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Breadth Experiential Courses to Meet Programme Outcomes for Engineers

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Abstract. In engineering education, it is recognized that non-technical courses are to enhance student enthusiasm. Breadth courses are not part of the classical scope of the curriculum structure and expose students to a range of perspectives outside of their engineering program. For this reason, such courses reinforce the students' motivation and self-confidence, but may also strengthen transdisciplinary skills, fully aligned with the engineering profession requirements. Based on this assumption, this paper reflects, via a qualitative analysis, on a navigation and sea risks course, including in-situ real experiences, aimed at future engineers in a generalist and integrated programme. Because it triggers decision and judgment making skills, the course permits students to develop higher confidence in their ability to grasp complex situations, to adapt dynamically to unexpected circumstances, and to act in uncertain contexts.

Keywords: Engineering education, breadth courses, integrated programme models, decision skills, judgment making, qualitative analysis.

1 Introduction

Bachelor or Master Studies in a liberal arts programme permit to cover knowledge and skills not directly relating to technical or professional body requirements. In the USA, liberal arts education is well established in colleges, leading to a Bachelor of Science or even in some cases a Bachelor of Science in Engineering degrees. In Europe, even if the liberal art style is deeply rooted in some countries, “there is no consensus in structuring engineering education, but rather a constructive diversity in programme design” [1]. Nevertheless, at Master level since the Bologna operationalization process, humanities and social sciences subjects are now constituent of many accredited engineering programmes, via classical lecture models or transdisciplinary approaches based on problem- or project-based learning (PjBL).

As a European example, in the French engineering education model, generalist curricula are a tradition in the highly selective *Grande Ecole* system [2]. Among these typically French selective higher education institutions, *Grandes Ecoles d'Ingénieurs* lead to a Master of Engineering degree in three years, preceded by two years of national intensive preparatory schools, delivering mainly in-depth knowledge and understanding of mathematics and physics. These engineering *Grandes Ecoles*, which traditionally offer a balance of scientific, technical and non-technical courses, increasingly consider integrated programme models so as to better align with up-to-date graduate attributes and programme outcomes [3], e.g. as fixed by engineering education accreditation bodies (e.g. the EUR_ACE® framework [4], the French *Commission des Titres d'Ingénieur* [5], or the Accreditation Board for Engineering and Technology) or as specified in syllabus by international educational frameworks like by the CDIO initiative [6].

Integrated educational architectures do not offer the same level of flexibility to curriculum designers as liberal arts programme architectures. In integrated programmes, several intended learning outcomes, which relate to programme outcomes areas defined by accreditation bodies or professional branches, are to be fixed at design time (cf. outcome-based programme design). Then, these outcomes may be mapped at all levels of the curriculum into learning activities, which are integrated into courses. By the end of their studies, engineering students may then validate their competence in the various areas pursuant to constructive alignment.

In France, with a separation of engineering from other Science programmes, general engineering programmes are attractive to students who had previously not considered engineering. In another context, Alpay [7] indicates that a general engineering programme is highly attractive to students who are considering an engineering degree, and also to some students who had previously not considered engineering. Nevertheless, strongly coupled and integrated curricula are factors which may impact student motivation when the focus is merely in engineering. In a University context in Scotland, Christie, Munro, and Fisher [8] showed via comparison groups that factors inducing the student to withdraw include poor choices of course, limited social support networks, and lack of 'fit' between student and institution. As regards the first factor, it seems legitimate to consider that the level of course coupling and integration in a curriculum will affect the student's motivation. Another factor, which may be called "career misconception" may also be explored, a "large number of professional opportunities makes it difficult for many engineering students to determine which career path to favor. As a matter of fact, each incoming student does not necessarily have a professional ideal. Moreover, many freshmen have a limited knowledge of the working world as well as false ideas thereon. Consequently, uncertainty and indecision often result from their appraisal of the career kaleidoscope, possibly

causing a decrease in their engagement and motivation level. It is therefore critical to reinforce students' self-confidence" [9]. More recently, Holmegaard, Madsen, and Ulriksen [10] found that students' expectations of engineering are poorly satisfied by their actual experiences during their first-year study programme. In their attempt to bridge such a gap, students apply some strategies, e.g. to compromise their expectations and identities to become more aligned with the study programme, which may turn out to be counterproductive.

