CDIO approach to write Reference Models for training decision skills

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ABSTRACT

Preparing engineering students for the future is becoming increasingly challenging as the pace in world and business environment escalates. The CDIO initiative provides curriculum designers and faculty with a template that stress the fundamental attributes that engineering graduates should possess when they enter the workplace. As discussed in this article, the template can also be applied as a framework to set forth educational guidelines on a particular subject. In particular this article examines how the CDIO methodological approach is applied to mature a procedure for enhancing certain managerial skills. The procedure is aimed to guide educational institutions how to implement training on judgement and decision-making skills in situations that are volatile, uncertain, complex, and ambiguous (VUCA). The outcome presents seven essential and successive decision skills that are to be adopted in the curriculum. The curriculum development is progressed via six stage-based reference models (6RM). Each of the six reference models constitutes the set of criteria needed for the implementation and adaption of the required change processes. Furthermore, each reference model comes with a rubric for a self-assessment on the current maturity of a VUCA based educational program. The point position to communicate the seven decision skills and other managerial challenges to address can also be scaled with the 6RM. The seven decision skills and the Six Reference Models are the offspring of the Erasmus+ funded program Dahoy that started in 2017 and completed in 2020. The 6RM were tested as a pilot study at the Engineering Department of Reykjavik University in 2020 with positive results.

KEYWORDS

Decision making, reference models, curriculum, Dahoy, Standards: 1-12.

INTRODUCTION

The context of this paper is how the CDIO guidelines, standards, and rubrics, can be applied to constitute a comprehensive reference model for establishing and developing an educational program in the academic field of decision analysis under conditions of uncertainty. The undercurrent of this endeavour is the increasingly complex world engineers must work and thrive. Whether they are to act as experts on environmental issues, technology, engineering, national emergency or other fields, future decision makers should also be specifically prepared to making decisions in what is named the VUCA environments (i.e. Volatile, Uncertain, Complex, and Ambiguous). The VUCA concept has been used earlier as platform to enhance engineering and other educational structures see for example Latha and Prabu (2020), Rouvrais, Gaultier Lebris and Stewart (2018) and Seow, Pan and Koh (2018).

Decision is a complex concept, with multiple dimensions. For engineers, decision making echoes in scientific methods (e.g. math-based), human environment (e.g. social-based), or even in professional pathways and development (e.g. career-based), or even in professional pathways and development (e.g. career-based).

The field of decision analysis, first introduced by Raiffa and Schlaifer (1961), was originally mostly a mathematical discipline, but it has evolved into a useful method for industry and government. Math-based decision-making methods have their limits. People are not always rational and are affected by cognitive and behavioural aspects that might e.g., limit the use of statistical analysis. In later years the seminal work of Daniel Kahneman and Amons Tversky on how cognitive biases influence our behaviour shape our decision-making has become instrumental part of decision theory see e.g. Kahneman and Tversky (1979). It is also worth mentioning the work of Taleb (2007) on what he calls black swan events, i.e. extreme events with low probability and high impact the covid-19 pandemic being a perfect example. This decision problem has e.g., been addressed in studies by Fridgeirsson et al. (2021) using the VUCA concept to capture risk influences in decision-making. The axioms of decision analysis will not be discussed any further, but a reference made to the authors publication see Gaultier et al. (2017). The attributes of the seven decision skills accounted for later in the text are products of decision making in context of the mathematical and social sciences briefly mentioned earlier in this section.

To stimulate pedagogical innovation in training decision making skills in VUCA-like situations the project D'Ahoy was initiated. The project was named Decision Ship Dahoy (a reference to A. G. Bell, the Scottish-born scientist who patented the first telephone and originally suggested 'Ahoy' as the standard greeting when answering a call) and was funded by the Erasmus+ program for the period 2017-2020. The main instigator of the project was Dr. Siegfried Rouvrais of the IMT Atlantique – Télécom Bretagne (France). Other participants in developing the scheme were from Ecole Navale (France), COGC (Scotland), SCQF (Scotland) and Reykjavik University (Iceland).

