Cross curricular Comparison of Professional Capabilities in Engineering Education

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A cross curricular Comparison of Professional Capabilities in Engineering Education

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Abstract
In this paper we studied the student's perception of the acquisition of professional capabilities in Challenge based learning environments with a strong reflective component. The results show students feel the relevance of personnel development from the very moment the enter their master studies. However, they only truly acquire all the relevant professional capabilities when working in interdisciplinary teams on real life problems in interaction with stakeholders.

Introduction

Current trends in education, such as embedding challenge-based education and reflective activities, presume that professional skills training in these contexts strengthens students' professional capabilities. Moreover, it should prepare them for a better professional life after their higher Engineering Education. However, the variety in curricular design, the moment of measurements, and students' profiles will likely impact the students' perceptions of their capabilities. This paper investigates three types of challenge-based education offered on critical parameters. Successively, we will assess the impact of students' reflective journey in CBE on their perceived professional capabilities. The central questions is: **"What are the professional capabilities students feel they have acquired during courses including elements of challenge based education and reflection on personal, professional, disciplinary aspects?"**

The three CBE contexts concern (1) an MSc Programme in Robotics, (2) a fundamentals course in Bio-Medical Engineering and (3) a Second-year master course focused on interdisciplinary R&D development with external stakeholders. Each of these programmes/courses includes challenge-based elements; it consists of real-life cases, multi/interdisciplinary learning, stakeholder involvement, self-directed learning of students, collaboration, (transversal) skills development and last but certainly not least reflective learning. Together with the opportunities of a challenge-based learning environment, the reflection should expose students to learning that improves their professional capabilities. Professional capabilities consist of different elements based on the concept of the "deliberate professional" of Trede; the elements are:
personal development, collaboration, critical evaluation skills and contextualisation.

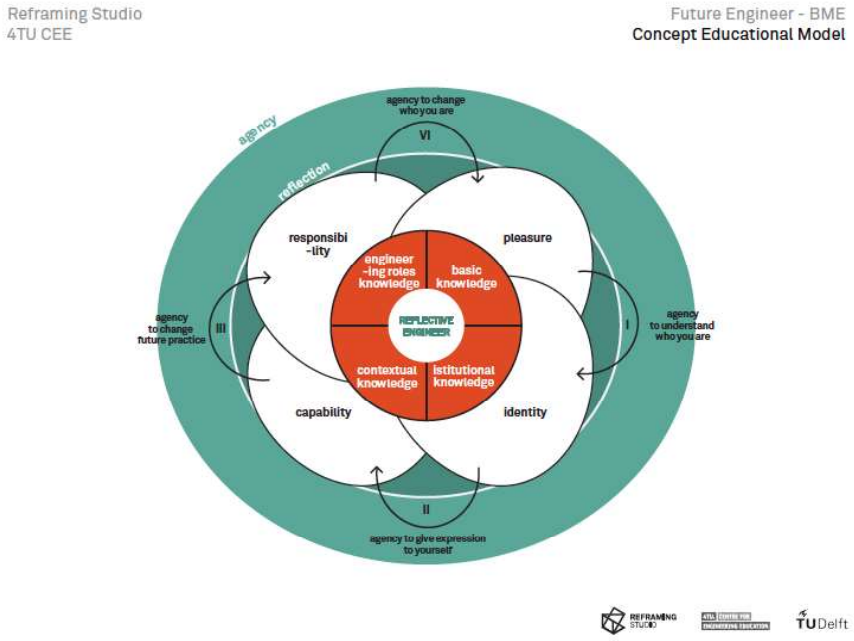
A survey has been administered to investigate the perceived professional capabilities. We will examine the curricular difference, moments of measurements, and to some extent, students' profiles related to the perceived differences. Finally, we will consider the implications for the curricular design of CBE and reflective activities.

THEORETICAL BACKGROUND

Nowadays, there is less congruence between scientific discipline and the occupational structure. New occupations and professions often emerge at the frontiers of disciplines, thus requiring a different kind of knowledge, skills and attitude (van Damme, 2022 (dies Natalis lecture wur). Biesta (2017) call this new purpose of education the task of qualification, socialisation and subjectification. The function of acquiring knowledge, skills and attitude for a job, the socialisation into a particular culture and the growing of identity as each individual are unique. Professional capabilities are representative of **the missing gap between** the more traditional disciplinary degrees towards the occupational structure, which also requires skills relating to socialisation and subjectification. According to Biesta, we need to balance these three educational functions and not over-emphasise one over the other. Trede (2016, 2022) has identified these additional capabilities, besides qualifications, as actions of the deliberate professional. She holds that reflexivity, action and dialogue will ultimately lead to purpose and values, decision making as supportive of choice and gaining change agency. The characteristics of the deliberate professional are expressed in fig. 1

Focusing on:

- Being aware of the complexity of the workplace practice, cultures and environments
- Being realistic about what can be done concerning existing and changing practices
- Positioning oneself in the field as well as making technical decisions
- Being aware of the consequences of doing and acting in relation to a particular practice.



