Paper 2: Pilot study boot camp: professional engineering roles experienced in a week

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KEYWORDS: One-week course, Boot camp, Professional Engineering Roles, Pilot Study, Transversal Competencies

ABSTRACT

Engineering education has recognised that engineering graduates require transversal competencies like communication, teamwork and problem-solving alongside technical competencies. The importance of transversal competencies has grown and curriculum elements have been implemented to stimulate these competencies. However, a gap still exists between what education provides and practice requires. To reduce this gap and increase engineering student's employability, lecturers need to expose students to transversal competencies and allow them to practice them throughout the curriculum. For the purpose to stimulate the development of students' transversal competencies necessary to engineering careers, a week-long style boot camp course was designed and implemented at the Delft University of Technology. In this study, a pre and post-questionnaire and a reflection were administered to students to evaluate the transversal competencies encountered and acquired by the students during the course, their engineering role awareness and course efficacy. Findings revealed that students improve in their transversal competencies including presentation skills, interdisciplinary thinking, innovation and creativity, and professional engineering role knowledge during the course. However, improvements in the attracting of students to the course and specification of the assignment need to be addressed for the next run of this course scheduled for next year. Lecturers are encouraged to implement authentic learning experiences like this, as these experiences provide students with awareness and practice of the engineering roles and stimulate students' transversal competency development necessary to be successful in those roles.

INTRODUCTION

Globalisation and rapid changes in technology since the 2000s have changed the engineering sector. This shift has led to industry seeking for engineering graduates who are equipped with not only technical but transversal competencies like creativity and innovation, communication skills, teamworking skills, and lifelong learning skills (Spinks et al. 2006). To develop these competencies a week course was implemented at the Delft University of Technology, the Netherlands. This course was also developed to provide students with awareness of and experience with the three professional engineering roles (Product Leadership, Operational Excellence, and Customer Intimacy) of the labour market established by the researchers involved in the European project PREFER (Professional Roles and Employability of Future EngineeRs). More information about the project and roles can be found in (Craps 2017) and (Craps 2018).

This study aims at evaluating the boot camp course and students' development of and exposure to transversal competencies and engineering roles knowledge. For this purpose, a mixed-method approach is used (pre- and post-questionnaires, individual reflections and feedback).

LITERATURE REVIEW / RATIONALE

According to the European Skills Panorama study (European Commission 2016b), European employers still face recruitment problems for STEM skill labour. More specifically in our context, the Netherlands expects a growth of 2.8% in shortage occupation with engineering professionals until 2020 (European Commission 2016a). The reasons for this are the short supply of workers compared to the demand, and the great percentage (38%) of graduates with a technical background who rather choose a non-technical profession (Saunders-Smits, 2008). Engineering education has responded to these issues by trying to increase the number of students and making engineering education more attractive by increasing their emphasis on competencies including communication, problem solving, working in teams, and lifelong learning (Passow and Passow 2017) and by introducing new teaching methods, as alternatives to traditional lecture-based methods, like active learning, collaborative learning, cooperative learning, and problem-based learning (Prince 2004).

In 1996, project-based learning and transversal competencies were introduced in the curriculum of Aerospace Engineering at Delft University of Technology (Saunders-Smits 2008). Since then, five design projects started to run in the three years of its Bachelor degree which were renewed and given a more central role in the bachelor revision of 2008 (Saunders-Smits et al. 2012). In these courses, students acquire both knowledge through learning by doing and competencies in teamwork, people management, networking, and

oral and written communication, as well as problem-solving, analytical and synthesizing skills (Saunders-Smits 2008). Moreover, at Master level, this concern to integrate transversal competencies in the curriculum has been present. For instance, the mandatory internship which has been a longstanding part of the Aerospace Curriculum promotes student employability skills (Kamp and Verdegaal 2015) and the Forensic Engineering course which in 2009 due to the change of lecturers gave more emphasis to critical thinking (Saunders-Smits et al. 2016, Saunders-Smits et al. 2015), and later on to communication and lifelong learning (Leandro Cruz and Saunders-Smits 2018).

While curriculum elements focus on the development of transversal competencies to respond to industry demands including collaborative skills and problem-solving (Hadgraft 2018), and leadership skills (Willmot 2017), none reports on projects specifically aligning these competencies to professional engineering roles as was done in the week-long boot camp style course as reported on in this paper.