From the beginning the CDIO Initiative inspired the academics and professionals working on the Dahoy project. In the CDIO Syllabus (see www.cdio.org), Decision Analysis with uncertainty (ref. 2.1.4) and initiative and willingness to make decisions in the face of uncertainty (ref. 2.4.1) are requirements for personal and professional skills. Making complex technical decisions with uncertain and incomplete information is also a CDIO requirement for exercising judgment and critical reasoning (ref. 4.7.7).

The CDIO standards are designed to be a framework for complete engineering programs. The research questions in this study are firstly if and how the CDIO framework and standards can be applied and adapted to specific subject within an engineering program, in this case to train decision making skills in VUCA-like environment. The adaptation was developed during the course of the three-year Dahoy-project. Secondly, as aa evaluation of the proposed adaptation, we present a case study where we apply it to the first year of engineering at Reykjavik University, which offers a traditional education in engineering.
This paper is segmented in firstly describing the Dahoy project, then how the project outcomes comply with the CDIO standards. Then we introduce rubrics for assessing the levels of curriculum maturity of an educational institute. Lastly, the reference model is put in practice by assessing an engineering program and the compliance of a teaching event towards the skillsets derived from the Dahoy project.

DECISION MAKING SKILLS AND THE DAHOY PROJECT

The objective of the Dahoy project was "to create inclusive, active and experiential pedagogies for better Decision-Making skills in VUCA situations, so as to render education systems more accessible and attractive" (Dahoy, 2018). The foundation for the Dahoy project were fundamentals theories in Decision Making. Rouvrais et al. (2020) discussed and argued for training of decision-making skills in a VUCA-like situations.

The Dahoy project empathizes that students understand the scope and limitations of mathematical decision-making methods and of computing tools. The VUCA approach to decision making is intended to enhance the student´s decision skills by adding elements of social sciences. Noteworthy in this respect are learning to recognize cognitive biases, utility-based decision modelling, scenario planning, etc. The authors like also to refer to a previous publication for more detailed orientation (Gaultier et al., 2017). Moreover, the decision skills to arrange and development future career were included in the program. The three perspectives of decision skills that were considered,(i) math-based, (ii) social-based, and (iii) career-based, are shown in Figure 1.

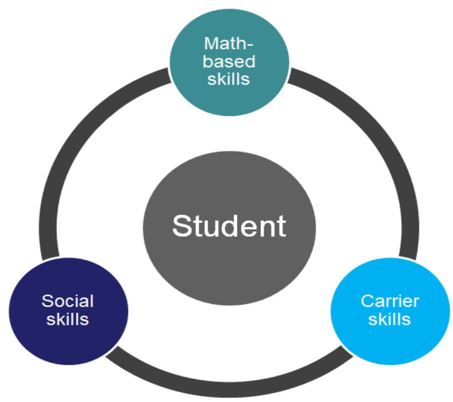

Figure 1. The interconnected skillsets of the Dahoy academic perimeter (Dahoy, 2018).

The realization of the objective of the Dahoy project was the writing of reference models and maturity assessment model for educational institutions. Reference models are useful to create standards to define the desired qualities and the benchmark for maturity. Furthermore, to stress the challenges of the change process and improve communications among the stakeholders. Moreover, to outline the entities of the concept and the applicable strategies for implementation. The authors acknowledge that the use of the term “reference model” might cause misperception, as this term is more traditionally associated with the realm of software development. However, this was the term selected for use in the Dahoy project and is applied in this study for the sake of consistency.

DEVELOPING STUDY LINES

Successfully developing a study line or a particular theme that is to be integrated in several courses within a study line, is based on careful planning and continual revision. The course goals must be clear and well documented in the learning outcomes, consistent with the overall outcome of the study line, the pedagogy must be strongly connected to the learning outcomes followed by the courses content and teaching methods. There are three methods of course design that are commonly used, i.e. forward, central, and backward (Richards, 2013). Other models worth mentioning are Dick and Carrey, Kemp, and Three Phases models (Kusrini 2018)

The CDIO initiative has been successful in revising and aiding in continued development of engineering education worldwide (www.cdio.org), and the experiential learning pedagogy is both implied and explicit in the CDIO paradigm and standards. In the Dahoy-project there was interest in applying the CDIO approach, standards, and rubrics, as a guiding light in implementing a program in training decision skills.