With a view offering to students some flexibility in its integrated engineering curriculum and increasing student motivation and self-confidence, without neglecting programme outcomes alignment, Telecom Bretagne (a public accredited French *Grande Ecole*, a School of engineering member of Institut Mines Telecom) introduced breadth courses in its programme architecture in 2003. Based on this, this paper first explores the expected benefits of such breadth courses in the next Section and then clarifies breadth courses integration in the so-called "inter-semester weeks". Alignment with programme outcomes is discussed in that flexible context, with a specific focus on transdisciplinary skills such as decision and judgment making, used as examples for this paper. Then, the specific one-week course "Navigation and Sea Risks" held in January 2016 is presented and supported by a qualitative analysis to show its benefits in the integrated engineering programme. This paper concludes with potential future work for the 2017 inter-semester session so as to reinforce student confidence and efficacy, such as decision making abilities in uncertain complex situations.

2 The Intersemester Weeks at Telecom Bretagne with Breadth Courses

As defined by the Simon Fraser University¹, to qualify as designated breadth, a course should be "intellectually accessible to non-majors; that is, a student's ability to master the course content should not depend on bringing to it the kind of specialized knowledge typically possessed by students majoring in a discipline. Thus, breadth courses mainly cover outside of the student's major, e.g. breath-Humanities, breath-Social Sciences. A breadth course expose students to concepts and ideas from a range of disciplines and perspectives outside of their programs".

2.1 Curriculum Integration

¹ SFU Undergraduate Curriculum Initiative: Breadth requirements. Available from https://www.sfu.ca/ugcr/for_students/wqb_requirements/breadth.html (consulted in August 2016).

Aside from semester multidisciplinary team-based projects [3] and classical core courses, Telecom Bretagne integrated breadth subjects since 2003 via so-called inter-semester week courses. More precisely, freshmen and sophomore engineering students have to select two subjects among a set of breadth courses, each year after their exam sessions. This set evolves each year, mainly depending on the dynamic context, student engagements and faculty motivations. In January 2016, 30 breadth courses, were proposed, including: Deep Learning; Business Intelligence; Risks in Mountain; Leadership; Art Design; Geopolitical Energy Crisis; Astronomy; French Political Life; The French Social and Economic Model; Korean Culture; Intercultural Approach to Music; Theatre Techniques; Digital Photography; Musical Composition Tools; Sign Language, a.s.o. As such, some of these courses may be categorized in Humanities, Communication, Society, Economy, Literature, Politics, Culture, Outdoor, etc.

Each breadth course at Telecom Bretagne is credited (2 European credits, aka ECTS), but optional, and has a one-week duration. As seen in Table 1, breadth courses (termed INT in the agenda) are positioned in the middle of the year, right after the semester exam sessions. In an academic year, a student has to select one major (16 credits, e.g. Maths and Signal Processing, Electronics and Physics, Computer Engineering, Networks, Economics and Social Sciences) and one minor (8 credits, more oriented towards basic understanding of systems rather than deep analytical or technological aspects) per semester. Per semester, he/she also must actively participate in a team project during the 14 weeks (6 credits), generally one day per week [3]. He/she must also achieve a required level in two foreign languages and follow a compulsory career-course (e.g. others).

Tab. 1. Programme structure at Telecom Bretagne (2003-2017 architecture).

Academic Year i				
Major	Minor	INT 1,2	Major	Minor
Languages			Languages	
Semester PjBL			Semester PjBL	
Others			Others	

In 2016, 17 courses were proposed in week 1 (out of the 30), also 17 in week 2 (in the pool of 30), with a cohort of around 350 students. Among these breadth courses, 11 were new courses with respect to the 2015-16 academic year, showing a healthy course turn-over.

