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Towards a new curriculum to support the changing front end innovation landscape
Educating engineering students to effectively participate in iterative data-enabled product development processes

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ABSTRACT
The new generation of Internet of Things product offers exciting opportunities to design and develop highly personal and adaptive products. Engineering students are traditionally not trained to use user data, generated by prototypes, as creative material for ideating the Fuzzy Front End phase of the design process. In this case study, Philips Design and Fontys Engineering propose a change for the current Fontys engineering curriculum to prepare engineering students for this new way of defining innovative, connected products. For these new challenges, we argue that the focus in educating engineers should be changed from starting with product specifications and “first time right” towards data-enabled design (user feedback) and iterative design cycles to come to product specifications and maturing prototypes. A survey amongst 73 Fontys engineering students shows that approximately 20 percent of the current engineering students are interested in, and have affinity with, this new way of working.

INTRODUCTION
Innovation is more and more concerned with the development of ‘data intensive’ smart connected products [1], [2], [3]. These products have the potential to incorporate a more personalized understanding of their users, their usage and their context. Examples are the Fitbit [4] that provides you with personal coaching according to your physical activity; the Nest Thermostat [5] that adapts room temperature to your way of living; and the Philips Hue [6] whose functionality can be programmed to user’s personal preferences.
This new generation of Internet of Things (IoT) products offers exciting opportunities to design and develop highly personal and adaptive products. However, defining, exploring, and developing these products introduces new levels of complexity to the innovation processes of which challenges are less defined. Especially in the Fuzzy Front End (FFE) process [7], the phase where new product concepts are ideated and explored, it is hard to imagine how different users will experience different versions of the same concept as tailored by unique personal data. Innovation teams are traditionally not trained to use user’s data, generated by prototypes, as creative material in the FFE process to explore these tailoring features. Still many companies design data-intensive innovations by imagining technical possibilities to personalize products. Data-enabled Design [8], an approach extensively used by Philips Design, is one of the new approaches that uses data as creative material in the iterative FFE process.

This user data is gathered through sensor-equipped prototypes which are put to use in their intended context. Engineers are highly valuable in this Data-enabled Design process to facilitate the creation of sensor-equipped prototypes while maintaining a sense of scalability, by continuously reconsidering and updating product requirements.

In our daily practice, at Philips Design, we noticed that this Data-enabled Design process requests new competences of engineers that are currently not part of their educational curriculum. It’s our experience that engineering students in general are educated to develop products based on given specifications and on the “first time right” principle. To come to specifications, it turns out that it is required to put more emphasis on iterative design and the use of quick prototyping. As research shows [9] data, on what engineering graduates will be doing during their professional life, is essential information in educating future engineers. Therefore, in this case study, Philips Design and the Electrical Engineering department of the Fontys University of Applied Sciences started a collaboration to answer: how should the current Fontys engineering curriculum change to prepare engineering students to facilitate Data-enabled Design in the FFE innovation process?

To answer this question, we take three perspectives into account. First, we dive into the detailed competence request from the industry, represented by Philips Design. Secondly, we focus on a student perspective in which they share their interest to join such explorative innovation environments. This is done by a survey amongst Fontys Engineering students. Thirdly, we reflect from an educational perspective on how the current curriculum can facilitate this new competence request.

The aim of this paper is not to present a final list of future competences, nor to validate a new educational model. Instead, with this case study, we set out to start a discussion with the educational community about the future role and competences of Electrical and Electronic Engineering in the domain of innovation in the FFE process.

1 INDUSTRY PERSPECTIVE: NEW COMPETENCE REQUEST

1.1 Data-enabled Design

In the quest of new FFE processes for ‘data-intensive’ products, dealing with complexity, many have acknowledged the value of incorporating users. User-centred design [10], participatory design [11], consumer-oriented innovation [12] and many more, set out to have participants (potential end-users, stakeholders and other non-designers) actively thinking along in the innovation process [13]. These approaches also outline involvement of participants in their natural environment to manage
complexity. However, asking participants to actively contribute to the innovation process of ‘data-intensive products is more challenging as these concepts often are outside their frame of reference [14].

