Is Fontys engineering's honours programme educating the brilliant engineer?

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The Electrical and Electronic (E&E) Engineering Department of Fontys University of Applied Sciences, the Netherlands has decided to have a personalized programme in cooperation with companies for students who want to excel in engineering. In September 2009 this PROUD programme for excellent engineering – PRogramme OUtstanding Development – has been introduced. This programme provides the students with early industrial experiences and skills in their field of study on top of their bachelor programme. This research ultimately answers the question *"whether our current PROUD programme educates the brightest engineers and if not how to improve this programme."*

Since the mid-1990s, there has been a global trend towards outcome-based assessment of undergraduate engineering programmes [1]. The main motivating factors of the outcome-based curriculum development is to educate graduates who meet and will meet the needs of the industry. Based on this the applied honours programme PROUD was developed at Fontys University of Applied Sciences.

PROUD was introduced in 2009 with the cooperation of various engineering companies in the Brainport region of Eindhoven which were willing to work alongside PROUD students [2]. The main aim of the PROUD programme is to give ambitious engineering students the opportunity to work on extra professional related competences on top of their studies. The students will bring back their experiences, additional knowledge and skills to their fellow students. This is organized through an extra set of requirements for the PROUD programme given by the University.

Each year, about 45 Dutch E&E engineering students start the second year of their study as well as another 50 international E&E engineering students. These are the target groups for the PROUD programme. Since 2009 183 first year students showed initial interest. Of these 84 students applied and finally 41 students were accepted in

PROUD programme until 2015.
The PROUD programme is currently at a phase whereby the integrity of the programme will be tested by evaluating the competences of the current honours students and subsequently making changes that may/will tailor the programme to attain improved results. As part of this self-assessment phase, this research was done to evaluate if and how this honours programme can be improved.

1 ENGINEERING COMPETENCIES

The engineering educational programmes in the Netherlands are expected to be accredited based on a redefined assessment system from 2012 onwards. This system is derived from the Dublin Descriptors as described by the Bologna Working Group on Qualifications Frameworks and described in collaboration with all applied sciences universities for engineering education in the Netherlands. This system is based on assessing eight competencies. Each graduate will achieve a certain, pre-defined level for each competency at the end of his/her study as is shown for the Fontys E&E programme in Figure 1 [3]. The eight described competences are: **analysis**, **design**, **realisation**, **control**, **management**, **advice**, **research** and **professionalization**. For each competency, there are behaviour descriptions made which can be graded at 3 levels. Based on this model universities have defined for each competency the level (1, 2 or 3) that their students will achieve at the end of their bachelor phase. This enables the universities to differentiate in their engineering programmes.

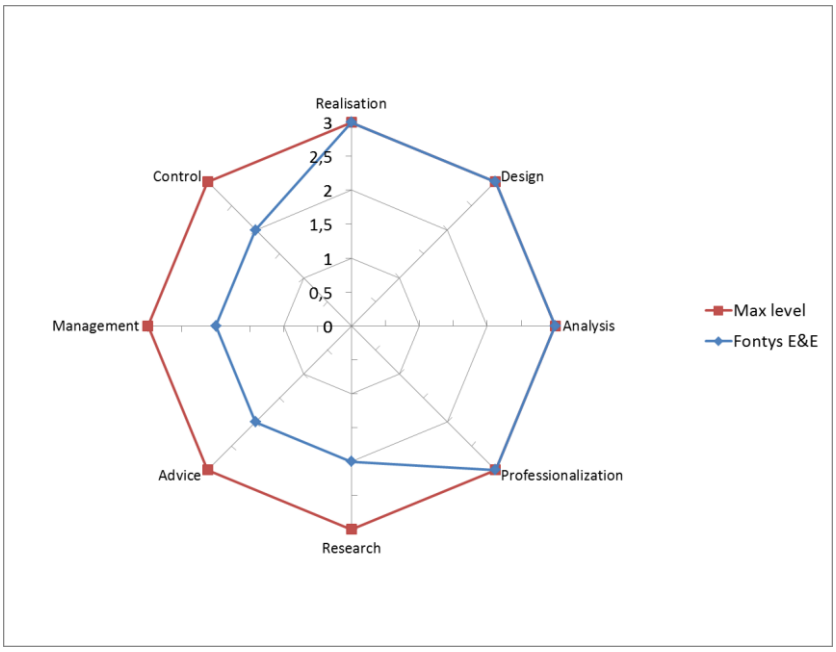

Figure 1 The Dutch engineering competences with the expected competencies levels for Fontys E&E graduates.

