INTERNSHIP PROJECT - DESIGN IN INDUSTRY VS. RESEARCH IN ACADEMIA – A CASE STUDY

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Abstract
A mandatory internship program for all engineering students studying towards a B.Sc. degree in Electrical and Electronic Engineering at the Academic College for Engineering ORT Braude exposes students to supervised internship in engineering design in industry or research project in academia for at least 1,000 hours. Some 20 years of experience with running the internship program gave us the opportunity to collect data concerning the characteristics of such projects. This study is based on qualitative analyses of interviews with students and their supervisors, observations on final presentations, and document analyses of the students' project books. This article presents a number of comparative characteristics of engineering design and applicative research internship projects in industry and academia. Additionally, it is shown that internship project contributes to the development and reinforcement of students' professional competencies and personal attributes.

Key words: *engineering design, research, internship*

1. Introduction

Internship comprises an integral part of the study program and a major curriculum requirement to attainment of the degree in such disciplines as medicine, teaching, law, accountancy and others. It is less abundant in engineering area, and curriculum of several academic institutions include requirement of internship in industry or research institute. According to the concept of the Academic College for Engineering ORT Braude, located in Karmiel, Israel, it is mandatory that all engineering students studying towards a B.Sc. degree in Electrical and Electronic engineering, be exposed to a supervised internship in engineering design in industry or in research project in academia. This article presents a number of comparative characteristics of engineering design and applicative research internship projects in industry and academia.

2. Theoretical Background

It is well established that engineering design as a central engineering activity (Dym, Agogino, Eris, Frey & Leifer, 2005), therefore it is very important to include it in undergraduate engineering curriculum (Wood, 2004). Such integration can help students to improve their academic achievement and skills and contribute to the development of thinking in undergraduate studies.

Project-based learning (PBL) was recently broadly studied. During the PBL students are exposed to problem-solving and design activities which demand high learning thinking skills (Dym, Agogino, Eris, Frey & Leifer, 2005). Project-based learning approach is useful because it "can provide students with real design experiences and opportunities to reflect on the design process" (Borgford-Parnell, Deibel& Atman, 2010, p. 749).

Clearly, undergraduate students carry out projects during their studies. One of the most famous experiments is a project of the University of Aalborg in Denmark. For more than 25 years they have operated a Bachelor's and Master's degree program in engineering which was based mainly on learning around projects (Dym, Agogino, Eris, Frey & Leifer, 2005; Fink, 2001). In this program students work on their projects for approximately 500 hours each semester. Projects are carried out in small groups of

5-6 students. High degree of cooperation with industry allows them to choose a wide spectrum of real engineering problems to solve. Each project requires analysis and definition of the problem, its solution, documentation and reporting. Significant differences were found between the students who participated in the Aalborg program and the students of other universities who learn according to a regular curriculum. The differences are reflected in students' ability to collaborate with people from different fields, take into account social aspects and technological innovations, define and solve engineering problems, and carry out the research and the technical development of the project.

Some researchers report that learning around projects improves students' achievements and thinking skills. Thus, Waks and Sabag (2004) show that experiencing through projects contributes to improved achievements of practical electronics engineering students. Dory, Barak and Tsaushu (2003) and Barak and Dory (2005) reported about significant increase in the achievements and significant improvement of higher order thinking skills such as asking questions, reasoning and systems thinking, of undergraduate students involved in learning science projects. They also pointed out that learning around projects improves students' understanding of basic science concepts and theories. Incorporation of design into freshman curricula shows that after one semester of engineering studies, students improve the quality of their problem solving approach in design processes (Mullins, Atman and Shuman, 1999).

Integration PBL into undergraduate curriculum in science and technology education, as described by Frank (2005), exposes students to the processes which are typical for engineering design: identification and analysis of requirements, collection and analysis of appropriate information, analyzing advantages and disadvantages and definition of alternative solutions, choosing the optimal solution, preliminary design, detailed design, construction of a model or prototype and evaluation. When performing design project, the students must see the final product (completeness) and understand the relationships and effects between the components of the product. Such activities cause improvement of systems thinking.

However, all the studies mentioned above refer to educational projects carried out in learning or research labs within educational institutions or in collaboration with industry.