In this" new model" (fig. 2), we have translated these principles into a cycle of Metamorphosis, wherein the kernel, the Qualifications and Socialisation are addressed at the level of basic disciplinary knowledge, the institutional knowledge of methods, tools and approaches and the accompanying skills, the contextual knowledge of authentic real-life situations of a company, institution or other stakeholder party and the finally, the individual engineering role or deliberate professional that emerges from the knowledge and skills accrued on the way, while centre-staging reflection on each of these (iterative) phases of growth. Where one first has to establish; who am I? How to express myself in a professional/academic context, have the insight and foresight to change future practices and eventually have the Agency to enact my role and change who I am. These translate into criteria that need to be met within the curriculum and are likely to be emboldened in challenging learning environments.

The three CBE contexts concern (1) an MSc Programme in Robotics, (2) a foundational course in Bio-Medical Engineering and (3) a Second-year master course focused on interdisciplinary R&D development with external stakeholders. These three courses have been chosen because they include reflection (on socialisation/subjectification) and are, to a greater or lesser extent, to offer a challenge-based environment (addressing qualification and socialisation) and in interaction and iteratively reinforce subjectification. Each of these programmes/ courses includes challenge-based elements; it consists of real-life cases, multi/interdisciplinary learning, stakeholder involvement, self-directed learning of students, Collaboration, (transversal) skills development and last but certainly not least reflective learning. These elements have been identified in scientific research from the 4TU Centre for Engineering education[1]. Together the opportunities of a challenge-based learning environment and reflection should expose students to learning that improves students' professional capabilities. Professional capabilities consist of different elements based on the concept of the "deliberate professional" of Trede.

In a recent review study by (Garcia-Alvarez et al., 2022), it is emphasised that higher education institutions are responsible for educating students to be relevant to the labour market and the need to adapt pedagogies of employability, where students learn to operate adequately across different contextual situations. They have investigated transversal skills in the literature and how oft these are mentioned by the industry as necessary skills to be learning in higher education to respond to and be aware of unpredictable environments. In contrast to this view, we would rather like to emphasise another stance, where it is not the industry that should or might determine what students need. Instead, it should be the students who have the tools and capabilities to shape and make sense of their personal lifelong learning trajectories. Despite this different viewpoint, there is a significant overlap in the knowledge and skills being addressed. However, it emphasises the individual's Agency to act with reason and decision in diverse situations. Thus, as Trede (2016) defined, professional capabilities have been operationalised in the elements; personal development, Collaboration, critical evaluation skills, and contextualisation, which are tooled to realise daily practices within a coherent model. (Higgs, figure 13.3, p……) see below fig. 3.

Fig. 13.1 Deliberate practice and deliberate education

We have further defined these elements in table 1 as;

Table 1 Constructs used to measure Professional Capabilities

Part 1 – Personal Development	
Self	Discovering who I am
Emotional Reflexivity	Dealing with emotions
Resilience	Bouncing back from set backs
Part II Agency	

Evaluating Information	Judgement against professional quality criteria/standards also known as evaluative judgement (Adawi)
Critical Stance	Critical thinking and taking a position concerning professional topics
Part III Collaboration	
Communication	Being able to collaborate with peers, within the community (team/groupwork) (Picard et. al)
Interprofessional Competence	Being able to communicate across domains/professional boundaries (Picard et. al)
Part 4 Contextual insight	
Informed Vision	Being aware of the wiser developments and one's (organisational) roles there in
Ethical Sensitivity	Ethical behaviour in complex sensitive situations. (Picard et. al)

In the table 2, we will show the elements of both the focus of reflection and the characteristic of challenge-based elements present in each course. Later on, we will reflect on these by combining them with professional capabilities.

Table 2. Characteristics of Challenge based education and the investigated courses.