2.2 Flexibility and Openness

At Telecom Bretagne, breadth courses are a complement in the formal integrated curricula. They permit to add flexibility to the relatively closed major & minor disciplinary structure, and as for the liberal arts model, to offer openness and variety, thus meeting students' curiosity. Maintaining a prominent place for breadth courses in curricula and granting credits for them, not only allow to attract students and clarify their mind after intensive exam sessions, but also to foster transferable skills for the benefit of the future engineer having to navigate in more complex professional environments.

The benefits of breadth courses can also be found at the system and faculty levels. Academics may find educational spaces to echo their personal interests or passion in their professional activities (e.g. photography, travelling, political engagement, sports like skiing or sailing), lecturers or professors may manage smaller classes with more motivated student profiles, and may test in a sandbox new pedagogical activities or new partnerships (e.g. design with School of Arts, Geopolitics with Military Schools). New thematic can be reactively incorporated in the curricula (e.g. big data, inclusion in the context of migrant crisis, terrorist attacks intelligence). Last but not least, breadth courses give academic developers a strong pedagogical liberty in the learning style and require most often smaller size teaching teams.

Many competencies of the engineer are not merely based on knowledge or exclusively built on scientific or technical aspects. But offering to engineering students variety and flexibility in the course choices [11] requires some academic control, even for non-engineering courses. Programme or student outcomes (aka graduate outcomes), in line with the most recent accreditation systems and national professional body's requirements, are to be met.

3 Teaching and Learning Activities for Decision and Judgement Making Transdisciplinary Skills

By tradition, the French *Grande Ecole* system is viewed as producing engineers with highly recognized management skills. The level of complexity for a future executive (for example an engineer) is supposed to increase with his/her level of responsibilities. In large project contexts, an executive may face complex situations during his/her career with increasing responsibilities: he/she will be assessed on his/her ability to manage complexity and this criterion will have the same weight as other technical criteria in several companies, especially for managers. As a leader, the engineer is expected to learn "to put things in perspective" in order to keep a global vision of a situation.

As defined by ENAEE, the European Network of Accreditation of Engineering Education, Programme Outcomes describe “the knowledge, understanding, skills and abilities which an accredited engineering degree programme must enable a graduate to demonstrate” [4]. Programme outcomes areas are proposed so as to classify graduate or postgraduate engineering student outcomes (cf. ‘a-k’ ABET or Eur-ACE criteria), e.g. Engineering Analysis, Investigations, Judgment Making, Communication and Team-working, Lifelong Learning. As an example, managing a complex project will require knowledge and understanding such as “critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields” [4], but also analytical skills such as “an ability to identify, formulate and solve unfamiliar complex engineering problems that are incompletely defined, have competing specifications, may involve considerations from outside their field of study and non-technical – societal, health and safety, environmental, economic and industrial – constraints; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods in problem solving” [4].

Although programme outcomes are well defined, many institutions continue to explore teaching & learning activities that effectively and efficiently develop these attributes [12]. A graduate attribute or student outcome may be covered by a dedicated course with a classical lecturing/practical model, but the complete development of an attribute is best covered by several teaching and learning activities, including several experiences. In order for engineering students to achieve these objectives by the time of graduation, skills and behaviours are to be acquired all along a curriculum, with instructional methods that engage students in the learning and doing processes. To meet such challenges, active and experiential learning methods (e.g. PBL, team based PjBL) are now in place in many engineering education institutions, in addition to internships or sandwich years in industry. To a certain extent, in a higher education academic context, experiential courses should reflect real professional situations taking place in the academic workspaces, sometimes with a lower or progressive level of complexity.

For the sake of this paper analysis, where real in situ situations are investigated for experiential learning as part of the engineering practice, student must develop a “critical awareness of economic, organisational and managerial issues (such as project management, risk and change management)” [4], but also judgment making abilities:

- to integrate knowledge and handle complexity, to formulate judgements with incomplete or limited information, that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgement;
- to manage complex technical or professional activities or projects that can require new strategic approaches, taking responsibility for decision making.