Performing of final project consists of 1,000 hours in industry or academia, in last 20 years is mandatory requirement of Electrical and Electronics undergraduate curriculum at the Academic College for Engineering ORT Braude, located in Karmiel, Israel. At the end of the internship, students are required to document their work in a professional manner as internship report, and to present their work at an internship evaluation forum. A number of studies investigate different aspects of students' project activities in design projects, which were performed in high – tech industry. Thus, Waks, Trotskovsky, Sabag and Hazzan (2011) provide a characterization of engineering thinking based on analysis of interviews with the experts who were supervisors of students' projects, Trotskovsky and Sabag (2010), Sabag and Trotskovsky (2010) show that those engineering thinking characteristics that were described by the experts, expressed by students during the project course; Sabag and Trotskovsky (2011) illustrate that real project provides the students with the opportunity to reflect on their thinking; Trotskovsky, Waks, Sabag and Hazzan (2013), Trotskovsky, Sabag, Waks and Hazzan (2013) analyze students' misunderstandings and misconceptions in engineering thinking and project design activities. Differences and similarities of various aspects of design and applicative research projects were not researched yet. For this goal, we use Bonen's methodology (2003) which estimates the time required for the development of a new product in an engineering design process based on a lack of knowledge. Bonen suggested a hierarchical structure that consists of four levels of firm or organization knowledge known as the 'knowledge gap'. The knowledge gap indicates the number of full-cycle design processes required for the development of a new product. The first level, or 'knowledge gap one' appears when an engineer designs a device which is the similar to one that he or she designed in the past. 'Knowledge gap two' comes out when an engineer designs a device which is new for him or her, but the same device was yet designed in the organization by somebody else. A 'third knowledge gap' refers to a situation in which the design is very different from the previous that the organization has developed in the past. The 'fourth knowledge gap' is applies to design of absolutely new product, that no one has ever designed before.

The current study aims at comparative characterization of design and applicative research projects in industry and academia.

3. Methodology

A total of four experts – the supervisors of design and applicative research projects, and eight electrical and electronics engineering students – four who performed the final design project in industry and four who carries out applicative research projects in academia – participated in the study.

A qualitative methodology was applied. The research tools were interviews with all participants of the study, observations on the students' presentations at the internship evaluation forum and students' final report analysis. All interviews were recorded and analyzed. All the participants were asked a number of questions: concerning the project target, the degree of student achievement of the goal, engineering competences that the student obtains or develops during the project, difficulties that the student meet and the ways of their overcoming. Additionally, the experts were asked about the differences between research and design project in industry.

4. Findings

The research revealed that the aims of students' design project were typical for the fresh electronics engineers such as development of verification program for new communication card with frequency of 40GHz and performance of his lab testing; design a diagnostic tool for the system which prevents thefts of fuel from fuel trucks; development of automatic system for testing suitableness of electrical schemes of different devices included in the same large system. On the other hand, wide spectrum of applying research project aims included building and characterization of high voltage stabilizator 0 – 60V on single JFET transistor by VLSI technology; creation a database of drills' sound for automatic identification when a dentist drill frayed; investigation of influence of mechanical, electrical and electrochemical parameters on fuel cells' performance; finding an algorithm and development of program that uses image recognition techniques to detect the information from the students' cards for Instant Feedback System that will enable the lecturer in classroom to probe his students' understanding during the lecture in real time.

All the students reported at the interviews that they achieved the goals of their projects and demonstrated operating systems, designed schemes, graphs and the measurement results and their explanations of investigated phenomena at an internship evaluation forum. But the supervisor of research project which investigated influence of various parameters on fuel cells' performance commented:

P: I wanted that the student, among others, will develop an empirical mathematical expression that describes the relationship between the number of layers in the anode and the power density of the fuel cell. He did all experiment by himself; analyzed the results correctly; the documentation was almost fine. But he was not able to drive the mathematical expression without help. He understood that more layers cause a raise in power density but she did not understand that the relationship should be exponential. He could not replicate the experiment the second and third time with identical conditions as the first time.

The quote above demonstrates that in spite of the student developed his technical skill in the project he did not arrived at deep science understanding of researched phenomena. Often this kind of understanding is not needed in design projects, because its central goal is a correct operation of developing device. Our expert explained essential difference between research and design projects:

K: The preliminary expectations of a research project are not always achievable. Therefore, negative result is a legitimate result. There is no obligation to get positive results. For example, a group of researcher can work up to ten years to develop a new medicine that will not get the FDA approval. On the other hand, project in industry must succeed. It costs more than predicted or it may take longer time to develop it, but at the end it will work as defined. The differences in the motivation to develop

the project dictate the student's attitude toward the project. In industry, the student knows that he must get the specified results therefore he will do his best efforts to get it, but in the case of research project the student energy will turn to understand and explain the results.

In the course of project development the students meet various difficulties and overcame them. All the students and experts described lack of specific knowledge and skills that were required for project performance. Thus, the students depicted new knowledge that they acquired for their projects:

R: I must learn acoustical phenomenon for the system which analyses burnout of dentist drills and signal proceeding.

L: I did not know OOP *(Object Oriented Programming)*, and in the end I programmed free on C# *(the language of OOP)*.

M: I learned about all kinds of batteries, their parameters, how to charge them, their technologies, advantages and disadvantages.

The supervisor characterized the process of development of learning skills of student L.:

K: At the beginning, he was terrified of reading English literature, but as the time went on he read more and more and got over his fear. He read so much that towards the end he felt like English is his mother tongue. Additionally, he was not able to write any significant program. During the project he overpowered the obstacles and wrote a complete program that recognizes a hidden code in a picture.