THE PROGRESSION OF THE DAHOY-

Reference models

The writing partners in the Dahoy-project were provided with guidelines based on the CDIO Initiative approach of writing standards. The writing guidelines ensured that the results were presented in a consistent mode. Overall, six reference models (RM) were composed as figure 2 shows.

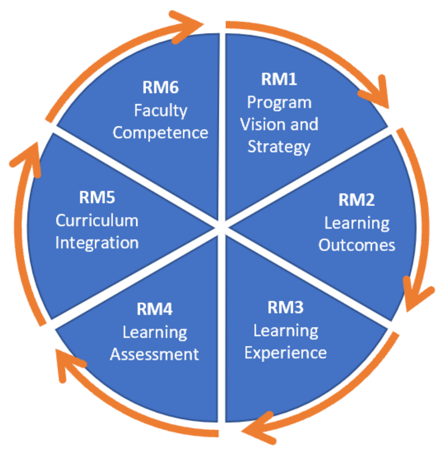

Figure 2 The Dahoy Reference Models (RM) (Dahoy, 2020).

Table 1 shows the correspondence between the Dahoy-RM and the CDIO-standards. The table shows explicitly how the standards were used as a template for establishing an educational program within an already established engineering program, or for a management program for that matter. Although the standards are used here as a template for the field of training decision-making, it might as well be used for other subdisciplines of engineering. The CDIO-standards used were on stating the philosophy of the educational program (1), learning outcomes (2), on the teaching and learning process (7, 8, 11), and on faculty development (9, 10). Four out of the 12 standards were not used, 3, 4, 5 and 6, as they were not relevant for training decision making.

Table 1. The six reference models (RM) as developed in the Dahoy-project and the corresponding CDIO-standards V3.0 (Dahoy, 2020) and (CDIO, 2020).

RM References for curriculum development specific for training decision skills in VUCA-like situations.	CDIO Comprehensive standards describing engineering programs committed to the CDIO philosophy.
RM1 Context Establish programme vision and strategy to include training and teaching decision analysis in VUCA situations and facilitate support from program leaders to sustain reform initiatives at higher institutional level.	1 Context. Adoption of the principle that sustainable product, process, system, and service lifecycle development and deployment – Conceiving, Designing, Implementing and Operating – are the context for engineering education. 12. Program Evaluation.

	A system that evaluates programs against these twelve standards and any optional standards adopted, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.
RM2 Learning Outcomes Include the seven decision-making skills in the learning outcomes of the program and put them in the context of activities that are complex and where there is unpredictive change.	2 Learning Outcomes Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, system, and service building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders.
	Standards not used: 3, 4, 5 and 6
RM3 Learning Experience Training in decision making should be based on three components, mathematical, social and career, with variable intensity and complexity. The training can be implemented by standalone modules or integrated in transversal courses modules or courses. Emphasis is on experiential learning.	7 Integrated Learning Experience Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skill. 8 Active Learning Teaching and learning based on active and experiential learning methods.
RM4 Learning Assessment Assessments should evaluate the skill sets acquired by students by participating in the relevant activities and modules and should reinforce reflection of activities.	8 Active Learning Teaching and learning based on active and experiential learning methods. 11 Learning Assessment Assessment of student learning in personal and interpersonal skills, and product, process, system, and service building skills,as well as in disciplinary knowledge.
RM5 Curriculum Integration The curriculum should be enriched by integrating decision making skills, emphasizing methods and processes.	10 Enhancement of Faculty Teaching Competence Actions that enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning.
RM6 Faculty Competence The educational programs should commit adequate resources for staff development and training.	9 Enhancement of Faculty Competence Actions that enhance faculty competence in personal and interpersonal skills, product, process, system, and service building skills, as well as disciplinary fundamentals. 10 Enhancement of Faculty Teaching Competence Actions that enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning.