Based on the advertised Fontys E&E programme the E&E graduate will achieve maximum level (level 3) regarding **analysis, design, realisation** and **professionalization** competencies as can be seen from Figure 1**.** Fontys E&E Engineering has chosen these in order to be able to educate excellent product designers and developers. The remaining four competencies will be taken in consideration in the curriculum but with less priorities in comparison with the above four since there is a lot of interest in E&E designers/developers in Brainport region of Eindhoven where Fontys E&E Engineering is located.

As PROUD committee, we are interested to evaluate our PROUD programme against this fairly new competency programme. However since the competency measurement mechanisms and tools are not fully developed yet, it was decided to investigate first other ways of evaluating the PROUD programme.

In literature there is little research that can be found related to successful engineers. However, G. Scott and K.W Yates [4] published a paper titled: "Using successful graduates to improve the quality of undergraduate engineering programmes." Their study involved 20 graduates of different universities who are working in seven different companies covering electrical, civil, mechanical, telecommunications and environmental engineering. The aim of their study was to identify the capabilities that were seen to be most important for successful engineering practice during the first few years after graduation. And in parallel measuring to which extent universities were typically developing these capabilities.

The Scott's paper defines a set of 49 capabilities/characteristics in 6 different categories that were used to assess the important criteria of a successful engineer. The complete list of the 49 capabilities can be found in in section 3.1. The 6 categories used in their paper were: Emotional Intelligence – personal, Emotional Intelligence – inter-personal, Intellectual capability, Profession-specific skills and knowledge, Generic skills and knowledge and Education Quality.

Figure 2 represents the results obtained by Scott in their research. This scattered graph shows the mean rating given by the respondents in the survey based on the importance and performance of each. In their research, **importance** *is defined as items that are important in the successful professional practice* while **performance** *is defined as the extent to which the university at which they studied had addressed these items.* Items high on importance and high on performance represent areas of good practice (the top-right quarter of Figure 2). Items high on importance but low on performance (the bottom-left quarter of Figure 2) identify potential areas for enhancement or follow-up. Items in the left sectors raise issues of relevance [4].

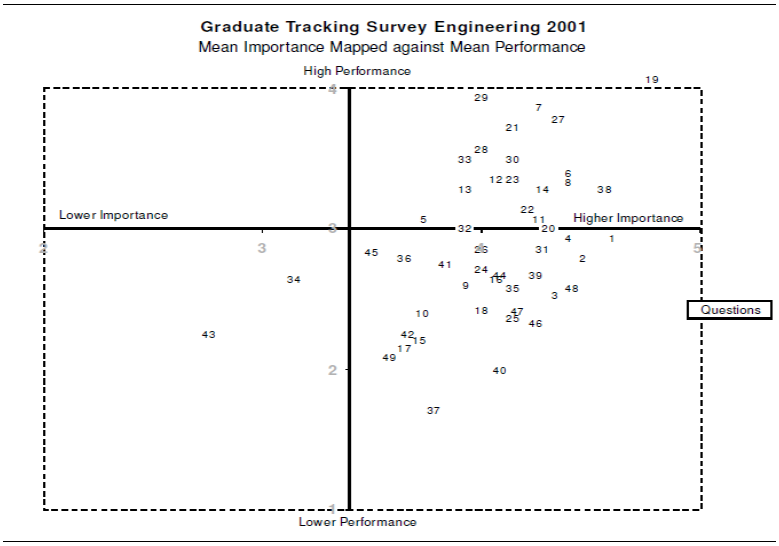

Figure 2 ***Results from Graduate Tracking Survey***

The Scott's paper concluded that successful engineering graduates in their first few years of full-time work have established a comprehensive way of identifying exactly what should be emphasized in the undergraduate curriculum.