Student L. justified the words of his supervisor:

L: At the beginning, I was very scared how I can understand all these things with this poor English that I have? How I could possibly understand everything? I read and read and saw that I understand more and more.

The next significant difficulty is time constrains. The supervisor the problem of lack of the time in research project in academy:

P: The time allocated for the project is only 1000 hours, not enough. It is never enough, you can never complete your work, and researcher must stop and observe his results.

On the other hand, the students who performed his project in high – tech industry, emphasized other aspects of time constrains:

Z: You have time to market. If you do not produce your card in time, you will lose the market. There is huge competition and your firm will lose. Therefore, you must be sufficient.

M: I wrote verification program and now I test the card. But every week I get updates of LVM (), and I must understand the changes in design and put changes in my program. This dynamics is very difficult.

Students described additional difficulties in the course of design project in industry and the ways of their overcoming:

O: All the time new problems appear, for example, cross talking between the components that must not speak one with other, and I must solve them. I need to decide how to solve all the problems and I have no idea how to do that. And I start to find solution.

Z: I build the system for checking design documentation which will operate in my firm long time after that I will enter it into the network. So I must think not only about what it is now, I must think about what will be, about future changes and surprises.

As can be seen, the difficulties depicted above by the students refer to the solution of various engineering problems.

Overcoming of the difficulties caused acquisition and development of new research and engineering abilities. On the one hand, students refer to professional competencies that they reached. Student S. described his experience of knowledge and skills integration:

S: In my project I tried to combine new things with ones that I learned in *(academic)* courses. I wanted to show an influence of different parameters on behavior of fuel cell, and I found how to do that with 3D graph in MATLAB *(programming language)*. I wanted to control my measurements automatically, for example, to define the measurement time in advance and stop it. And I found how to do it with LabView *(development environment and visual programming language)*.

Next quotation shows that the student developed his understanding of physical phenomena:

N: It was short - channel effect in JFET transistor in the voltage of 80V. My supervisor explained me that to increase it I need to lengthen gate and a distance to drain. I started to change dimensions and step by step understood how every little shift influences on all the parameters. I understood why it has happed.

Quotation below refers to understanding of new concept:

M: I understood that reliability of the product is very important. We supply the product to customer, so its reliability stands on the first place.

On the other hand, students reported about development of their personal abilities. The next citation illustrates how students' self – confidence and self – evaluation had changed in the project progress:

S: I started the project and thought: how will I raise up it? How will I do all these experiments and measurements? In the end I was very proud – I did it! And now when I get new project at my job, I first of all turn to be frightened, and after that I calm down myself and I say:" I did it and I will do it".

L: Now I know that I am able to carry out research, and I feel that I am worth something.

The next quotation shows how interwoven decision making and responsibility aptitudes developed in the process of industrial internship:

N: I saw that the schema that I developed will be the last. They give me credit and my boss will not check every detail. So I must decide about everything and I am full responsible on my device, if it is good or bad. At the beginning it was very difficult, but afterward I became used to decide.

In industrial environment the working process is well organized and specialized, and the student learns to work systematically:

Z: I must document every little change that I make. Every day in evening I must describe current state *(of the project)*. This way of working is very useful because I accustomed myself to think about what I did every day.

5. Conclusions

In this article we have brought a number of attributes characterize students' engineering design projects in the industry and research projects in academia, that are the part of the requirements for B.Sc. in Electrical and Electronics Engineering.

Our findings demonstrate certain difference between two kinds of projects: while in engineering design projects the specifications of developed product are well defined and the project must succeed, the objectives of research projects more flexible and it can finish by negative result. This observable difference is stemming from the different aims of science research and engineering design: scientific research is directed to broadening knowledge by creating new knowledge and engineering design is directed to the application of existing knowledge in new product development [10].

In the course of the project all the students encounter difficulties relating to lack of specific knowledge and skills. According to Bonen's classification (2003), the students who perform their real project in industry, where the experience of development of similar product usually exists, work on knowledge gap one or two. But the students who carry out their research project generally work on knowledge gap three or four. To overcome this gap they need well developed high order thinking

skills, and our practice shows that not always they sufficient to develop them within the time allotted to the project.

Accordantly, time constrains in two kinds of the projects have different character. When the time is over, research project can be stopped in intermediate phase. On the other hand, design project in industry must be completed successively in urgent time frame. These findings meet the arguments of Waks, Trotskovsky, Sabag and Hazzan (2011) that stressed time schedule leads to individual responsibility and could contribute to the development of the ability to think quickly and effectively.

As it was shown, students' the project activities contribute to development professional competencies, such as ability of acquisition and integration of new knowledge, deep understanding of physical phenomena, development of experiment, design or testing process, and personal abilities, such as self – confidence, self – evaluation, decision making aptitude, responsibility, ability to work systematically. Our findings are in the line with De Lange (2001) who claim that these non – technical skills required from engineering students when they enter to job market.

In conclusion, we claim that the students' research and real design project activities contribute to the development and reinforcement of professional competencies and personal attributes and can help the students in the transition from learning to work.

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