Characteristics	**BME – 1st year MSc**	**1st entire year Robotics Programme, MSc level**	**Joint Interdisciplinary Course 2nd year MSc**
			Reflection (metamorphosis) Reframing/4TU- CEE based on Trede (2016)
Who am I	Personal reflection	Goalsetting	Establish personal learning goal at the beginning
Develop insight and foresight	Peer feedback from other teams	Continues feedback from staff and peers on reflection in portfolio assignment	Continuous feedback from peers, staff, stakeholders – during the course. Formalised reflection moments
How do I give expression to myself	X	Reflect on the received feedback in portfolio assignment	Reflect on feedback – write reflection doc.
Who I am and determine change	X	Feedback-cycle, setting new learning goals and making choices in that direction.	Growth feedback moments and reflection writing as a team and individual as part of the final assessment.
			CBE- based on
Learning Students work with teachers, in order to develop a deeper knowledge of the subjects they are studying. It is the challenge itself that triggers the generation of new knowledge, necessary tools and resources	Students follow lectures, workshops and at the end do a project with "real life" case. No external stakeholders are involved	Students design learning path, formulate learning goals (20 EC electives), follow multidisciplinary (5 EC) and integrated programme with focus on individual choices in the context of challenges in society. Transversal skills development /reflection portfolio (together 11 EC)	Students independently tackle and R&D project either with a societal or phenomenal problem.

Product It requires students to create a solution resulting in a concrete action	Results focus on solving the project assignment and passing the exam for their own learning	In the multi-disciplinary project students work with companies on real life cases by finding a robot integrated solution. A reflection portfolio is continuous.	Project report, including a concept design, prototype, model or research report
Focus it faces students with an open, relevant, problematic situation, which requires a real solution	It faces students with a relevant situation and pre-defined problematic for which a solution needs to be found	Students have to define the problem in teams and have to take the company's expectations into account, when generating ideas and creating solution findings for the multidisciplinary project.	it faces students with an open, relevant, problematic situation, which requires a real solution
Process students analyse, design, research and develop and execute the best solution in order to tackle the challenge in a way they and other people see and measure.	Students work with the assigned project in teams and generate products for their own learning	Students work during the whole programme on their development in skills in the (project) courses by reflecting in a portfolio and the guidance of mentors in mentor groups. As a final assignment the have to present their portfolio.	Students work in teams in collaboration with company staff and academics to come to a desired solution for a real-life problem
Students in the lead of the process, and from interdisciplinary backgrounds	Students (with narrow interdisciplinary backgrounds) coached on predefined problems space.	Students (with narrow Interdisciplinary backgrounds), work in teams, create an individual portfolio are coached by a mentor and partly define the problem space.	Interdisciplinary and intercultural students' teams are in the lead of the entire process
Teachers' role coach, co- research and designer	Instructing/ coaching students as expert.	Mentoring groups, mentors focus on student's personal development	Everyone (students, company staff/academic experts/IIP) is looking for answers.
Evaluation of the activities	Quality assurance and additional surveys + interviews	students reflect on the (technical) experiences. Instructing, coaching, guiding, advising.	Testimonials, surveys, interviews etc.

METHODOLOGY

In this mixed-method study, we have questioned whether students, through reflectional activities and course activities, felt better able to perform particular behaviour related to professional capabilities. The questionnaire has been developed to measure these professional capabilities across various contexts in two Master's programmes of an Engineering School, besides the interfaculty course referred to in this article. All of the Sample contexts include Reflective activities on personnel and skills development, some challenges – ranging in openness of the design briefs and "real" life cases, involvement of stakeholders, a level of flexibility in students' choice and a Master's level.

Professional capabilities are measured at four levels:
1st: Personal Development: Knowing oneself (Self), Emotional reflexivity and Resilience
2nd: Agency: skills to critically think about the problem at hand and take a stance; evaluate information at a professional level, such as evaluative judgements
3rd: Collaboration, consisting of interprofessional competencies and teamwork.
4th: Contextual Insight concerns contextualisation and ethical sensitivity.

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The overall model components are derived from Trede's model on professional capabilities explained in her book the Deliberate Professionals (Trede, 2009). Such as having an informed vision, emotional reflexivity, resilience, and taking a stance. Questionnaire questions have been taken from existing and validated questionnaires or qualitative studies, amongst others from the IMPQ (Picard et al. 2021), which investigated professional teamwork skills. Furthermore, the critical thinking white paper from Davies & Stevens (2019) Pearson's talent management offers evaluative judgement and critical thinking items as a construct.

Table 3. Cronbach's alpha of each construct

	items	Cronbachs' alpha	Source
Part 1 – Personal Development		**.90**	
Self	N = 4	.75	Trede
Emotional Reflexivity	N = 6	.79	Trede
Resilience	N = 8	.79	Trede
Part II Agency		**.85**	
Evaluating Information	N = 5	.78	Critical
Critical Stance	N = 4	.77	Critical
Part III Collaboration		**.86**	
Communication	N = 5	.69	IMPQ
Interprofessional Competence	N = 5	.81	IMPQ
Part 4 Contextual insight		**.80**	
Informed Vision	N = 7	.67	Trede
Ethical Sensitivity	N = 4	.83	IMPQ