Data-enabled Design [15] involves the participants in the innovation process through experience by objecting them to design exploration situations. Thus, instead of inviting participants to imagine a futuristic concept, participants receive sensor-equipped prototypes to experience the concept. The data generated, by using these prototypes, is used as a dialogue facilitator. Namely, the data helps the participant to recall the experience of using the prototype and helps the innovation team to explore the data relevancy in real contexts. This is a continuous dialogue where user’s insights (distilled from data) lead to optimized concept ideas, resulting in prototype updates which will then generate new insights again. In this agile-like process [16], the product specifications become more mature. Note, the more scalable the sensor-equipped prototypes are designed, the easier these can be updated remotely (e.g. over-the-air firmware updates or adding new sensors) the quicker the situated exploration iterations will be.

1.2 Role of the engineer in Data-enabled Design

The FFE process with a Data-enabled Design approach strongly builds on the act of making sensor-equipped prototypes and trying things out in the field. The development of these data-intensive prototypes iteratively moves from a very explorative artefact to materialization of the final concept. The role of the engineer is to facilitate the creation of these prototypes and to contribute to the explorative process of iteratively advancing the concept where the definition of feasible specifications becomes increasingly important. This process takes place in a multidisciplinary team, consisting of designers, user researchers, strategists, and data scientists where the engineer plays an integral role.

1.3 Detailed competence profile

Based on experiences at Philips Design, where the Data-enabled Design approach has been utilized for about two years, we defined a competence request for engineers being part of this FFE process. We conducted in-depth semi-structured interviews with seven project members that run Data-enabled Design projects on a daily basis (2 designers, 2 user researchers, a project manager, software engineer and a prototyping engineer). We requested them to describe a competence profile for engineers. Afterwards the overall competence request for engineers from an industry perspective was discussed within this team. This profile, consisting of three main requests is illustrated in the first column of Table 1. The three major categories are: 1. Participating in the explorative Data-enabled Design process, 2. Creating sensor-equipped prototypes that iteratively advance and 3. Being part of a multidisciplinary team.

2 STUDENT PERSPECTIVE: INTEREST AND AFFINITY

2.1 Survey setup

Via an online survey, we asked fourth year engineering students (N=259, n=73, response rate 28.2%) of the Fontys University of Applied Sciences in Eindhoven to respond to the profile description defined by industry. Each of the three categories were translated into survey questions for engineering students. Firstly they were asked to respond to items that describe what type of engineer they are (e.g. I learn best by making and doing rather than reading and analysing); secondly, what type of project characteristics they prefer (e.g. I prefer questions with a clear scope, a point to go to);
thirdly, how their ideal working environment looks like (e.g. *working in a big team of mainly engineers where I have individual tasks*); and what preferences they have concerning the different phases of the innovation process (e.g. *introduction phase: action steps where production and marketing launch occurs, service and installation starts*).

The outcome of this survey is given in column 3. In the fourth column, the current situation of Fontys Engineering is described and in the last column (5) the gap between industry requests and current curriculum is indicated and will be discussed in chapter 3.

*Table 1.* Overview of three perspectives: industry, students and education

<table>
<thead>
<tr>
<th>Competence request from <em>industry</em></th>
<th>Interest and affinity of <em>students</em> (N=259, n=73)</th>
<th><em>Educational perspective</em></th>
</tr>
</thead>
</table>
| Participating in the explorative Data-enabled Design process | Become part of innovation process in which product specifications will be defined  | 92% are interested in developing new innovations.  
41% are interested to work in the FFE.  
12% is open to work without a clear scope | Education which is focused on developing from specifications onwards  
1. More open product innovation  
2. New development methods  
3. Collaborate interdisciplinary |
| Questioning specifications | 44% like to start small not knowing where it may lead to.  
82% prefer designing in an iterative way from quick and dirty prototyping, reviewing and customer feedback. | Taking specifications for granted  
Bring awareness to unspecified and unknown requirements which may affect specifications |
| Dealing with uncertainty | 16% like to work without clear specifications | Thorough design mind set  
Make students more comfortable with uncertainty in Project Based Learning (PBL) [17]; how to change grading of PBL to emphasis? |
| Hacking mind set, use existing tools to quickly try and learn | 73% prefer to learn by doing. | Development mind set, start from scratch to build exactly what you need  
1. Use existing boards, products to develop very fast working prototypes  
2. Develop these into real products in an iterative way |
| Fast prototyping to unravel specifications | 49% prefer to develop review based (when specifications do not change). | First time right, electronics to validate.  
Make students aware of the different tools of prototyping. Arduino, Raspberry Pi, Edison' boards are great starters, 3D printing for anyone! |
| Open design construction (platform design) | Not questioned in survey. | Single-purpose design  
Teach how to grow from (available) platform designs to single-purpose dedicated designs |
Iterative and increased learning: start small