2 COMPARING PROUD PROGRAMME WITH SCOTT'S COMPETENCIES

2.1 Expected versus Achieved Competencies

When the PROUD programme was developed, a list of requirements was drawn up that the student had to fulfil at the end of his/her educational period at Fontys University. The PROUD student is required to:

1. Work in an industry for approximately 800 hours as extracurricular activity
2. Give workshops and/or guest lectures to other students
3. Provide technical support for fellow students in projects (semester 3-4) or practical assignments or help in studies
4. Introduce and guide a second year project based on the gained skills and experiences from the company in which the student work
5. Contribute to the Engineering`s Promotion team or in one of the University's student committees
6. Contribute and critically evaluate the Fontys E&E engineering curriculum
7. Interact with equally motivated and successful engineering students

As this is the pioneer research of the PROUD programme, it was decided to focus our research on only the items ranked on importance. Accordingly, the top 25 characteristics that were ranked important in the Scott's survey were identified. These are the 25 characteristics most at the right of Figure 2. These characteristics are then compared to the requirements of the PROUD programme to illustrate how the PROUD programme can be evaluated using the Scott's survey, see Table 1.

Table 1 Requirements of PROUD vs. Characteristics from Scott's Survey

Importance rank Scott	Characteristics in Scott's paper	Application in PROUD
1	19.Being able to develop and contribute positively to team-based projects	1,3
2	1.Being willing to face and learn from my errors and listen openly to feedback	1,2,3,7
3	38. Being able to organize my work and manage time effectively	1
4	2.Understanding my personal strengths and weakness	7
5	48. Make assessment more real-world and problem-based and less focused on memorizing factual material	1, 3, 4,6
6	4.Being able to remain calm under pressure or when things go wrong	1,3, 4
7	6. A willingness to persevere when things are not working out as anticipated	1, 3, 4
8	8. Being willing to take responsibility for projects, including how they turn out	1, 4
9	27. Being able to set and justify priorities	1, 4
10	3. Being confident to take calculated risks and take on new projects	1, 3, 4
11	20. Knowing that there is never a fixed set of steps for solving workplace problems or carrying out a project	1, 3, 4
12	14. Being able to develop and use networks of colleagues to help me solve key workplace problems	1, 4, 5, 7
13	7. Wanting to produce as good a job as possible	1, 4
14	11. Having a sense of humour and being able to keep work in perspective	2, 5
15	31. Being able to manage my own ongoing professional learning and development	7
16	46. Ensure that all teaching staff model the key attributes identified as being important in this study	6
17	39. Focus more directly on the capabilities identified above as being important in university courses and assessment	6
18	22. The ability to use previous experience to figure out what is going on when a current situation takes an unexpected turn	1, 3, 4

19	21. Being able to identify from a mass of detail the core issue in any situation	1, 3, 4
20	30. Being able to use IT effectively to communicate and perform key work functions	2, 5, 7
21	23. Being able to diagnose what is really causing a problem and then to test this out in action	1, 3, 4
22	47. Ensure that teaching staff have current workplace experience	6
23	35. Knowing how to manage projects into successful implementation	1, 3, 4
24	25. Being able to readjust a plan of action in the light of what happens as it is implemented	1, 3, 4
25	44. Include learning experiences based on real-life case studies that specifically develop the interpersonal and personal skills needed in my particular profession	1, 3, 4

It should be noted that these matching of the top 25 characteristics to the PROUD programme requirements was done before the survey was conducted. The main reason why the matching was done was to validate that the Scott's research was related to the PROUD programme and to our research. From this comparison, it can be derived that the PROUD programme enables students to work on all of the top 25 capabilities that were found important in Scott's research. Our research is aimed at finding out what are the top 25 capabilities (out of the 49 defined) that the PROUD students consider important and to find out if the outcome is comparable to the Scott's research. It is our hypothesis that the PROUD students have a clear overview on the skills required for a professional engineer as they have so much extra working experience in an engineering company.

2.2 Research Method

The main aim of this action based research is to understand the level of the PROUD students at Fontys when compared to engineering students from abroad. This can be accomplished by comparing the top 25 characteristics from the Australian group against the top 25 characteristics from the PROUD students.

The survey instrument used for the current research was copied from Scott's paper [4]. This paper defines a set of 49 characteristics in 6 categories that are used to assess the important criteria of a successful engineer. The survey was hosted online and all PROUD students were invited to participate in the survey. From the 23 available PROUD students 12 students filled out the survey.

