Experiences Standard prompts "pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, system, and service building skills" (Malmqvist et al., 2020). Resilience skills can be introduced and reinforced only through the use of pedagogical approaches that expose students to VUCA, in an integrated approach. The CDIO learning assessment standard could be extended with Bloom-based proficiency levels, starting from level 1 with exposure to VUCA situations, to higher levels where students are expected to lead and innovate in VUCA situations.

CONCLUSION

The aim of the paper was to compare and discuss T&L activities addressing VUCA and resilience, occurring at different engineering curriculum levels. The four presented courses are good examples of progressive contextualization of VUCA contexts for students, from freshmen to postgrads. Furthermore, as discussed in the paper and as reflected in the progression of the four courses, introducing resilience is a logical continuation after addressing VUCA-like scenarios, at least in engineering education. Based on the need for aligning curriculum integration with new learning outcomes, engineering curricula can echo in their intentions, within a framework of development such as the CDIO, the inclusion of VUCA and resilience. The emphasis on rapid changes that are a part of VUCA is highlighted in the most recent upgrade of the CDIO syllabus, although VUCA and resilience could be stated more directly.

As already argued, it is critical that engineering students develop resilience skills in order to prepare them for a VUCA shaped workplace. Previous research has emphasized the importance of developing the necessary skills to enter the workplace, contributing to high-level goals to ensure that engineering graduates are able to fit in well to their work (Gerwel Proches et al., 2018). VUCA is the 'new normal', and while there may be little that can be done about the external factors, what academics can concentrate on is to strengthen the internal aspects (Garti & Dolan, 2021). So far, however, there appears to be few approaches addressing such training. Based on the experience of comparing four different courses, the paper delineates how engineering programs can better prepare their graduates to design more resilient socio-technical systems, including effective learning methods and learning outcomes.

While we cannot generalize beyond our individual contexts, the paper does offer valuable insights and indicates areas of study which could be explored in further research. First, a continuum of the four cases with a same cohort is to experience for validating arguments and meet research questions. In the future, new evaluation techniques will be required for programs, like the ones presented in the paper. For such, a direction could draw on more formal qualitative and quantitative analysis to compare the T&L approaches with learning outcomes proficiencies.

The resilience of the higher educational system itself could be explored, by examining curriculum properties to face VUCA circumstances. Future research could also explore how to develop the VUCA and leadership skills of program managers and faculty to ensure resilience of their programs. As change agents, an examination of the approaches to reinforce program managers' and faculty's capability to handle the unknown, and to ensure that the curricula and educational systems they manage become sustained by resilient characteristics, is indeed necessary. As highlighted in the CDIO Standard on Enhancement of Faculty Competence, "the collective faculty needs to enhance its engineering knowledge and skills so that they can provide relevant examples to students and also serve as individual role models of contemporary engineers" (Malmqvist et al., 2020). This will promote the development of faculty capable of facing VUCA situations, thus ensuring better resilience of the higher educational system itself.

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