4 System D and Active Learning

As noted by Rouvrais, Mallet, and Vinouze [13] in 2010, many teaching & learning short activities have been designed to promote team work and experientially-based skills. Accordingly, “icebreakers, kick-offs, warm-ups, energizers, escape games; or brain-teasers are often used in student group activities [14]. For example, at MIT, “short active learning games were introduced as activities to support formal classroom education. Polytech Singapore has proposed a One-Day One-Problem™ framework confronting students to a problem in order to generate solving skills” [13].

Classically, project management skills are addressed in team based projects, with a focus on the selection and application of the most appropriate and relevant methods from established analytical, computational and experimental methods (e.g. WBS, GANTT and PERT tools, risks identification, analysis, and mitigation). For instance, the focus may be on the magnitude and complexity of the tasks or the number of stakeholders with dynamic requirements [15]. But the engineering professional environment is not always fully rational and predictable, even with risks analysis. Students may also need to be able to handle some kind of improvisation and rapid dynamic adaptation. The concept of improvisation and creative “*bricolage*“ was studied by Weick [16] in a context of time pressure, complexity and irreversibility of error in the decision-making process with a view to reaching a higher level of reliability in the organizations. For Weick, the organizational reliability depends on the ability of the actors to organize and reorganize, in order to anticipate and cope with unexpected and crisis situations. Weick highlights four sources of reliability and resilience: (i) respectful interactions between team members, (ii) a well established system of roles, (iii) skills of improvisation and creative *bricolage* and (iv) an attitude of wisdom when facing a situation.

In another context, as reliability represents a real stake in the Navy, in order to stimulate these skills among cadets, the French Naval Academy (*Ecole Navale*, located in Brest just like Telecom Bretagne), has set up nautical exercises soliciting these four sources of resilience. These nautical exercises are organized so as to develop flexibility among cadets (to adapt to any kind of situations and develop improvisation and creative *bricolage* skills), but also an attitude of watchfulness during navigation, a good level of interactions and a good-working system of roles in the teams. As another example, the French Naval Academy also proposes a human sciences project called “Ingenuity & System D” to develop, in particular, the cadets’ skills of improvisation or creative *bricolage*. These competition aims to highlight the practicality of team working (e.g. 5 students), to solicit the ingenuity that lies within the group and to compete with other schools from the Region. In May 2016, the theme related to life and safety issues on ships. This competition requires teamwork, creativity and a good practical sense.

5 Navigation and Sea Risks for Experiential Learning

To address the aforementioned System D skills (aside the formal curriculum which concentrates on large project management skills) the authors chose, as breadth inter-semester course (specified INT164), a specific class of phenomenon [17] to train students to take decisions and react in unexpected and unpredictable situations. The real experiential situations so selected reflected real-life nautical scenarios with a high level of complexity and time pressure, where specific skills were to be acquired or reinforced, such as risk and priority management, watchfulness, team management with respectful interactions, etc. It is to be noted that Telecom Bretagne, although located on the sea-side, is a generalist IT School of Engineering, and does not offer any diploma specifically oriented toward sea activities. Nevertheless, these nautical exercises constitute an opportunity for students (who are, like young cadets, future decision-makers) to learn collective mind, flexibility, resilience with their team with a view to achieving reliability (which is profitable to any kind of organizations) using the maritime environment to develop these skills. These in-context and in-situ experiences are valuable in an engineer career where responsibilities are increasing (e.g. executives and decision-makers face complexity, uncertainty and urgency), especially in uncertain employment contexts. Moreover, a first student experience as a non-expert may create a learning-loop for future experiences and work-based situations, including improvisation [18]. It may also reinforce self confidence through the identification of best practices.

5.1 INT164 Course Syllabus

Tab. 2. INT164 week agenda.