Response Rate
The sample population consisted of voluntary participants in a survey of those students who followed the course/programme. For BME, the response rate was N = 28 out of 100. For the Robotics, N= 47 out of 200, and for IiP, N = 54 out of 150, amounting to around 20 to 30% of the sample population. As the subgroups were not big enough for major comparative statistical procedures, we are reporting the aggregate average and (SD) on a construct (continuous variable) for each group. The ideal sample size with 95 confidence interval would be 177 in total. However we only have 126, which means we can interpret the data at a 85% confidence level, taking an error margin of around 5% into account, while at the same time not discarding relevant findings (Bacchetti, 2013)

As most of the Cronbachs' alphas were moderately high, we have been able to include all of the constructs. Hopefully, we'll be able to do a CFA when we have

collected additional data in the next academic year. We do emphasise, however, that the question items have been taken from validated questionnaire scales, and we, therefore, assume they, together with the reliability measure, meet the quality criteria.

Focused Group Interview

After the survey, a focused group interview was held with students of the BME course N= 5, mentors of the BME- course N = 4, and Robotics N= 2 students. The JIP students have left testimonials. We have organised the group interviews around a journey map on which students could indicate their highs and lows within the course on specific key issues, such as engineering roles or organisation. After which, a conversation ensued about their likes, dislikes and recommendations for improvement. Equally, they indicated what they learned the most. No guiding comments were made apart from the engineering roles on aspects of the questionnaire. Here we will report on the Miro documented journey map and learnings. And possibly some quotes, as a systemic analysis has yet to happen on the transcripts of the group interview recordings.

RESULTS

In this part, we will 1st report on the survey results. Successively, we will proceed to the focused group interviews. In the conclusions, the results will be summarised..

Survey

We are comparing three different groups here. The constructs have been aggregated for a continuous variable. As almost all the assumptions for a One way ANOVA are met, no outliers, normal distribution (Shapiro Wilkes,05), apart from the Levine's test of homogeneity of variance, we have used the WELCH ANOVA to correct for differences in homogeneity and have used a post- hoc Games- Howell test and have found sig difference between all the groups. The following paragraphs will look at the levels and separate sub-constructs.

Table 4 Welch Anova test

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
Self	Welch	17.596	2	58.154	<.001
EmotionalReflexivity	Welch	21.694	2	62.087	<.001
Resilience	Welch	12.181	2	60.746	<.001
informedvision	Welch	11.938	2	63.925	<.001
EvaluatingInformation	Welch	19.469	2	55.782	<.001
CriticalStance	Welch	13.851	2	62.875	<.001
Communication	Welch	9.203	2	69.485	<.001
Interprofessionalcompetence	Welch	11.852	2	61.304	<.001
ethicalsensitivity	Welch	8.501	2	69.796	<.001

a. Asymptotically F distributed.

Personal development

In the personal development table one, we notice that the interfaculty interdisciplinary project (IIP) scores the highest average on personal development, closely followed by Robotics and the BME course, as shown in table 5.

Table 5. Personal Development (means /sd)

	SELF	EMOTIONAL REFLEXIVITY	RESILIENCE
IIP	M = 4.3 (SD.37),	M = 4.2 (SD. 44)	M = 4.15 (SD .40)
ROBOTICS	M= 4.1 (SD.51)	M = 3.8 (SD .48)	M= 3.9 (SD .46)
BME	M = 3.4 (SD.73)	M = 3.4 (SD .64)	M= 3.5 (SD .65)

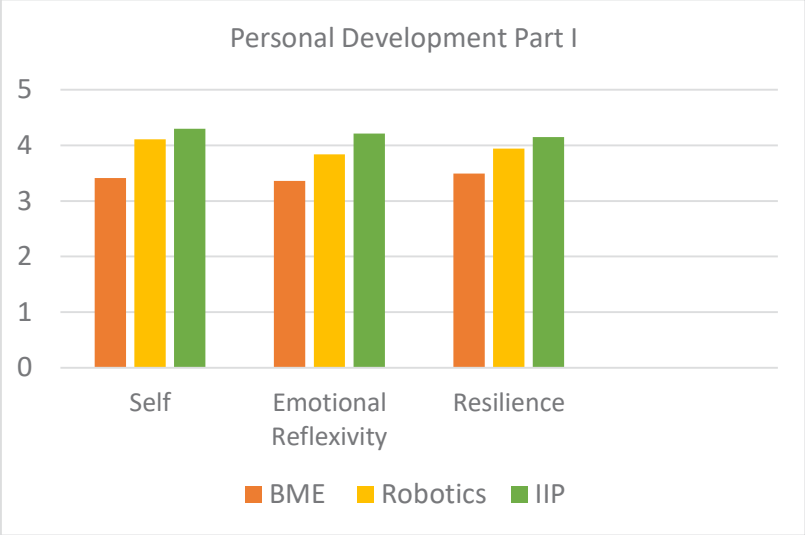
Despite the slight differences, there are significant differences for each sub-construct, Self, Emotional Reflexivity and Resilience smaller than < .001, between the IiP and BME groups. The IiP and Robotics group on the sub-construct Self do not score significantly .096. On the sub-construct Emotional Reflexivity, the Robotics/BME group scored significant (.005) differences. And on the sub-construct Resilience significance of .054 between Iip and Robotics and significance of .007 on Robotics BME. We are making the distance between IiP and Robotics more similar than the equation Robotics – BME.

