**Students’ Reflections on their Internship Design Project in Industry**

1N. Sabag, 2E. Trotskovsky

1E.E.E. Dep. at ORT Braude College of Engineering, Karmiel, Israel, nsabag@Braude.ac.il

2 E.E.E. Dep. at ORT Braude College of Engineering, Karmiel, Israel, elenatro@Braude.ac.il

**Abstract**

The roots of reflection lead back to Thales's days (the sixth and seventh century BCE), when mathematicians started investigating geometry proofs. Thus, a new scientific method was born with reflective thinking at its core, which means thinking about thinking, not only about objects. The importance of reflective thinking for the promotion of learning is expressed by many researchers. In spite of this, and of the ancient traces of reflection, nevertheless it seems that for the individual student, rather than a daily custom, reflective thinking in learning is a rare occurrence.

A mandatory internship program for all engineering students studying towards a B.Sc. degree in Electrical and Electronic Engineering at Ort Braude College of Engineering exposes students to supervised engineering design in hi-tech industry for at least 1,000 hours [1]. As part of the program, the students are obliged to meet all the project specifications as defined in advance, and at the end of the internship, to document their work in a professional manner and formally present it at an internship evaluation forum. Some 16 years of experience with running the internship program gave us the opportunity to collect data concerning students’ reflective thinking.

A qualitative method was employed in this study. Interviews with students, observations on final presentations, and document analyses of the students’ project books, were chosen as the research tools. The accumulated data over the years led us to the conclusion that the engineering design of a real project provides the opportunity to reflect on thinking. The Preliminary Design Review and the Corrective Design Review forums, which are organized in a highly methodical manner in hi-tech industries offer excellent ground for the development of reflection. Moreover, the malfunctions that appear during the design process of the designed engineering system itself, force the designer (the student) to reflect on his (or her) thinking. In the full paper we present some reflection examples revealed in students' interviews, project books, and final presentations.

1. **Introduction**

This article describes events of students' reflection during their internship design projects. We are blessed to have the experience in engineering design internship implementations for a period of over seventeen years at ORT Braude College of Engineering, located in Karmiel, Israel. According to this concept, 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, either in industry or at a research institute, for a proven duration of at least 1,000 hours [1]. There are also some students who conduct only 400 hours internal projects. The proposed projects are scrutinized by an academic committee whose approval is a condition for entering the internship program. More than 500 students had their internship in the industry and more than 50 students perform internal projects at this time. We will show that when the project is significant in the students' eyes a deep reflection is aroused.

1. **Literature review**
	1. **Preface**

Reflection and reflective practice is one of the most promising innovations in education [2]. The roots of reflection are very ancient; according to Kashdan [3] it started in Thales's days (approximately 624 -545 BC); Galea [4] mentions Plato’s (427 – 347 BC) ideas on reflection; nevertheless it seems that reflection thinking is still not a daily habit for the individual thinker. One of the reasons might be Procee's [2] argument that even its defenders admit, reflection in education suffers from a lack of conceptual clarity. We claim that our knowledge about reflection is not sufficient and there is a lot to be done to promote reflection.

* 1. **Reflection in learning and teaching**

According to the American Philosophical Association [5], critical thinking is a target oriented adjudication process performed within self-regulation. The results of the judgments are explanation, distinction, analysis, evaluation, and conclusions, fair-minded self-correction, i.e. critical thinking based on reflection [6].

Dewey [7] defines a reflective action as a constant and careful action in response to the problem created, involving intuition and emotions as well. He described five aspects of reflective thinking: raising suggestions, ideas, conceptualization, and hypothesizing, drawing conclusions about possible explanations, and examination of the hypotheses through action. According to Dewey, reflective thinking is a kind of high thinking integrated in self action research aimed at improving the performance of the action. Reflection is one of the prominent features of critical thinking.

