INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
3 & 4 SEPTEMBER 2015, LOUGHBOROUGH UNIVERSITY, DESIGN SCHOOL, LOUGHBOROUGH, UK

CHOOSING AN APPROPRIATE DESIGN PROCESS BRIDGING THE KNOWLEDGE GAP BETWEEN PROFESSIONS AND PARADIGMS USING VON HIPPEL'S END USER THEOREM – A CASE STUDY

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ABSTRACT
Thorough understanding of end user needs is often considered a necessity for achieving success when engineers are designing products. Taken to extremes this approach requires the engineer to be an attentive, critical and creative end user before success is obtainable. This is naturally not possible, never the less the issue is especially relevant in relation to the education of engineering students when doing product design aimed at an unknown territory. In this paper, a guideline for doing product-design in close cooperation with non-technical end users is outlined. The procedure is based upon the Von Hippel End User Theorem, although the setup also addresses the steps prior and subsequent to the use of the theorem. From a didactic perspective, the student is forced to acknowledge "non-engineering" views and values and their importance for the product design. This paper is based upon observations gathered through a project at the final semester of the Mechanical Engineering Education at VIA University College in Horsens, Denmark.

Keywords: Engineering for alien environments, Von Hippel End User Theorem, prototyping, product design methodology, product design education.

1 INTRODUCTION

Product development in product design education is a practice-oriented discipline focusing on efficiently achieving goals through the optimal choice and use of methods for the task given. The combination of a decreased average product lifetime and the opening of markets makes the task of delivering "the right product at the right time" continually harder to achieve. From the perspective of the development engineer, mutual considerations to various parties and stakeholders must be taken, with focus on meeting the demands of the end user. Although numerous methods for uncovering the needs of the end user has been introduced over the years [1] the engineering task is becoming more multifaceted thus making the product design discipline more experience based. The challenge is therefore: How to educate novel engineers to operate fast and efficient when developing products for a use and working environment they are unfamiliar with?

Using the Von Hippel End User Theorem (VHEUT) [2] as a method for the interaction between students and end users provides a short cut to understanding user needs while at the same time making the student aware of own professional identity. This includes identifying "black spots" of deficiencies when interacting with alien professions having a different mind-set and professional values compared to the one of the engineering world.

In this paper, we describe how an introduction of VHEUT to a small group of engineering students enabled them to gain user inputs for the first phases of a product development project, using the input to reveal needs and choose between multiple solutions in an iterative and continuous dialogue with the end users. The procedure involved the students doing prototypes and defining a workshop session with the purpose of end-users executing "on the spot" improvements of the prototype. Furthermore, the students were responsible for the planning and communication with the end users' organisation. By utilizing this method, the students managed, in cooperation with the users, to develop a novel product concept paying attention to important yet non tangible end user requirements while at the same time being in accordance with “good engineering practice” in terms of mechanical stability and produce ability. Based upon our observations a guideline including areas of attention, for applying VHEUT in engineering student projects is listed in this paper.

2 BACKGROUND

The Mechanical Engineering education at VIA University College is a bachelor education using Problem Based Learning (PBL) [3] and project based group work as one of the backbones throughout the education. The education is international with a student mix of approximately 1/3 Danish and 2/3 non-Danish students, the latter mainly having heritage in Europe all though students from all continents usually are present. From third semester, all lectures are taught in English[4]. The last semester includes the Final Bachelor Project covering a budgeted workload of 20 ECTS equivalent to a workload of 550 hours of work per student. The students are encouraged to form groups on their own as well as choosing subject for their final project. The assigned supervisor also acts as examiner when the project is evaluated at an oral examination.

2.1 Project setting

The urological “Ward 8” at the regional hospital of Viborg employ a staff of approximately 30 professionals with a majority of nurses. A common treatment is cancer surgery in the prostate. After surgery, blood from the operated areas flows to the urine bladder were it coagulates into blood chunks (clots) causing severe pain. Standard procedure for removing the blood chunks is a two-step process done by the nurse staff. The procedure comprises the injection a salt-water solute with a 50 ml syringe into the urine bladder through a catheter. The aim is that the salt-water dissolves the clots. These are then removed through the catheter by suction with the syringe. The procedure continues until the nurse determines that the level of blood in the bladder is acceptable. This is done by comparing the extracted solvent with a printed colour scale. The process is questionable from various aspects: ergonomic, hygiene, ethical and risk. Furthermore mastering the procedure is a taught competence gained by letting experienced nurses train newcomers in a peer training process normally of a 2-3 week duration. Mastering the procedure is best described as craftsmanship-competence based upon practical experience and “feeling”. This approach turns the procedure into a dogma, making the nurses focus on the patient treatment by mastering the procedure – no questions asked.