The estimated medium effect sizes eta- squared are Self .30 Emotional Reflexivity .30, and Resilience .21. The numbers show a large effect size as their all higher than .14, meaning a larger proportion of the variance can be attributed to the personal development variable than what we can expect based on the standards of variance. Where Self and Emotional Reflexivity are vital aspects of knowing who one is. If we look at the course criteria, the BME course does not yet include all the reflection opportunities available, whereas the Robotics and IIP course does.
This finding suggests that going through the full circle of reflection is of importance; equally, the extent to which autonomy, interdisciplinarity and a real-life case is present may have impacted these results. Specifically, since Robotics is moving up to the fully challenge-based and interdisciplinary, autonomous shows results towards the IiP course. With items such as

- "I am aware of my engineering role."
- "I have become aware of my passions."
- "I have been able to make a choice that fits my personal value."
- "I feel more independent (in control)."
- "I am better able to make decisions."
- "I am better able to ask for help."

very close to the IiP course. Noteworthy is the item: I feel confident to share my ideas, which scores highest for Robotics average at 4.2 and an only average of 3.7 for IiP and BME. All the other items are scored close to BME.

Table 6. Visualisation average means Part I



Agency

The sub-construct Agency has the capability of giving expression to one Self. This Agency is supported through the creation of judgement and evaluation of professional standards in the survey evaluating information. Secondly, critical thinking helps to take a critical stance. Included in table x are the mean averages and SD.

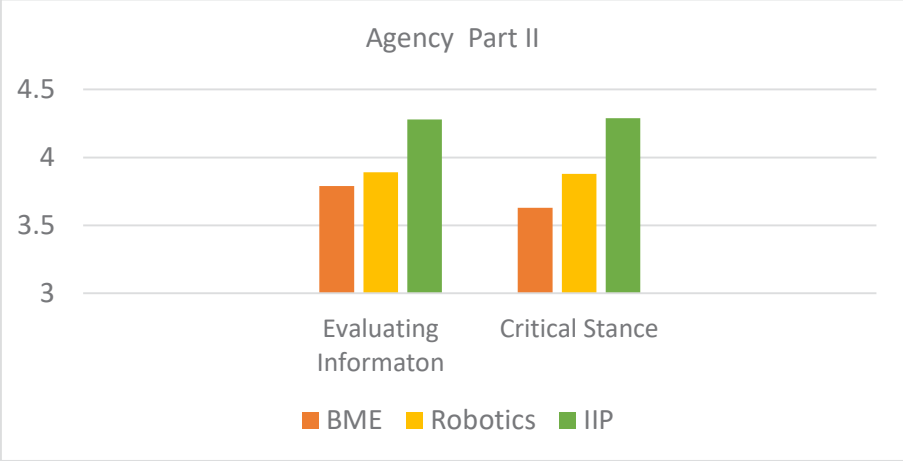
Table 7 averages part II

	EVALUATING INFORMATION	CRITICAL STANCE
IIP	M = 4.3 (.40)	4.3 (.49)
ROBOTICS	M = 3.9 (.42)	3.9 (.50)
BME	M= 3.8 (.65)	3.6 (.67)

Here we find a significant difference between IiP vs Robotics < .001 an IiP and BME .002 on Evaluating Information. The construct Critical Stance is significant <.001 between IiP vs Robotics and BME. Between Robotics and BME, we do not find a significant difference in Evaluating Information and Critical Stance.

Effect sizes being large again for Evaluating Information eta squared is .21, and for Critical Stance, the eta squared is .20. Albeit a little less than personal development, the impact still mainly shows the importance of evaluating information against professional standards with real stakeholders and learning to take a critical stance when dealing with peers, staff and stakeholders in real challenge situations. Although the Robotics group does have a slightly higher mean on individual items, they did not yet seem to have practised enough with these skills and remained close to the BME course, particularly on taking a critical stance.

Table 8 Visualisation Part II



Collaboration

The Construct Collaboration consists of the sub-constructs of Communication with peers and staff and Interprofessional Competence where the Communication with external stakeholders is emphasised and allows for reflection on the context of different disciplines, and provides insights and foresight to change these contexts. The means (rounded) averaged and standard deviations are reported below.