COURSE DESCRIPTION

The boot camp was designed as a week-long 2 ECTS course in which students in small groups (3-5) work on a design problem, intensively. The learning objectives of the course were:

- Plan and manage time and tasks as a team
- Be creative and innovative to invent, design and develop a product
- Identify solutions to optimise products
- Present, convey and persuade stakeholders about product efficacy
- Engage in lifelong learning through reflections on own strengths and weaknesses, and own future engineering career

The project objective for the students was to create a learning activity or product for primary school children that allows them to discover what an engineer is. During the first phase of the boot camp, the team was told about the different professional roles an engineer can have and they were given the assignment. After that, the team was expected to interview a number of primary school teachers who volunteered to act as a client so that students can better understand their customer. Based on this information, students would generate ideas, analyse the feasibility of their ideas and choose one to design and build. At the end of the first day, the team is expected to deliver a pitch that explains what they propose to develop and what their plan is to achieve it. The team had to create a teaching activity or product. The students' prototype must be ready by day 3 at mid-day, and the team was expected to present and demonstrate their prototype to a selection of primary school teachers. Feedback on their design and presentation was provided to students in this phase of the boot camp. In the second phase of the boot camp, the team was expected to optimise their product. Further,

based on the feedback received, students were expected to think about variables (cost, materials, etc.) which they could alter to boost their product. Their final product or teaching activity had to be ready by day 5 at mid-day after which the boot camp was concluded by the presentation of the final product and their marketing slogan. A workshop on creativity and Innovation and a workshop on Argumentation and Persuasion were included in the boot camp.

The course was offered as an elective for Master and PhD students and although 13 students registered on the first day only 3 students showed up.

AIM AND OBJECTIVES / RESEARCH QUESTION(S)

The aims of this study were threefold. First, to measure students' improvement of a set of transversal competencies. Second, to assess students' knowledge of the three engineering roles. Finally, to evaluate the implementation of the one-week long boot camp style course which intends to, on the one hand, stimulate the transversal competencies, and on the other hand provide awareness and practice of the professional engineering roles of the labour market.

The following research questions were addressed in this study:

- Do students improve their competencies (entrepreneurial, innovation, teamwork, communication, lifelong learning) during the period of the boot camp?
- Are students aware of the three engineering roles after attending the course?
- Does the boot camp concept work to assist students in develop transversal competencies and practice the engineering roles?

METHODOLOGICAL APPROACH

The three research questions were answered using mixed-method research. This approach was chosen to strive for triangulation of results from different methods (qualitative and quantitative) (Johnson and Onwuegbuzie 2004). The quantitative method was selected to generate results independent of the researcher with statistical analysis, however, due to the low sample size (3 respondents), the use of a qualitative approach turned out to be more valuable to study the cases in detail. The following methods were used:

- Pre- and post-questionnaires (N = 2, quantitative and qualitative methods): The pre-questionnaire was administered at the beginning (day 1) and the post-questionnaire after the conclusion of the course (three weeks after, in the feedback session of the

course). Students were asked to rate themselves on their overall competency level for each role on a scale of 1 to 10 (with 1 – very poor and 10 - excellent), to choose the professional role they most preferred, and to indicate their perceived level of expertise (absent, basic, advanced or expert) in each of the 36 competencies listed. In the post-questionnaire, the questions of the pre-questionnaire were repeated. Additionally, a question asking students about what they felt they learned during the course was added, along with a section with questions evaluating the course itself.

- Individual reflections (N = 3, qualitative method): The first part of the reflection asked students about their understanding of the professional engineering roles. Questions asking respondents to define each role and to name three essential competencies for each role were asked. The other part of the reflection was about students' competency experience during the course. For example, which three competencies did they perceive to have developed in the course and a competency they found they still need to improve on. In addition, based on students' development and experience of the engineering roles during the course, they were asked to select the role they would like to pursue in their first job after graduation.

- Feedback (N = 2, qualitative method): Conducted three weeks after the completion of the course. Students were asked whether they would recommend this course to others and why and what improvements needed to be made to the course.

KEY FINDINGS

Competency improvement

Students' competency improvement during the boot camp and their overall perception of competency level for each role are present in Table 1 and Table 2 respectively.

Engineering roles knowledge

Students defined *Product Leadership* as the innovator or developer of innovative solutions. The *Operational Excellence* was described as the engineer who masters process, outcomes and dependencies and therefore is able to optimise or improve the efficiency of the products and processes. Finally, *Customer Intimacy* interacts closely with the customers and comes up with solutions according to their needs or satisfaction.

Besides defining the roles, students named three essential competencies for each role (Table 3).

Table 1 - Competencies improved and to improve during the course according to students' perspectives. Results from pre- and post-questionnaires (N = 2) and reflections (N = 3).