Each RM entity (as outlined in Table 1 and Figure 2) consists of:

- *Introduction:* The content of the RM section and give information on why the section is needed as well as background information if applicable.
- *Goal:* A goal describes the educational institute edifying decision skills should expect or hopes to accomplish strategically, tactically and/or operationally over a specific period by the respective RM.
- *Stakeholders:* In education, the term stakeholder typically refers to anyone who is invested in the welfare and success of a school and its students, including administrators, teachers, staff members, students, parents, families, community members, local business leaders, and elected officials such as school board members, city councillors, and state representatives. Stakeholders may also be other

collective entities. Each section should identify the main stakeholders the respective RM concerns and the role of the stakeholder.

- *Description:* The Description should explain the scope of the respective RM, i.e. it should describes what the corresponding RM section does.
- *Rationale:* Rationale describes the underlying basis for the RM and should list exactly what the educational institute to do to use/deploy the corresponding RM for the purpose of edifying decision skills.

Maturity rubrics

The 6RM´s are supported by a maturity rubric to sustain the progression of developing the program. The role model for the maturity assessment is the CDIO generic rubric applied to each of the 12 CDIO standards. Each RM can be rated based on a self-assessment and for demonstration the rubric for RM1 (context) is shown in Table 2:

Table 2. Example of a maturity rubric for the first Reference Model, RM1 (The context) (Dahoy, 2020).

Level	Maturity level
1	There exists no plans to incur VUCA principles in the visions and missions of the University, nor teaching agenda in the foreseeable future on decision skills in these contexts
2	There is an institutional vision stated, and documented plan or activity related to the VUCA criteria in the school for teaching and training purposes. Interest among stakeholders but consolidated activities and functions are missing.
3	There is an awareness of the needs of how to adopt the VUCA teaching criteria and a plan, validated with key stakeholders, is formalised and a process is in place to address them and direct activities are work in progress.
4	There is a plan implemented in place to address the VUCA criteria for teaching and some VUCA activities are in function as part of the teaching schedule and the syllabus, across the curriculum. VUCA advocates are among the faculty.
5	The VUCA statements and decision programme outcomes are formalised in the institution’s strategic documents. There is documented evidence of the full implementation and impact of the VUCA based teaching strategy across programme components and several VUCA activities for decision skills reinforcement are in function. A clear emphasis on VUCA teaching consolidated in the syllabus and among faculty members is visible and verifiable
6	Evidence related to the VUCA based teaching strategy is regularly reviewed according to the missions of the institution and its strategic plans, and used to make continuous improvements. VUCA is teaching as core competence in the graduates profiles in the syllabus.

Testing the model

The 6RMs were applied at the Department of Engineering at Reykjavik University to assess the current maturity of decision skills teaching and learning in the context of the project. The Department of Engineering is a member of the CDIO initiative as over 100 other progressive universities. A grid was arranged, and the maturity of the scheme evaluated subjectively by two experienced faculty members. Apparently, the six reference models appear to be a useful indicator of the level of maturity and a realistic platform for further development of the teaching and learning programme. Table 3 shows the results of the current state. The level numbering refers to the textual description of the maturity in the context of the respective RM.

The assessment was carried out via expert panel consisting of faculty members. The RM´s were deemed as usable to assess current state of teaching in context of the Dahoy program. Moreover, the model gives decent indication on the tasks needed to develop the curriculum towards VUCA based teaching Decision Analysis based on mathematical and social principles.

Table 3. Assessment of the maturity of the 1st year engineering program at Reykjavik University.

RU 1´ST YEAR ENGINEERING PROGRAM		
REFERENCE MODEL MATURITY ASSESSMENT GRID		
Reference Models	**Level**	**Explanation**
RM1 – Context	3	There is an awareness on the needs of how to adopt the VUCA teaching criteria' s and a plan, validated with key stakeholders, is formalized and a process is in place to address them and direct activities are work in progress.
RM2 – Learning outcomes	2	There is some reference to decision skills and/or VUCA capabilities in the programme outcomes or in a graduate profile.
RM3 – Learning experience	3	Active or experiential learning methods for decision skills is being implemented across the curriculum including the VUCA dimensions.
RM 4- Learning assessment	3	There are summative assessments in place for all VUCA activities and decisions skills related T&L, and there are actions in a plan (?) in place to include formative assessments.
RM5- Curriculum integration	2	The need to analyse the curriculum along VUCA dimensions is recognized and initial mapping of transversal decision skills learning outcomes is underway.
RM6 – Faculty competence	2	A benchmarking study and needs analysis of faculty competence and faculty teaching competence has been conducted on Decisions Skills.