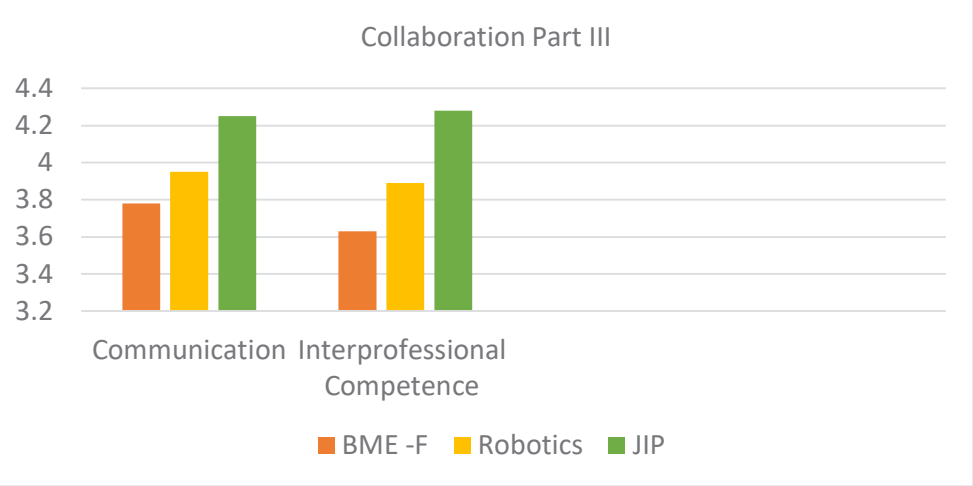
Table 9. Average Part III

	COMMUNICATION	INTERPROFESSIONAL COMPETENCE
IIP	M = 4.3 (.49)	4.3 (.49)
ROBOTICS	M = 3.9 (.56)	3.9 (.53)
BME	M = 3.8 (.48)	3.6 (.75)

The analysis of Communication shows significant differences between IiP and Robotics .017 and IiP and BME <.001. Robotics and BME do not significantly differ in Communication. For the interprofessional competence, we find both significant differences <001 for IIP vs Robotics/BME and non-significant differences between Robotics and BME.

Effect Size on Communication is moderate eta squared .12 and on interprofessional competence large .17. It shows that Communication within academia is at the end of the 1st year of normalised professional capability irrespective of the level of autonomy of students, the openness of the challenge brief and the reflection. However, for interprofessional competence, we again find that interactivity with external stakeholders and with peers and staff from other disciplines is of importance for the development of professional capability.

Table 10 Visualisation averages Part III



Contextual insight

Finally, contextual insight consists of having an Informed vision of the disciplinary context and ethical sensitivity. These skills should allow for contextualisation, determining one role and flexibly adapting based on individual values, responsible and moral judgement.

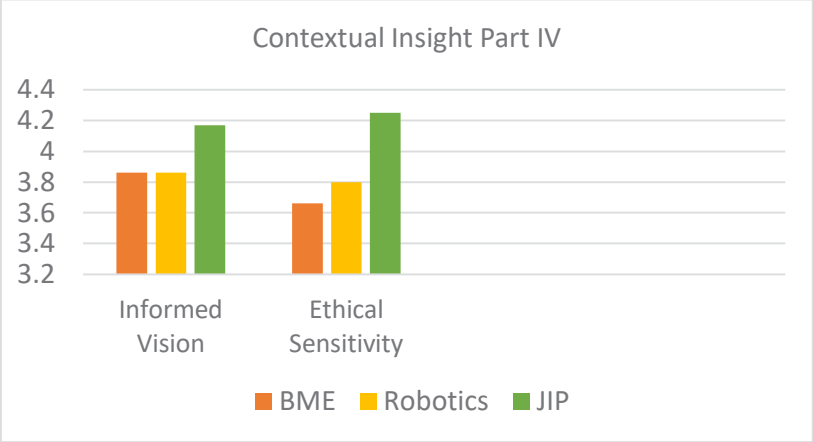
Table 11. average Part IV

	INFORMED VISION	ETHICAL SENSITIVITY
IIP	M = 4.1 (.40)	4.2 (.67)
ROBOTICS	M = 3.9 (.39)	3.8 (.70)
BME	M= 3.7 (.50)	3.7 (.63)

gain, significant differences at the <.001 level between IiP and Robotics/BME for informed vision and no significant differences between Robotics and BME. For Ethical Sensitivity, we find a significant difference at the .007 level between IiP and Robotics and .001 between IiP and Robotics, showing the Robotics group is much closer here to the IiP. For Robotics and BME, we did not find significant differences.