12% like to work in projects that do not have a clear, predefined scope

V-model [18]

Start with the FFE as early as possible

Taking into account an end-user and business perspective (Questioning approach, opportunity searching)

29% like to question more than to listen

Try to meet specifications (listening approach, problem solving)

Make user contact essential in the PBL so engineers become more critical

Multidisciplinary team: software & hardware developers, data & ethnographic scientists, designers, marketing managers etc.

37% are interested to work in a multidisciplinary team of which 48% prefers a small team where they are the only engineer.

Project based learning with mainly engineers

1. work multidisciplinary or
2. make people responsible for different jobs with a project
3. Teach students to communicate across disciplines

Independent working

Not questioned: is general competence requirement

Project based learning

This is a general applied science university competence

2.2 Survey results

Almost all engineering students (see Fig.1) want to work in an innovative environment (92%) with clear specifications (84%) and a clear scope (88%). Another item showed that the main preference is to work in a small engineering team that has one common task (49%). For the project process, there is a split among the students who prefer an iterative process (79%) and those who prefer designing “first time right” (50%). Besides, most students like to listen more than to question (45%) and learn by doing over reading and analysing (73%). However, from responses to the preferred role that engineers have in a team (questioned through Belbin’s description of team roles), about all roles are preferred equally. Finally, the majority of the current students (73%) indicates to be happy with the way of education and working environment created nowadays.

Figure 1 shows survey results of students (n=73).
2.3 Survey conclusions

After interpreting the survey results we draw the conclusion that about twenty percent of the current engineering students at Fontys is interested and has affinity for working according to the requested competence from the industry. As one can see in the last column of figure 1, 15 students out of 73 (20%) indicated to really prefer designing in an iterative way: from quick and dirty prototyping (using Arduino’s, 3D printing and wood when needed), reviewing and customer feedback and in this way improving and in a few cycles coming up with a solution and so product specifications.

Meaning, these students are looking forward to work in the FFE phase of product specification: multidisciplinary, uncertainty, data-enabled design and work on fast prototyping rapidly changed on user data input. The main reasons for having no interest or affinity with the formulated engineering competences are: not preferring the open and undefined process searching for specifications and not preferring to work in a multidisciplinary team without other engineers, so working on their own. Interestingly, the request to iteratively build and improve their prototype is valued by many. We expect that the students might have referred to iteratively building and reviewing their prototype in the case of given, fixed specifications as they are used to. However, the survey question was meant for the iterative design on searching for interesting specifications and not solutions.

3 EDUCATIONAL PERSPECTIVE: CURRENT CURRICULUM AND GAP

3.1 A fixed development process to fulfil specifications

Fontys’technical education system teaches students how to tackle engineering problems using structured design methods. Students apply these procedures step by step, according to the waterfall model [19] or the V-model [18]. These structured processes do fit very well in projects where specifications are clear and students work towards solutions. The FFE processes which are uncertain, iterative, open and flexible and where the specifications are not known is not practiced in our curriculum.

In dialogue with colleagues and graduates we note that our grading system highly impacts students’ preferences on the project’s starting point. Namely, PBL grades of students are highly related to the expectation of fully finished prototypes. This makes the students not to like working without a clear list of specifications and a clear deliverable. It might be that, without knowing the specifications, the process to unravel what is relevant takes (too) long and might not lead to a fully finished prototype, and thus might affect their grades and points.