	Monday	Tuesday	Wednesday	Thursday	Friday
AM	Course1: <i>Context, rescue videos, songs</i>	Course2: <i>Coastal navigation tools</i>	Practical2: <i>Man over board</i>	Course4: <i>Retex & decision models</i>	Course5: <i>Meteoro- logy</i>
PM	Practical1: <i>Safety on board & material</i>	Course3: <i>Marine electronics</i>	Project: <i>Navigation preparation</i>	Project: <i>Rescue protocol</i>	Orals & presenta- tions

As presented in Table 2, the “Navigation and Sea Risks” intersemester breadth course held in January 2016 was structured as follows: On Monday, 20 students were presented the context, the learning outcomes, before introducing themselves and exposing their motivation and conceptions in relation to sea risks. Then, a 30 mins video of sea rescues was shown, including both inshore and offshore real stories and

testimonials, with a focus on hypothermia factors. As learning activities, traditional maritime songs were collectively used as warm-ups and team cohesion. Students grouped themselves in four teams of five each. The afternoon was dedicated to the usage of safety maritime materials, on a beach (e.g. life raft hitting, distress flare firing, dry suit tests, etc.). On Tuesday, the teaching activities were more traditional and focused on the basics of coastal navigation tools and electronic support on board, while identifying factors of faults, errors, and failures.

On Wednesday, the students went outdoor to practice in teams several unexpected man over board sessions, with resources such as a rubber dinghy, a 10,50 meters-long (35 feet POGO) sailing boat and an OSCAR mannequin (as seen in Figure 1). The tutors just observed the exercises, and never took part in decision and action processes. All the experiences were video recorded (two sessions took place, with two teams the morning and two teams the afternoon). In parallel, the other student groups prepared “on paper” a coastal day navigation for the coming week-end, either with a motor boat or a sailing boat, taking into consideration the various risks and factors they identified. The objectives (e.g. minimize risks and maximize pleasure) and resources were specified. On Thursday morning, feedbacks and video were collectively analysed in the prism of factors and rules, and return on experience was capitalized by the groups. A formal lecture then added theoretical foundations to the return on experiences (RoE).

From then, students prepared in teams a formal rescue protocol (their “clients” being the student sailing club of the institution), as a poster, and realigned their navigation proposal for their crew. The last day started with a teaching session on local meteorology and forecasts, thermic winds, tides and streams, always with a factors and reliability perspective. The afternoon was devoted to student teams oral and poster presentations (i.e. protocol and navigation), assessment, and course evaluation. An online questionnaire was filled before the course to clarify motivation and profiles, so to grasp qualitative data after the course.

Fig. 1. Students in action to rescue an OSCAR mannequin.



5.2 First Cohort Background and Motivational Factors

In 2016, thanks to a first online questionnaire filled by students (16 respondents over 20) one month ahead the breath course, motivational factors were mainly intrinsic, as showed in the following student quotes initially in French (to be read as ‘I chose this inter-semester breadth course because’):

- *‘I love the sea environment’;*
- *‘I am passionate about the sea area’;*
- *‘I like sport catamaran and I find it nice to do sailing activities for a week’;*
- *‘I’m interested in the boating licence’;*
- *‘I like anything that has to do with navigation and why not for the motor boat license and I think it’s important to know the rules when boating’;*

Some other motivational factors were more linked to curiosity:

- *‘I never take time to go on the water during the year’.*
- *‘I do not live near the sea and it is a chance to do it’;*
- *‘I am motivated by curiosity and not by need’;*
- *‘Simply by curiosity’.*

Some of the students had previous sea experiences, e.g. jet-ski, fishing with dinghy, surf, kayak, windsurfing, among 16, two of them were self-considered as experienced: (i) one occasional sailing instructor in a club, (ii) one junior beach lifeguard, (iii) one occasional regatta sailor. As seen in Table 3, it is worth noting that half of the students had very few if none sea experiences: *“I have never been on the sea”, “I went on a Seine river boat for a dinner cruise in Paris”.*

Tab. 3. INT164 student profiles regarding sea experiences.

Confirmed	Regular practitioner	Amateur	Novice	Totally novice
1	1	3	5	6

As showed in the following student quotes, initially in French, the main difficulties anticipated or experienced by students in the first questionnaire were:

- Due to personal factors:
 - *'I still have a lot of difficulties and self-confidence problems, and I got seasick on a nautical trek and I hope that this intersemester course will help me to overcome this evil';*
 - *'I do not know if I can get seasick or not, but I want to participate anyway'.*
- Due to external factors (e.g. tides):
 - *'Mismanagement of the tide to sail out of bay. We knew it would be just at the start but we went there (and back with the help of the engine ...). I knew we would have a problem to return back to port. After this event, I am more comfortable to say "no" to a navigation program if I consider it not reasonable'.*
 - *'Surf session in South West of France, 2km drift by the current before reaching the beach. Need to learn to stay calm';*
 - *'A very dangerous tidal pool gave me trouble getting out of water'.*
- Due to external factors (e.g. resources):
 - *'Some difficult situations in my summer sailing lessons thanks to the famous Murphy's Law (broken stuff, crew in the water, etc.) but nothing too dangerous due to the presence of instructors';*
 - *'During a night at anchor, weather conditions rapidly degraded to be very bad, the small boat in which I slept drifted to take us in an oyster park. The person with me has managed the crisis well and there was only minor damage, but I was not able'.*

6 Analysis

For qualitative analysis, data sources came from a second online non-compulsory

questionnaire to be filled by the students, right at the end of the course. The sample permits to analyse 75% of the students (n=15 over 20). The form included Likert scale questions and open questions. The vast majority of students considered that they had sufficient prior knowledge and experiences to participate in this course, confirming that it was ‘introductory’ in nature. Just some warnings were made about jargon and nautical terms (a memo or index required).

6.1 Motivation

To the question “*Did you made a good choice taking this course*”, students replied (quotes initially in French) on some motivational factors, as presented in Table 4.

Tab. 4. INT164 student post-motivational viewpoints.

Pedagogical Variety	Motivational Factors
‘It changes from what is done daily in engineering schools while remaining relevant to our training (in particular the leadership course following the sailing trip)’;	‘Yes. That was exactly my expectations. I am totally novice, of course, but I love the sea and sailing too’;
	‘Yes, it is a pleasure to learn about the world of sailing!’;
	‘I think this week was very interesting. Security has always interested me (internship discovery among firefighters, first aid) so it seemed interesting to discover a new environment and new life conditions’;
‘It was great. [...] This is a special experience and we had the opportunity to work in a group in an environment quite different from what we are accustomed’;	‘Yes!!!! I am very glad I chose this intersemester. To be more comfortable on the Pogo / catamaran later and for my culture and profession (meteorology, leadership)’;
	‘Great atmosphere, very interesting immersion’;
	‘I learnt a lot. I enjoyed the outdoor activity of Wednesday, the mood of the Monday songs’.

6.2 Rescue Experience and Skills

To the question “*what do you value in the outdoor rescue activity?*” students pointed knowledge and skills but also identified some emotional factors such as efficacy, as presented in Table 5 (quotes initially in French).

Tab. 5. Student viewpoints on INT164 values.

Knowledge and Skills	Confidence and Efficacy
‘discovery and understanding of several new marine concepts’;	‘the atmosphere was really nice, I was not ridiculous to fail in my attempts to rescue the

	<i>poor Oscar</i> ’;
<i>‘learned a lot of things to know, save a MOB, steer a sailing boat, use a VHF, prepare a navigation’</i> ;	<i>‘the human exercise at sea was difficult for 2 person with the Pogo. We had finally realized the risks that may be encountered in the open sea’</i> ;
<i>‘we learn the necessary safety measures in case of emergency’</i> ;	<i>‘things learned for myself reported my lack of relevance in an emergency’</i> ;
<i>‘I have learned a lot, especially on leadership and the need to properly allocate roles on board’</i> ;	<i>‘regarding MOB situation operation, even by having knowledge, when you find yourself in a situation without MOB crew briefing / procedure we realize that manoeuvre is not obvious’</i> ;
<i>‘it allowed me to discover this aspect of resourcefulness and leadership skills, “debrouille” and decision making, autonomy in the context of navigation’</i> .	

The outdoor session took place in January, which is winter time France, with a rather cold environment. Weather conditions may be very windy at that time, and the 2016 session took the benefit from a sunny day and reduced student over board risks, as noticed hereafter:

- *‘I had many cold but the atmosphere was perfect’*;
- *‘The weather was quite favourable which made the good performance but maybe with another weather that would not have been as nice. Otherwise it was very rewarding and we learned a lot I think. Being in situation allows us to learn more from our mistakes and to recall actions and gestures to do first’*;
- *‘I have very good memories of the sailing trip. We were always supervised and I personally felt safe thanks to the board of supervisors’*.