2.2 Challenge

The concrete product development challenge was therefore for the students to design a novel urine bladder rinsing device that could address the various aspects (ergonomic, hygiene, ethical and risk) of the existing solution. However, as the existing solution/procedure to a large extent is a craftsmanship competence, the *real* core challenge was: ”How to do product design regarding a need that in its essence lack identification from the end users nor is easily tangible in engineering terms?”

2.3 Framework / Context

The task was assigned to a group of two students wishing to do their Final Project within the specialization framework “Innovation & Product Design” [4]. The students had different nationalities: Danish and Rumanian, and had not been acquainted prior to the project start. From start to hand-in, the project period lasted 22 weeks.

3 METHOD

3.1 Project set-up and execution

After an introductory visit to the hospital, it was decided to incorporate the use of prototypes in the overall project run set-up. The reason for this was the assumption that a functional model would be a necessity for obtaining effective means of communication with the involved nurses. From the beginning, the students realized that the difference in mind-sets and profession was so big and alien that ordinary written and oral communication would fall short. The execution of the project followed the plan illustrated below (Table 1) – however iterations were foreseen from the beginning.

Table 1. Time Perspective

Phase	Duration (weeks)	Activities	Considerations
1	4	Defining the task Understanding needs: Interview with nurses Setting up requirement specification Defining market size and prize Setting up product assessment matrix	As stated earlier, the overall concerns of the existing procedure were stated at a high level thus being rather difficult to transform to measurable quantities for the subsequent solution. Instead, the requirements to the solution were rated against each other in order to define the priorities to the solution See Table 2.. Market size estimation was done by extrapolating the need at the ward into a national perspective.
2	2	Idea generating – product concepts.	On basis of the previous phase, conceptual solutions were generated.
3	1	Session with end users - Nurses choosing solution	A session with the end users was executed discussing pro and cons of each of the product ideas and rating them against each other's based upon the priorities set –up by the end users.
4	2	Prototype manufacturing	The manufacturing of the prototype was done by the students utilizing tool shop and a 3D printer.
5	3	Preparation & execution of End User workshop based upon VHEUT	The workshop was done in three sessions the same day with different groups of nurses all from the urological ward. Each session was recorded with a wide-angle HD camera.
6	10	Product development based upon the previous phase and Report writing	

Table 2: End user priorities

Consideration	Rank	Weight in percent
Hygiene	1	20%
Ergonomics	2	15%
Process time	3	15%
Risk	4	14%
Training	5	10%
Evaluation of waste water	6	10%
Ethics	7	10%
Disinfection	8	3%
Price	9	3%

By revealing and discussing various solutions with an end user committee early in the project, the above design parameters were defined (Table 2). From an engineering perspective, the assignment at first glance appeared to be an obvious automation and control task; through a "pump and a processor solution", the nurse in charge would merely have to mount and detach the equipment leaving the rest to the machinery. This suggestion was instantly rejected by the end user committee. The reasoning is perceived to be as follows: Nursing education is built upon a combination of medical theory and empathic approach gained by training through practical placement sessions thus becoming a craftsmanship discipline. A solution implying extended automation would distance the nurses from the procedure thus diminishing their ability to execute their empathic skills. The example also illustrates a typical engineering "Blind Spot": Neglecting relevant parameters not being part of the classical engineering identity (for instance empathic relations).
Adequate product requirement information cannot be gathered efficiently solely through meetings and user interviews when concerning "hands on products". One of the authors had the privilege of visiting