Dahoy-Project outcomes

Firstly, seven skill statements were identified in the Dahoy-project that learners of decision making under uncertainty should be capable of. These are listed in Table 4. These skills are mirrored in the 6RM's and the respective maturity rubrics as applicable. Furthermore, other more site-specific factors like the managerial challenges, stakeholder identification, change processes, curriculum development, faculty integration are addressed with references to EU and national doctrines as possible.

The compliance of certain teaching event towards the seven decision skills can also be assessed. The authors assessed the event "Disaster Days" by a compliance grid, see Table The engineering programmes at Reykjavik University (RU) have since 2011 run a two-day intensive course, Disaster Days (DD), early in the first semester (Audunsson, Fridgeirsson and

Saemundsdottir, 2018). The context of the project in “Disaster Days” is an unexpected challenge that must be dealt with in teams in a single day, and each team must make decisions in a VUCA-like situations. The DD endeavour was originally developed to introduce freshly enrolled students at Reykjavik University to alternative teaching methods in line with the experiential learning strategy. The DD also turned out to be a success on connecting students and forming social relationships that contributed to the learning progression of the student during his stay at RU. The original concept did not include the VUCA idea directly although the relationship was apparent. The DD as a test case to audit the “VUCA-lity” of the DD teaching event was therefore interesting to the content creators that are supposed to bring on new and innovative challenges each year. The audit turned out to give realistic results on the current state of VUCA’lity and indicate how the event could be improved.

Table 4. Compliance to a particular educational event based on the seven decision skills that were identified in the Dahoy-project.

RU 1´ST YEAR ENGINEERING PROGRAM - DISASTER DAYS				
VUCA ASSESSMENT GRID				
DECISION SKILLS	**V**	**U**	**C**	**A**
D1 - Recognize and qualify a VUCA situation	Medium	High	Medium	High
D2 - Analyse a situation	High	Medium	High	High
D3 - Make a judgment	Medium	High	Medium	Medium
D4 - Face complexity	Medium	Medium	Low	Medium
D5 - Organize and implement actions	High	Low	Medium	None
D6 - Take a responsibility of a DM process	Low	Low	Medium	None
D7 - Learn from experience	Low	Low	Low	Low

DISCUSSION

Of many schemes of developing and implementing new study lines or courses (e.g. Richards, 2013), we felt it was appropriate and worthwhile to apply the CDIO standards in the specific case of implementing the training of decision making skills for engineering students. Above we presented the reference models (RM) and maturity rubrics developed in the Dahoy-project, both of which were based on the standards and rubrics resulting from the CDIO approach. The CDIO standards provided the Dahoy partners with excellent platform to make the work effective and efficient. The outcome in the form of Reference Models, skillsets and Maturity models were tested in real life by auditing an engineering program and experiential teaching event. The model turned out to be usable in its current state and reflect adequately the academic and managerial challenges for engineering programs planning to teach VUCA based decision skills. However, the 6RM´s are definitely in the first stages and could arguably be simplified and made more accessible for use. In short, as an answer to the main research question posed initially, we can conclude that the CDIO framework and standards can be applied and adapted to specific subject within an engineering program, in this case to train decision making skills in VUCA-like environment.

CONCLUSION

The training of engineers should reflect the world in they operate. The VUCA concept is sensible to influence the mind of the engineer towards scenarios characterized by uncertainty and complexity. It is therefore valuable for the developers of curriculum in higher education institutes to have access to references paving the way for VUCA augmented programs. We have outlined how the CDIOstandards and rubrics, were applied to construct a comprehensive reference model for establishing and developing an educational program in the field of decision analysis under VUCA-like conditions. The program on decision making as discussed here is intended to be run within an already established engineering program, such that only a part of the CDIO-standards was needed. It appears that the standards are comprehensive and general enough such that the methodology presented here might be applicable for other educational programs.

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