3.2 Doing things the “first time right”

Several studies [20], [21] have proven that PBL is a suitable method for attaining the engineering competences that are suitable for today’s world outside the faculty. Fontys has been integrating the PBL concept, in company projects, in each year of the education for decades. The students are taught how to develop “first time right” products. Besides, the problems and solutions are often so specific (in-depth engineering questions) that the quick prototyping is quickly overseen. In the FFE the engineering requests are much broader, more explorative and they need to be finished quickly. Therefore, it would be better to get students also acquainted with fast prototyping skills, with foresight towards in depth, thorough design solutions.
3.3 Not working in multidisciplinary teams

PBL combines learning and application attributes, however, at Fontys Engineering, it misses the fundamental process of understanding the multidisciplinary skills needed to come to the product specifications of innovative products. The project descriptions, which students receive, often come from company clients (that do work in multidisciplinary teams). However, these clients create the project descriptions as design requirements targeted to a team of engineers. This means that the engineering request is put in isolation from the original project. In the Fontys engineering situation, students do not get to know other disciplines (besides their major discipline) and thereby hardly develop inter-disciplinary languages.

4 THE RECOMMENDED CURRICULUM

Within Electrical and Electronic (E&E) engineering, a discussion has been started on how to alter the curriculum in order to facilitate the wishes of the different students. Of course, not all engineering students are needed as designers in the FFE phase. Most of the students are needed in the design processes after the FFE phase and the majority of the current students (73%) indicates they are happy to work in these phases. But only 20 percent of the engineering students wants to explore the opportunities of Data-enabled Design.

As found in practice it is of great importance to work in a multidisciplinary team with open assignments. And more time is needed within their education to realize enough iterative, data-enabled design cycles.

The current idea within the E&E Engineering department is to start a pilot and educate students from the second year onwards in a specific stream with more focus on the FFE environment. Starting with around 20 percent of our student’s population, they will work for approximately one fifth of their time in data-enabled, agile, multidisciplinary, business oriented product specification developments and realisation. This provides the students with more time (ECTS) to explore the Data-enabled Design in the second year of their study. In the minor (the third year) they can apply their knowledge and skills to a real-life problem. The other engineering students’ education will not be affected, we continue preparing them for the post-FFE phase in design.

When designing optional courses in Data-enabled Design the students of these latter stream can “meet and greet” one or more courses of the FFE environment just to get informed and experience this new way of defining and specifying data enabled products. Fontys engineering sees this development as the start of educating the new generation engineers for the industry 4.0 [22] and cyber physical systems environment as shown in a previous research on Fontys Electrical and Electronic Engineering [23].

5 CONCLUSION

Industry nowadays creates ‘data intensive’ products and services that are tailored to the user. A promising innovation approach for these new types of product is Data-enabled Design. Data-enabled Design projects at Philips show that this approach benefits from having engineers as an integral part of the multidisciplinary innovation team. The competence request from industry in these situations is an engineer who can iteratively develop data-intensive prototypes that can be put in context and
iteratively move into a final prototype and setting specifications. A collaborative research programme, by the industry (Philips Design) and the education (Fontys Engineering) explored the possibilities of preparing this new type of engineer required in the FFE phase, gave positive results and a direction to go to.

We argue that in a new program set up, the engineer should not receive a list of specifications of the new product, but should be part of the process to unravel which specifications are relevant. A survey (N=73) at Fontys engineering has shown that approximately 20% of the current engineering students is interested in, and have affinity with, this new way of working. They indicated to look forward to work in the FFE phase, multidisciplinary, with moving specifications and many iterations in the prototyping. The curriculum does not yet provide these students the ability to learn these competences required by industry. Therefore, it is proposed to make a new structure in the educational program for students who are interested in Data-enabled Design. A dedicated stream for FFE interested students will have courses in the second year linked to companies’ projects. In this way, it is assured that theory and practice are well aligned and enough time is available to explore Data-enabled Design in the FFE phase for those students willing to innovate and create in the industry 4.0 way of innovating new products.

6 REFERENCES