Competencies improved (Pre- and post-questionnaires)	N	Competencies improved (Reflections)	N	Competencies to improve (Reflections)	N
Value/cost consciousness	2	Planning & Organisation	2	Teamwork with international teams	1
Pitching skills	2	Creativity & Innovation	1	Communication skills	1
Business acumen	1	Out of the box thinking	1	Initiative	1
Risk tolerance	1	Presentation skills	1		
Negotiation skills	1	Patience	1		
Critical thinking	1	Stress resistance	1		
Adaptive communication style	1	Interdisciplinary teamwork	1		
Idea implementation	1	Client focus	1		
Ideation	1				
Presentation skills	1				
Self-confidence	1				
Listening skills	1				
Interdisciplinary thinking	1				
Give constructive feedback	1				

Table 2 - Grade given by students (N = 2) at the beginning and end of the course to their overall competency level for each role on a scale of 1 (very poor) to 10 (excellent).

Students	Product Leadership		Operational Excellence		Customer Intimacy	
	Pre	Post	Pre	Post	Pre	Post
1	5	8	5	8	6	7
2	9	9	9	8	6	9

Table 3 – Competencies selected by students per role. N is the number of students who selected the competencies.

Product Leadership	**N**	**Operational Excellence**	**N**	**Customer Intimacy**	**N**
Vision	3	Conceptualisation	2	Networking	3
Innovation	2	Planning & organisation	2	Negotiation skills	2
Out of the box thinking	1	Solution oriented	1	Stress resistance	1
Scientific knowledge	1	Initiative	1	Client focus	1
Determination	1	Decision making	1	Outspoken	1
		Attention to detail	1		
		Perfectionism	1		

Course evaluation

The second part of the post-questionnaire was analysed to evaluate the feasibility of the boot camp course. The findings showed that the activities provided in the course greatly or somewhat contributed to students awareness and practice of the engineering roles.

Regarding the organisation of the course, students were satisfied with the course duration and workload activities of the course. They appreciated feedback and working in teams rather than individually in an assignment like this. However, students perceived unclearness in expectations and definition of the assignment.

Based on students' course evaluation, they suggested that we could improve on the definition of the expectations, tasks and end goals. They also mentioned that the initial communication with the students at the registration could be better and the commitment of more students was needed especially to create the spirit of competition which triggers engagement of the teams with the assignment and stimulate teams to perform better.

Overall, the two students, who were asked in the feedback session whether they would recommend the course to other students, said they would recommend it. A student mentioned that he wanted to make a break in his research and he found this course nice and enjoyable to work on something very different. Another student argued that this course is very different from other courses because it is very good to develop soft skills like working in teams of unknown people and of different cultures and personalities, as well as to gain persuasion skills like he had the opportunity to develop in one of the workshops.

DISCUSSION

Courses like this week-long style boot camp, which provide an authentic experience of real-world challenges, facilitate students' learning of transversal competencies as present in other similar approaches in the literature (Willmot 2017, Hadgraft 2018). However, it is the first time that transversal competencies are aligned to professional engineering roles. Firstly, the findings triangulated between the questionnaires and reflections seem to suggest that the boot camp stimulated students presentation skills, creativity, innovation and work in interdisciplinary teams (Table 1). Secondly, this course contributed to developing students' awareness and practice of the engineering roles. Students increased their knowledge about these engineering roles (Table 3) and they perceived improvement of competency level in each role (Table 2). Although some findings were extracted from the chosen methodology from the qualitative approach, more data should be collected to better assess the impact of the boot camp. The course will be rerun again next year.

Conducting active learning is challenging and it takes some time and iterations to design an ideal course. Improvements in the communication with the students and specification of the assignment will be taken into consideration in the second implementation of the boot camp.

Small changes in the curriculum like this will hopefully encourage more lecturers to embrace active learning as active learning creates an environment that facilitates student learning and practising of transversal competencies and raise student awareness of their possibilities for future careers which traditional educational approaches cannot provide.

CONCLUSIONS / RECOMMENDATIONS

The aim of this study was to assess the first implementation of a week course at the Delft University of Technology in terms of students' competency development, engineering roles awareness and course efficacy.

Positive outcomes of the first pilot study were that students develop transversal competencies including presentation skills, interdisciplinary thinking, innovation and creativity during the course; students gained knowledge about the engineering professional roles; and that the course is effective in providing an authentic experience of the engineering professional roles and transversal competencies needed for those roles.

On the negative side, the study showed that improvements need to be made in improving the low student attendance, limiting the width of the assignment, and better addressing the expectations students have from the course.

Conducting active learning is challenging and it takes some time and iterations to design an ideal course. Therefore, the authors will take into consideration the lessons learned in the first implementation of the boot camp and will repeat the study on a larger population.

The authors strongly recommend more of this type of initiatives in engineering curricula to stimulate students' transversal competencies as well as give them an authentic learning experience to the engineering roles which will be useful for their future career.

ACKNOWLEDGEMENTS

This work was supported by the Erasmus+ program of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project (http://www.preferproject.eu/).

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