2.3 Research Data

The top 25 characteristics of the reference paper was obtained from the graph in Figure 2.This was done by reading the graph from right to left on the x-axis to obtain the highest rated characteristics on the importance scale. Table 2 consists of the top 25 characteristics that were obtained from the graph. Once the top 25 characteristics were obtained, each question was given a score from 1 until 25 to rank them. For example, the highest score (capability 19) was given a score of 25, the second highest (capability 1) was given a score of 24, capability 38 was given a score of 23 and so on and so forth, as can be seen in Table 1.

The capabilities were then grouped into the 6 categories that were defined in the Scott's paper and the total score was obtained by summing up the individual scores. Table 2 identifies that the category of emotional intelligence is ranked the highest on the importance factor for a successful engineering career by our PROUD students. Also the results of the 49 questions are depicted in Figure 3.

Table 2 Proud student's scores of categories Scott's paper

Category	Proud Score	Proud students	Reference paper
Emotional Intelligence-Personal	144	23.2 %	44.3 %
Intellectual Capability	54	20.7 %	12.0 %
Generic Skills and knowledge	43	25.1 %	16.6 %
Emotional Intelligence – Interpersonal	39	1.9 %	0.0 %
Profession-specific skills and knowledge	0	18.0 %	13.2 %
Educational Quality	24	11.2 %	13.8 %

It shows the results that were obtained for the PROUD students and the reference paper based on the ranking and accumulated score of the top 25 questions in the 6 categories. The scores were converted to percentages for a clearer overview.

As can be seen from Figure 3, the most areas are educated well. Students indicate on these items that they are important and also the performance on these items is on a high level (the right upper corner). The highest scores are for items: 12 (collaboration), 2 (self-reflection), 23 (diagnose and solve), 17 (giving feedback) and 48 (real world assessments). On the other hand we also find items indicated as very important but unfortunately the students indicate that these are relatively poor in performance. The four most important items for Fontys quality team to work on are item 47 (teachers work experiences), 38 (efficient planning), 28 (An ability to recognize patterns in a complex situation) and 13 (A willingness to listen to different points of view before coming to a decision)

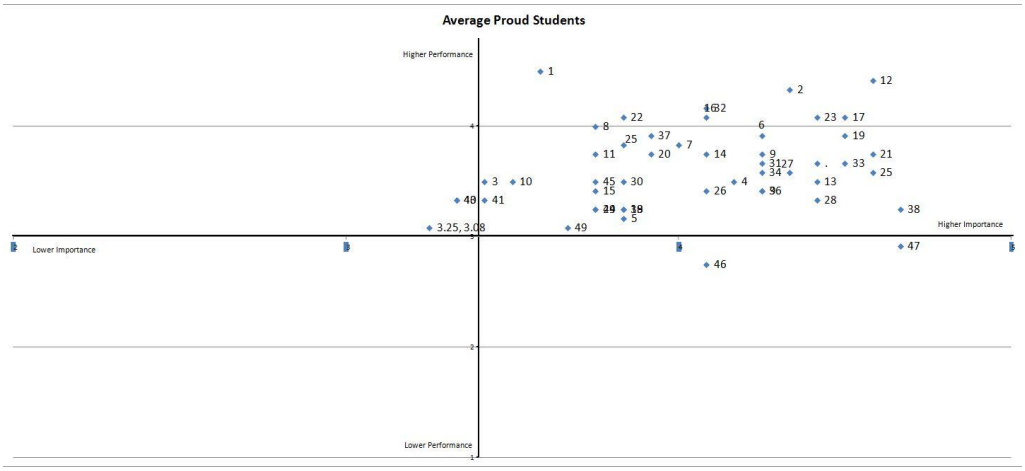

Figure 3 *: PROUD students performance vs. Importance of the 49 capabilities.*

3 DATA ANALYSIS

Based on the results obtained and represented in Table 2 the following discussion points can be highlighted:

a. Emotional intelligence – Personal and Interpersonal (items I and II of Table 2 together). The reason why, when compared to the Australian research (56%), the PROUD students have ranked it as a less important (44%) skill set is probably due to the fact that the mindset is based heavily on product design and development. They see it as a natural part of their mindset and due to their experience, don't encounter problems with it.

b. Intellectual capabilities

PROUD students have ranked this item as the most important item while the Australian research have ranked it as the second highest skill set of a successful engineer. This due to the fact that as the student steps out of the school environment into the professional outside world, the students realise that intellectual capabilities are the stepping stone of an engineer. As an engineer, the student needs to be able to identify problems, focus on solving problem and explore the possibilities of different solutions. If a student is not able to analyse and solve a problem, the student would not be able to create a design or develop an innovative product. So emotional intelligence is seen as the second important characteristic directly after the intellectual capabilities needed for the “real” design work.

c. Profession Specific skills and knowledge.