Effect sizes for informed vision are large .17 and for ethical sensitivity .12 moderate. Noteworthy on individual items is that the robotics students find it hard "to put themselves in the shoes of someone whose life could be affected by a project result". However, this fact may also be related to the fact that Robotics is focused on the artefact to a larger extent than the other two courses and possibly causes an indirect impact or no impact at all. Another Item is "I am aware of the historical development of my disciplinary field", in which Robotics scores (M = 3.6) are much lower than the BME (M= 3.8) /IiP (M= 4.0) courses. Possibly, as there is not much history yet. The item "I am aware of the wider (societal, academic, technical) system in which my discipline operates" is scored on par with the IiP at 4.0.

Table 12 Visualisation average Part IV



Focused Interview results

In this section, we include some of the major outcomes of the post-it notes (of the Miro board) on learning. One of the questions we have asked the student is what did you acquire in terms of professional skills during the BME and Robotics programme. Included below are the quotes.

Personal Development students mentioned;
BME – student; *"it is a good course to help the students understand their role as engineers and direct them to future choices*."
BME – Students: "*Looking back I can say that it was good to think about my role in society and I have learned a lot from the self-reflection assignments."*
BME – Mentor; *"Thought of role, they were never confronted with before, which may help them for the future."*
BME – Mentor; "*I liked that the course forced participants to think of engineering in a social context. It is an area often overlooked, or secondary to professional development, but ultimately it holds great importance and is key to the success of the individual."*
Robotics- students: *"Providing feedback and taking feedback in a constructive and valuable way."*
Robotics -student: "The portfolio was hard to set up in the beginning but helped me in my personal development, and I think it was very good to have, by design, spread out over the 1.5 years."

Professional skills:
BME- students: – "*Some workshops, e.g. on the debate, were really appreciated."*
Robotics students: - "*Communicating with many different backgrounds and being open-minded."*

Robotics students: "*I like the variety of the assignments and the connection to developments in the outside world; it always felt like we were working on contemporary topics."*

Engineering knowledge:
Robotics students:

- *"it is always important to go back to the general question and not to get lost in details. "Breaking down the problem helps with developing a solution."*

Students in the BME course asked for more interaction with the stakeholder field and external professionals or involvement from the industry. Additionally, they asked for more professional skills training. And their wish for a stronger focus on personal development. Equally, better mentorship guidance would have been appreciated. Indeed, the Robotics students noted that the mentor's guidance was valuable in becoming more autonomous learners. In IiP, the continuous feedback from peers and external stakeholders, together with the reflections on content and personal development, forced them to work independently very quickly.

CONCLUSIONS AND SOME EXTRA OBSERVATIONS

In this study, we have learned that students value working on personal development from the very start of their Master's Programme. However, in the 1st course, students are not confronted yet with real-life cases; they are experimenting with a technical solution for a BME problem and focus on discovering who they are and their role—resulting practically in less pronounced development in professional capabilities. This result could either be due to the limited maturation of the students or the fact that they did not get challenged and autonomous enough during this course.

Furthermore, professional capabilities such as Agency, supporting how to give expression to myself, Collaboration: having insight and foresight to change future practice and contextualisation are particularly acquired in a situation where challenge-based education with real-life cases, external stakeholders and different academic disciplines are brought together. Although the maturation of students may also have affected these results, reflection at each level is one of the key tools to accomplish a greater mastery of professional capabilities. The portfolio reflection particularly helped students with their personal development and expression of their ideas, but only to a limited extent for the other professional capabilities. The CBE course for Robotics may have come too late in the process, as growth truly occurs when integration of the engineering knowledge, skills and personal development come together. An integration which the students highly appreciate. Equally, mentor coaching and InterVision in the robotics programme were highly appreciated and felt as if students were better prepared for their final thesis work.

DISCUSSION

In the introduction, we asked the central question: **What are the professional capabilities students feel they have acquired during courses, including elements of challenge-based education and reflection on personal, professional, disciplinary aspects?".**

We conclude that programmes where students work on real-life challenges with third party stakeholders, address personal learning goals, and critically reflect on their personal, professional development, and engineering knowledge seems to yield higher learning awareness levels. This increase in learning awareness levels can either be achieved through early integration in the programme or when students have a higher level of maturity. It might be more effective to offer students challenge-based education over a more extended period than to offer them internships, although this bold statement should be investigated.

When particularly looking at the course design, we note that:

- More attention should be given within the curriculum to evaluative judgement and critical thinking, and taking a stance
- Interprofessional skills informed visions, and ethical sensitivity is particularly learned when external stakeholders and a real-life challenge are available
- Personnel development can best be developed with goal setting, discovering who you are, beginning at a very early stage with the support of a portfolio, leading to more autonomy and maturity.
- Integrated curricula with self-management are likely to better prepare students for their master thesis work.
- Creating learning awareness should start early on through reflection and skills training, which may support motivation and autonomy.