the ward at several occasions when initially defining the task and later on in the role of supervisor. Through these meetings, a recurrent experience was the rise of new inputs and requests from the users. The essence of VHEUT is the term “sticky information” addressing the condition that relevant user knowledge is unconscious to the end user. Common examples are the ability only to remember a pin code when a keypad is present or explaining the procedures of a software program only when being able to access the commands with the mouse. In order to reveal this hidden information the end users are asked to improve a prototype made with respect to engineering aspects such as manufacturability, costs, etc. From the position of the engineering student, this approach is an effective and reasonable short cut when dealing with development tasks for an alien territory like the bladder rinsing equipment. Instead of spending time and resources, trying to reveal and understand the user needs before commencing the design, the student can focus on exploiting her engineering skills within the boundaries of her profession thus avoiding the trap of dead ends by misjudging user needs. The task for the student is therefore altered into doing a prototype easily changeable/adjustable by a known group of end users, at the same time paying consideration to business, quality and technology. Thus, the purpose of the prototype was to:

1. Assess the value of the chosen overall concept in a “near to real life” environment.
2. Defining (and on the spot adding) overseen issues in the solution concept.
3. Improving details by forcing the nurses to relate directly to the functionality when confronting them with the prototype in a use situation.
4. Also, although not explicitly stated: Ensure credibility and motivation for the subsequent development task.

The prototype used at the workshop looked as illustrated below.

Figure 1. The prototype Mock-up for end-user test

Along with the prototype, a “toolkit” was brought to the workshop. It consisted of tubes, syringes, catheters, urine bags etc. along with a range of common tools like scissors, tape, glue screws etc., all with the purpose of making it easy for the test persons to adjust the prototype on the spot when the need occurred. The workshop lasted one day covering three independent sessions (approximately 90 minutes each) with the participation of teams of 2-4 nurses - all from the urological ward. All sessions were recorded (picture and sound) with a HD wide-angle camera. The workshop took place in a training ward with dummies instead of patients. After a short 5-minute introduction of the prototype and toolkit, the nurses were asked to use the prototype to perform a bladder rinsing procedure on the dummy, and encouraged to modify the prototype using the “toolkit” when needed.

4 OBSERVATIONS AND RECOMMANDATIONS

The workshop made the typical engineering dilemma obvious: When to stop analysing the problem and start developing? The used pragmatic approach succeeded in narrowing the solution area at an early stage postponing the hidden requirements to the VHEUT session. A positive side effect was the early “sell-in” to the end user committee. Incorporating the end user committee in outlining the overall solution at an early stage gained involvement and increased support from the beginning while on the other side bringing the comfort to the students that they apparently were on track. After having mutually confirmed the overall product principle, the next step was preparing the VHEUT session.

Designing and manufacturing the prototype for the VH workshop turned out to be the most unexpected time trap of the project. Luckily, one of the students possessed a machinist degree enabling the manufacturing of the prototype to be done relatively quickly without massive involvement of external parties. Providing the prototype for the end user trial lasted app. 2 weeks.

The outcome from each VHEUT workshop session turned out to be consistent from session to session revealing the following:

1. The operation of the syringe was acceptable in concern of ergonomics and manual power needed.
2. The geometrical size of the system was acceptable.
3. Use of two syringes (clean and waste) was reduced to one in order to simplify the procedure.
5. The setup was modified by prolonging the tubes in order to achieve a “clean” and a “contaminated” side of the system providing the nurse to use one hand for manipulating the catheter and setting the valve while operating the syringe with the other hand.
6. Two of the three groups questioned the possibility of achieving the required level of sterility of the device.

All in all the workshop was considered a beneficial instrument in improving the overall concept, or as the students wrote in their report:

> *“Overall, the workshop was a very great success in many ways. First of all, it was very satisfying to see that all the nurses that tried the prototype gave a positive feedback and they believe in the usability of such a device, everyone saw it as an improvement of the today’s method of bladder flushing; in relation to the problems, the old procedure leads to.”*

Although the procedure of the VHEUT is rather simple to comprehend for the students, based on our observations, we would like to propose the following guideline, including areas of attention, for applying VHEUT in engineering student projects:

4.1 Defining the relevance of VHEUT for a given task

The following questions could indicate the relevance of VHEUT for the given task.

1. Is the product in question used by persons with an “alien” professional education and attitude?
2. To which extent is successful use of the product based upon a tactile experience?
3. Is access to relevant end users provided for, and are they motivated for change and participation?
4. Are the identified end users able to spend the time needed for participating in the workshop?