Procee [2] provides a philosophical analysis of the central concepts on reflection. He claims that the current literature relies mainly on the pragmatic school of Dewey. In contrast, Procee argues that Kant’s philosophy incorporates ideas better suited to understanding reflection in education - particularly through his distinction between understanding and judgment, a distinction that supports an epistemology that accepts the special nature of reflection as judgment as opposed to formal learning. Procee claims that for Kant, judgment is a special faculty of the mind, which is not governed by logical rules; instead, it is a personal power to determine which concepts and theories are appropriate for a given situations. Understanding is necessary for knowledge. According to Kant, it is the mental capacity to formulate and to grasp logical relationships, concepts, theories, and laws. Judgment is of a completely different order. It is the power to determine which rules are best aligned with concrete situations and problems.

Schön [8],[9],[10] established the concept of Reflection **in** action which occurs in doing as opposed to Reflection **on** action that occurs after doing. He said that in daily life we sometimes find ourselves knowing how to do things spontaneously and intuitively, but we cannot explain what we know. There is merit in motivating the individual to describe professionally, based on clear criteria, what he did. He emphasizes the need to frame and reframe the problematic in surprising situations in order to think on possible solutions. It is important to explain the success as well as the need to know to explain what caused the failure of the act.

According to Kozulin [11], meta-cognition is often considered to be the highest level of mental activity, involving knowledge, awareness and control of one's lower level cognitive skills, operations and strategies. The ability to plan and monitor one's problem-solving actions, predict possible outcomes and compare them with actual solutions are amongst the more basic meta-cognitive skills. Students' ability to reflect upon their own learning and problem-solving strategies is considered to be an indicator of a successful educational process.

* 1. **Reflection in design projects**

Doppelt [12] claims that project-based learning enables pupils to: research, plan, design and reflect on the creation of technological projects. He describes a study in which 128 high school pupils had designed and created projects. The projects were assessed according to a creative thinking scale that was designed to assist pupils in documenting the design process. He admits that there is much to be learned about documenting teamwork and pupils’ reflection. The current paper describes meaningful reflection events that occurred among students while designing their first engineering projects in the frame of internship.

Mioduser and Kipperman [13] studied Grade 7 pupils' work while engaged in design tasks within an unstructured learning environment. They report that during the evaluation phase, pupils focus on testing the artifact and on planning subsequent actions according to the test results. When the test results are positive (the device works, even if not as expected), the findings indicate that pupil regard the goals as “achieved” or “partially achieved” (e.g., “It turns but slowly”). This usually leads to the decision to improve or expand the original goal to enhance the performance of the device (e.g., “I will improve it”, “I will increase its power”). We show in our finding that in case of real life project in the industry, the student seeks not only to improve the project's performance but to find an elegant solution.

Barzilay and Hazzan and Yehudai [14] suggest that reflection as a habit-of-mind can contribute to improve the understanding of software engineers' mental processes. They recommend on adopting a reflective mode of thinking. In practice, reflective tasks can require students to learn from their successes and failures, to track their trial-and-error processes and draw conclusions from them, and to articulate their feelings about the teamwork. Such tasks encourage students to think on a higher abstraction level and raise their awareness to the different facets of software engineering processes. We believe that their recommendations are appropriate to electrical and electronic engineering as well.

1. **Method**

The participants in the study were students studying towards a B.Sc. degree in Electrical and Electronic Engineering, at the ORT Braude College of Engineering, some of them had internship in the industry and some had internal design projects. The students were required to record their ideas relating to: solving the project's problems, correcting malfunctions, reporting on Preliminary Design Review (PDR) and Corrective Design Review (CDR) forums, reflecting on their own thinking; they are required to describe these activities in the project booklet. Eventually, they present their work in a formal presentation. Our purpose was to understand their way of thinking. The nature of this activity dictated using qualitative tools such as interviews, observations during the final presentation, and analysis of the documents obtained in the course of the data collection.