6.3 Open Personal Student Perspectives

An open question “express yourself” permitted to grasp free comments from students. Apart from the ‘thanks’ and ‘keep this course for next year’, some comments showed transferability of knowledge and skills related to the course, i.e. (quotes initially in French):

- *‘I intend to travel further offshore, this intersemester helped me to know general safety at sea’*;
- *‘it was very nice for me personally because I have gained new knowledge that will be helpful to me that summer because I will cruise one month in Egypt’*;

- *'I liked this intersemester. I learned many things, I even had the desire to develop a professional sea activity. I was already fishing on the shore, I want to try fishing in coastal waters';*
- *'I had no idea yet on a future work or profession, and I think it helped me'.*

7 Student Assessment and Formalized Skills

Overall, the feedback analysis sheds light to internal and external motivational factors and transferable skills. It is worth noting that several students developed self-confidence in their (i) ability to grasp complex situations, (ii) ability to adapt dynamically to unexpected situations, or (iii) ability to act in an uncertain context with judgment.

7.1 Assesment Criteria in 2016

The student assessment was based on the two presentations made by each teams and resulted from a peer evaluation and a faculty evaluation on same items. For the navigation oral presentations, criteria taken into account are presented in Table 6.

Tab. 6. INT164 Assessment Criteria for the navigation proposal.

Criteria
<i>weather, tides, waves, and currents rigorously taken into account;</i>
<i>estimation and control of the ship characteristics</i>
<i>analysis and management of uncertainties, critical mind;</i>
<i>priority management and focus points;</i>
<i>judgment and decision skills;</i>
<i>key success factors identification;</i>
<i>risk factors identification according to the crew experiences;</i>
<i>overall reliability and persuasiveness.</i>

Figure 2 shows a sample of a rescue protocol, designed by a team of students. Based on their outdoor experience as a complex situation, the main activities, linked to resources, are organized, but rules (and meta-rules) remain unclear in this proposal, as will be explored hereafter with theoretical foundations.

7.2 Theoretical Foundations on Reliability in Complex Situations

The exercises proposed to students rely on researches relating high reliability, formalized by the University of Berkeley, to understand the normal functioning of High Reliable Organizations (HRO). Their purpose is to identify the characteristics of HRO and to explain their exceptional performance.

Unlike the other theoretical frameworks on Reliability (Theory of Normal Accidents, Theory of Crisis...), HRO theoretical frameworks [19, 20] and also the Actionists one [16] are close. They both investigate reliability through human behaviours identified as a source of reliability. Moreover, they both underline flexibility in the decision-making process. For such, Weick identifies three characteristics of the HRO: (i) information overload, (ii) constant turbulence, (iii) increasing complexity. These characteristics are opportunities to activate a sense making process. They were used as theoretical foundations to implement the rescue scenarios during the outdoor sessions of the breadth course presented above.



Fig. 2. A MOB rescue protocol, including three phases, proposed by a student team in 2016 (in French).

7.3 Meta-rules for Appropriate Decisions in Complex Environments

For purposes of addressing the challenge of making relevant, and appropriate decisions in complex environments, the concept of meta rules was presented to students during the Thursday course session, following the collaborative RoE. The concept of meta-rules appears in different research fields, such as education, business research, and entrepreneurship [21]. Meta-rules correspond to one form of meta-level knowledge, and Davis [22] defines them as rules governing a set of lower-level rules, constituting a framework of rules for which the priorities might change. The main advantage of meta rules are:

- to enable decision makers to gain an overview of the managed entity (e.g., service, organization) which is required for future leaders;

- to improve reliability by avoiding decision errors, which may lead to a degradation of the capacity of a system, a service, an organization to achieve its objectives.