Obviously the answer to the above needs to be a “yes”, however setting up exact conditions for this is a more complicated matter that needs to be defined in relation to the specific development task. Based upon the referred project it is the impression of the authors that question 1) seems to be the one easiest underestimated. We therefore claim that unless the students / product designers can describe themselves as end-users, performing a VHEUT with third parties is of relevance.

4.2 Check list for students when preparing a VHEUT

Prior to preparing the workshop, the students need to define:

1. What outer boundaries are set up for the solution (e.g. cost, size, legislation etc.)?
2. How can details in question be prototyped in a way that is easily changeable by the users?
3. Do not overdo the prototype – make it express need for improvements.
4. What is possible to achieve within the time-frame of the work shop?

3) From the case-study it was revealed that engineering is just as alien to nurses as nursing is to engineers. In order to avoid misinterpreted respect, it is important that the prototype’s level of finish encourage the workshop participants to make improvements. Despite its unattractiveness of the manufactured prototype, the functionality of the moving parts is at a level where relevant feedback can be obtained. This approach should on the other hand not been taken to extremes resulting in the end users feeling professionally offended.

4.3 Check list for students conducting a VHEUT

One simple rule seems to be sufficient, however, of great importance:

1. Students must shut-up and observe!

Revealing own creations towards a third party can be a self-exposing experience for most students. Excuses, explanations and suggestions causes bias during the workshop (but are welcome later). Therefore, the students need to let the end users execute the workshop without interference. The fact that the workshop was conducted in Danish and one of the students was from Rumania allowed the latter to concentrate on doing observations directly on the progress without being disturbed by the discussions of the nurses (and the interference of the fellow student).

4.4 The role of the supervisor in student projects involving VHEUT

The role of the supervisor in the described project required a more proactive approach than usual:

1. Inform the costumer about what to expect of the outcome.
2. Quantify investment and deadlines for the end users.
3. Be prepared to facilitate the students on “fluffy” non-engineering matters.

1) When dealing with end users not familiar to engineering and engineering procedures, a mutual balancing of expectations is a necessity for successful cooperation. In the described case-study it was agreed that the outcome of the project should be a concept suitable for a take-over by a third party – however no guaranties could be issued. Furthermore, the project’s placement in the curriculum needs pointing out to the end user. The documentation part of a student project consumes a rather big amount of the total project, thus likely to give an impression to the end users that development has stopped at the expense of rather unnecessary report writing.

2) The customer being a ward at a public hospital meant that focus was set on a time budget already under strain. Even though the face-to-face sessions were minimized, planning and correspondence at times seemed weary for the students. Setting up a single point of contact was beneficial, however, it is suggested that maximum response time is defined from start in future projects.

3) From experience, engineering students tend to focus on the “beauty of the technical solution” more than the practical efficiency of the solution itself. In the case study, the disappointment when the nurses chose the technically simplest version of the proposed concepts was unambiguous. An effort in retaining the overall purpose is therefore an aspect that the supervisor needs to be prepared for.

5 CONCLUSIONS

Based upon the case study of the student project, the authors conclude that used properly, the Von Hippel End User Theorem is a relevant and efficient method for enabling engineering students to act efficiently in “unknown territory” while simultaneously gaining awareness of own professional identity including implicit gaps. We propose a guideline for incorporating the Von Hippel End User Theorem in context of student projects within Product Design Engineering. From the case study and our observations, we have seen that using the proposed guidelines, students will be able to enhance a product, incorporating end user needs, thereby bypassing the traditional investigations of end user requirements. The authors envisage that the procedure described in this paper is transferable to a wide range of engineering tasks when involving end users with unfamiliar cultural and professional background. In perspective, the authors propose more research in this area, for instance how the guidelines can be adjusted to take the end-user / lead-user perspective into account.

ACKNOWLEDGEMENTS

This project was partially sponsored by “Fonden for praksisnær innovation” under “Ministry of Higher Education and Science” in Denmark. The authors would also like to thank staff at urological ward 8 at the regional hospital of Viborg for their dedication, enthusiasm and patience in conducting this project, in particular former head nurse Tove Brems Sørensen who provided the project in the first place.

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