1. **Results**

The student [S.1] designed a system for calibrating and testing of "Air Data Converter System" in one of the well known firms of Israel. In his project book he reports on the next engineering problem. The system was designed to calibrate four ADC (Analog to Digital Converter) cards and EEPROM (Electrically Erasable Programmable Read Only Memory) components. It is required to split the original clock signal into four clock signals. The first component that was selected to perform the task had a very small input capacitance that cause large "electrical efforts" which greatly increased the time delay of the clock. During the PDR (Preliminary Design Review), it was decided to replace the component with a standard component with a greater input capacitance and therefore its impact on the time delay is not large. This choice had a good influence on the timing of the system. The participants in the PDR forum are well experienced engineers; its aim is to promote reflective thinking while raising ideas concerning the improvement of the project. Based on this example and on numerous others, we can claim that the working environment with experienced peers and supervisors enables reflective and educated discussion on several solution alternatives and choosing the preferred solution.

The student [S.2] has designed a data collection system that integrates coordinates of geographic point according GPS (Global Position System) and sea depth data at the same location and displaying them simultaneously. Among other design considerations she had to decide whether to implement the design with a single micro-controller or using a combination of three micro-controllers. It might be assumed that student, during her studies, would prefer a single controller. In her project book she presented a reflective analysis of her way of thinking, which includes a professional discussion with her supervisor, leading her to choose the implementation that requires three micro-controllers. This choice enabled a great simplification of the software required to deal with the information received from multiple sources simultaneously.

The student [S.3] was assigned an internal project (i.e. in the college's labs). He designed and built a control card programmed to guide a robot to move from point X to point Y. Furthermore, in case the robot detects an obstacle on its way, it overrides the barrier and continues on its way to the destination. The student noticed that the batteries run out too quickly. He developed a neat measuring scheme of the current consumption of four different operational modes of the robot and found that in one operation mode (called Run3) the current consumption is 300mA. This is definitely a high current consumption. The solution offered by the student is to connect the robot through a long cable to the electricity grid. This kind of a solution may be suitable for a project carried out at the college, where the student only seeks to fulfill his obligation. Such a solution is undoubtedly not acceptable in industry aiming to sell the product. The complete solution in this case requires a design with low power consumption components and using appropriate energy source. This example emphasizes that learning environment does not always enable students to make real optimal decisions. Furthermore, the learning “incubator” does not always force students to aim to perfect engineering achievements.

The student [S.4] performed an internal project in which he designed and built a system that allows drawing a track on a touch screen; the track data is transmitted via a Bluetooth communication card to the robot's micro-controller causes the robot to follow the designed track on the floor. The robot in use is controlled by micro-controller with minimal instruction set, which does not contain a mechanism for interrupts. Interrupt method is more convenient way to control the robot by micro-controller. Through a deep reflective thinking, the student switched from thinking about the interrupt method to a completely different way of thinking suitable for use in polling. In the polling method, the micro-controller routinely samples the inputs to treat the entry of information from peripheral components. In the course of applying polling he discovered that the system does not recognize some individual cases of data received. This problem was solved by the student in a creative way by inserting a software procedure to approval from the micro-controller for the data received; in case the approval is not received the data will retransmitted to the robot. This description certainly fits the statement in [14] that reflective tasks can require students to learn from their successes and failures, to track their trial-and-error processes and draw conclusions from them.

The project of the student [S.5] was designed to solve a known problem to software users. Sometimes, computer users who work with files write documents, make changes to files, finally save their files but forget where the files are located. The student aim was to design software system which can remind the user where his file is located. He describes his reflective activity of identifying and repairing errors in the process design as stated in [14]. For example, at the beginning the student thought to use a single file in which all changes made to a software during engineer's work will be list. Very soon he discovered that the file dimension was too large, so he changed the method and used two files. When one file is full, he switches to work with the second file and when the second file is full he re-writes the first file thus deleting the old content.