More recently, based on this approach, Le Bris [18] explored whether the use of meta-rules might improve the efficiency of a complex decision-making process. Her conclusions reveal that in complex situations, for non-experts (i.e. the majority of the students concerned by the presented inter-semester, as breadth courses being introductory) introducing meta-rules in a decision making process provides greater reliability than the mere use of rules. This point is discussed between the HRO promoters and the Actionists, the later considering that the strict respect of rules can be a source of danger [16], while the former defend it is a source of greater safety. Thus, the use of meta-rules offers a modality to resolve this theoretical tension and also the tension between “learning” and “performing” in complex situations.

8 Conclusion

In educational and instructional design, it is important to recognize common programme architecture styles. Programme reform or transformation can be inspired by other educational systems, styles or components, including their teaching and learning variations. There is a rich range of programme architecture styles in higher education worldwide, sometimes linked to national histories and traditions. As an example, the liberal arts style with its large course choices offers a lot of flexibility to curriculum designers and students, whereas cohort-based programmes, which are closer to a pipeline model with stricter course choice, tend to address a single graduate student profile. These styles, as well as their strengths and weaknesses, are to be aligned with stakeholders requirements, i.e. students, accreditation and professional bodies or branches, faculty, or society expectations.

In this paper, breadth courses are discussed as a mean to introduce some flexibility into integrated engineering programmes, which are sometimes too strongly coupled. Flexibility is validated both from a student perspective, pressing for larger course choices and from an educational system perspective requesting more dynamicity and openness to support course variety and offers. As a complement to mere static majors, minors, or semester-long project activities, the breadth courses presented herein rely on highly motivated faculty members, small class sizes and targeted guidance, fully dedicated resources, and even sometimes outdoor real in-situ activities as exemplified in this paper. For extension purpose, the “Navigation and Sea Risks” breadth course frame and objectives may be foundations to define a framework of multi experiential outdoor breadth courses (e.g. underwater, air, mountain, forest), including federated educational contents and risk factors and rules.

Based on a qualitative feedback analysis, the authors showed that student self-confidence, self-efficacy and thus motivation for the overall curriculum can be enhanced thanks to breadth courses. With activities aligned with the most recent programme outcomes as required by accreditation bodies, breadth courses can moreover reinforce student abilities in a performance-based approach to transdisciplinary competencies. Nevertheless, the analysis conducted in this paper should now be compared quantitatively with questionnaires results from all breadth courses conducted in 2016.

The learning outcomes on decision and judgement making skills were only partially met in this course for the 2016 session. Nevertheless, in the short term, this Navigation and Sea Risks course may have an echo on the semester projects of the formal curriculum (PjBL), where team working, project and risk management skills are under focus. For the engineering practice, a comprehensive understanding of applicable techniques and methods of analysis and investigation is foundational, but will also tell us more about their limitations. The engineering students' perceptions of soft and non-technical skills, industry expectations, and career aspirations [23] may be realigned with real-life experiences. In the medium term, the ability to adapt to unexpected situations and the knowledge of rules transferable thereto, may find an echo in future student interviews (e.g. for internship or first job offers), in a context which is neither fully rational.

Even if based on a concrete outdoor experience, the concept of meta-rules was for example not applied by the students in their rescue protocol deliverable, thus confirming low abstract conceptualisation. For the 2017 session, following a learning loop between Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation [24]; the Navigation and Sea Risks breadth course designers expect to reinforce the reflectiveness of students directly on board (e.g. using video as in 2016 but also white boards for in situ briefings and debriefings). The objective is to introduce conceptualisation through a collaborative workshop session about risks, to explore more deeply the concept and usage of rules and meta-rules, and more actively experiment inferred meta-rules.

A lead to explore may take the form of a iterative Man Over Board scenario, where a first nautical Simple Situation (SS1) could include the application of already specified rules (variable 1) with a low level of complexity, followed by a second nautical Complex Situation (CS1) requiring the application of rules but with a higher level of complexity. The level of reliability (variable 2) will be analysed during this sequence of two situations based on the effect of the complexity level. Then a sequence of SS2 and CS2 with meta-rules will be experimented by extension of the initial sequence, only after conceptualisation. The effect on reliability will then be analysed more formally. The aim is to identify the effect of meta-rules on reliability and to analyse the learning process of a decision-maker in a real situation.

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