In line with Biesta's observations, we feel that attention to Subjectification and Socialisation processes leads to better professional capabilities.

Limitation of study

This study has been realised with small numbers and should be replicated to substantiate the results. We intend to collect more data in the next academic year to get more data points and longitudinally analyse the impact of the intervention embedded in the programmes/courses. Also, more data points may allow for Confirmatory factor analysis of the theoretical framework to further validate the questionnaire. Nonetheless, we consider the results here as sufficiently validated as we worked both with validated questionnaire items and results showing despite the small group numbers, relatively large effect sizes, and a substantial impact across different course contexts. We equally felt the focused group interview substantiated the survey observations and gave them more depth.

Naturally, having said this, it should be noted that the issue requires additional study. In particular, a more detailed overview of the CBE elements that directly contribute to one of the four levels of reflection and learning awareness. This investigation should include teachers triangulating results and matching these results against the summative assessment results of students, in parallel with the study of the reflection portfolio across different contexts. However, as the embedding of these professional capabilities elements becomes more necessary today in higher engineering education to tackle the complexity of today's world, extended and continuous research seems the only answer.

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Annex 1

Professional Capabilities Questionnaire

Measured on a 5 point likert scare from 1 strongly disagree to 5 strongly agree.

Personal- Part I Personal Development
Self

- Q1 I am aware of my engineering role(s)
- Q2 I have become aware of my passions
- Q3 I have been able to make choices that fit my personal values
- Q4 I can articulate what I need to personally grow

Emotional reflexivity

- Q5 I tend to reflect and discuss positive/negative experiences
- Q6 I feel more confident
- Q7 I feel more independent – in control
- Q8 I stay calm when under pressure
- Q9 I am better able to make decisions
- Q10 I can empathize better with people in different (professional) positions

Resilience

- Q 11 I am better able to ask for help
- Q 12 I ask more questions based on my reflective activities
- Q13 I feel confident to share my ideas
- Q14 I have learned from my own mistakes
- Q15 I feel engaged with the offered learning materials
- Q16 I am proactive in seeking new learning experiences
- Q 17 I recognize the need for professional boundaries
- Q 18 I persevere in difficult circumstances

Part II Agency

Evaluating Information
Q8 The ability to evaluate the quality of information presented
Q9 I am aware of the assumptions I make with respect to the problem at hand
Q10 I recognize assumptions others are making with respect to a problem discussed
Q11 I validate the inference I make from data (truths or falsification)
Q12 I am aware when certain conclusions are drawn following from information in given statements

Critical Stance
Q13 I interpret and weight evidence and decide if generalization or conclusions are warranted
Q14 I recognize relevant and irrelevant arguments given to solve a particular problem
Q15 I make judgement on the basis of accumulated evidence and reasoning
Q16 I find it easier to establish what to do or what strategies to adopt to the problems we are solving.

Part III Collaboration
Communication
Q17 I am good at trying to understand the perspective of other team members. D
Q18 I am good at making sure that all the necessary information is shared with other team members. D
Q19 I am good at explaining my ideas in ways that other people can understand. D
Q20 When someone disagrees with me, I am good at paying close attention to see if I can learn something from their alternative perspective. D
Q21 I can normally work productively with another team member even if I am angry or frustrated with them. D

Interprofessional Competence
Q22 I am good at recognizing the knowledge and skills of different professions involved in a project team. E
Q23 I am good at being sensitive to the way in which different professions may use the same word. E
Q24 I am good at clarifying with people from other professions how their knowledge and skills contribute to each stage of a project. E
Q25 I am good at identifying the skills or knowledge that other professions in the team have, which I should try to develop. E
Q26 I am good at sharing responsibility with the other professions in the team for the overall success of a project. E

Part IV Contextualisation

Informed vision
Q1 I feel committed to sustainable development goals such as; equitable economic opportunities, environmental awareness, sustainable production etc.
Q2 I am able to envision alternative futures for the improvement of my disciplinary field
Q3 I am aware of the historic development of my disciplinary field
Q4 I am aware of the wider (societal/academic/technical) system in which my discipline operates
Q5 I am aware of the political, national/global contexts
Q6 I am aware how these context shapes individual lives
Q7 I am aware of the different stakeholder perspectives

Ethical Sensitivity
Q27 When working on a project, I am good at asking myself if a project like this could have a positive impact on someone else's life. C
Q28 When working on a project, I am good at asking myself if a project like this could have a negative impact on someone else's life. C
Q29 I am good at putting myself in the shoes of someone whose life could be affected by a project's results. C
Q30 I am good at identifying all the people who could be impacted by a project, no matter how directly or indirectly. C