The student [S.6] designed and implemented an automated system for measuring water consumption. The amount of water consumed is transmitted through a cellular network and the internet to the water provider's computer. He writes a description of his work:

"The block diagram of the project had changed several times during the project design. As far as I progressed on working, through a reflective thinking, I learned more and more about the advantages and weaknesses of circuits and components. I learned what parameters are the most important to insist on and what are the degrees of freedom. All this has contributed to constitute professional and creative modes of thought that yielded more quality solutions."

The next quotations indicate a change in the students' perception that occurred following feedback received from the designed system during the tests. A reflective cognitive process of understanding the phenomenon and re-construction of knowledge based on deep insight can be identified in these cases. All previous examples can be attributed to one type of reflection, where an abnormal response or a system error triggers the designer to conduct an analytical process which leads to further examination of his/ her previous thinking and to finding the source of the error.

The next examples describe a different kind of reflection in which the logic of the solution did not seem elegant enough for the student.

The student [S.7] designed a tester for a sophisticated system in a prestigious firm. He reported on the problem of signal integrity while using LVDS (Low-Voltage Differential Signaling) protocol due to noise on the lines connecting the tester and the unit under test. In his report he described systematic reflective thinking, while using the advanced measuring equipment existing in the industry, he found high noises affecting the quality of the test. The student found that the source of error is incorrect wiring of the power supply line (Vcc and Ground) but was not satisfied with the error correction. He chose to improve the tester by dividing the line into two parts: for most of the line (about 14 meters) he used communication standard that is less sensitive to noises (RS 422) and for the final segment of 30 cm. he switched again to LVDS standard. At the same time he corrected the ground connections between the tested device and the tester. It later turned out that this solution also solved another problem in the system: the LVDS component used to burn out from time to time due to the difference in ground potentials.

Here is additional example of student that could be satisfied with the system's performance which seemed to have no malfunction but continued to study and improve the system with a sense of responsibility.

The student [S.8] designed a sophisticated system for disconnecting loads from the Israel's national electricity network, to protect the national power supply in cases of a potential danger for the operation of the generator stations. For example: shutting down one generator station, for some reason, causes to increase the power generated from other generator stations. The increase of power of the other stations is a slow and gradual process; if it is not managed correctly it can lead, in extreme cases, to collapse of the national grid. Therefore, it is necessary to disconnect consumers from the main lines, based on predefined priorities, and re-connect them when the power supply stabilizes. The control system includes several sub-systems with mutual backup in certain functions. Although the system operated in an exemplary manner, the student noticed that after re-connection of some consumer group by one sub system, it happens that the same group is reconnected again by another sub system. This is not an interference with the electrical system and yet, this is a logical error that diagnosed and amended by the student.

It can be seen that the student did not face any problem or mismatch. Even though his aspiration for elegant design drove to improve the logic of the system and induced a reflective process that led the student to correct his thinking. This case reveals that the student's motivation to perfection can stimulate reflective thinking.

1. **Conclusions**

In this article we have brought reflection examples that occurred among students that performed engineering design projects in the industry or in one of the colleges' labs, as part of the requirements for B.Sc. in Electrical and Electronics Engineering. These findings meet the arguments of [12] that project-based learning enables students to design and reflect on the creation of technological projects, and [14] that reflection as a habit-of-mind can contribute to improve the understanding of mental processes. Engineering design activity is different from formal learning and occurs in different environments, as advocating by Procee [2]. Mioduser and Kipperman [13] argue that students tend to improve their projects. The examples of students [S.7, S.8] show that when the design project is performed in the industry, the students have motivation to improve the design even if the system’s functionality is perfect. The sense of responsibility caused the student [S.7] to repair a system connected to the tester he designed, and the student [S.8] that was not satisfied with the elegance of the solution did not stop his activities until he found a more elegant solution. In conclusion, we argue that the activity and the environment in which students design and build real projects, especially in the industry, promote reflection that considered as one of the highest levels of cognitive activity as cited in this article. We suggest that engineering educators should encourage their students to perform reflection, primarily by designing and implementing projects in the industry.

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