This percentage is so low in score compared to the other 5 items because there were only a very few questions in the original survey on this subject (only 3 out of the 49 capabilities in total). So also in our comparison this item can’t have a high score. PROUD students have indicated that professional specific skills and knowledge are important, but are not sufficient to be a professional engineer. Due to the opportunity to work in a professional environment for a long duration, the PROUD programme enables the students to develop a better understanding regarding professionalism in engineering as e.g. in risk management and organizational structures. Both parts are not taught in regular school classes.

d. Generic Skills and Knowledge

The percentage of generic skills and knowledge from PROUD students does not vary much from the percentage obtained in the Australian research. Both groups have identified it as an important thing to work on.

e. Education Quality

PROUD students are aware of the importance of education quality. Education quality is explicitly linked to the PROUD programme. One of the requirements that a PROUD student has to fulfil is to contribute and critically evaluate the E&E engineering curriculum.

Finally one may conclude from above results that the PROUD students are sharing the same thoughts as the Australian Engineers regarding the important characteristics for successful engineer. If one compares the two outcomes of the surveys, another conclusion can be drawn: the PROUD students are far more comfortable with the education they get at Fontys E&E compared to the Australian engineers. Almost all their scores are in the upper right corner of the scatter diagram as can be seen in Figure 4. This is due to the many company projects that we run every term. To give an impression: every year we run over 200 company projects: mono and multi-disciplinary. This all to make project work a ‘regular’ part of the student’s work and skills.

It should however be noted that due to difference of culture and mind-set, the results obtained in our research were not identical to the Australian research. This is

because the Australian research was conducted with students from a wide range of engineering fields such as management, consultancy, IT, etc. while the curriculum at Fontys Engineering focuses on designing new (electronic) products and therefore it is expected that the mind-set, and competences needed, of the students would be different.

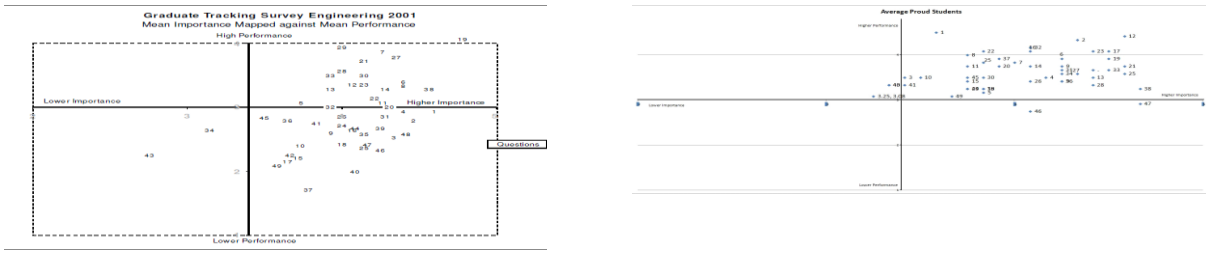

Figure 4 The two Australian and Dutch scatter diagrams depicted.

4 CONCLUSIONS

This research tried ultimately to answer the main question "*whether our current PROUD programme educates the brightest engineers and if no, how to improve it*". The results of this research supports our hypothesis that PROUD students are able to explore and to identify the important skill sets needed to be a successful professional engineer. This has been verified by using a survey for our PROUD students that is based on Scott's competencies model for a successful engineer. It can be concluded that the current PROUD programme on top of the E&E engineering curriculum is well suited to educate the brilliant E&E engineers. PROUD students have also identified that generic skills and emotional intelligence are very important. These skills can be gained through projects and group work in real life settings and cannot be learnt in a classroom-settings. Also it can be noted that further investigation is required to improve Fontys curriculum in teaching modelling in complex situations in projects, approaching problems with en open mind and exposing the lecturers to more industrial work experiences .

Lastly, another research can be carried out to compare the competencies of PROUD engineers against the Dutch competencies for E&E graduate engineers. Since this competency based assessment was made for E&E engineering then we believe it is more suitable for the PROUD programme.

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