Exploring the Correlation Between Systems Thinking and Soft Skills for Improved Effectiveness of Project Based Learning

Aziz Shekh-Abed
Department of Electrical and Computer Engineering
Ruppin Academic Center
Emek Hefer, Israel
azizs@ruppin.ac.il

Nael Barakat
Department of Mechanical Engineering
University of Texas at Tyler
Tyler, TX. USA
nbarakat@uttyler.edu

***Abstract*— This research to practice work-in-progress discusses how engineering educators continue to explore approaches that integrate different needed skillsets and knowledge bases in a holistic and efficient educational process. Experiential learning based on hands-on projects provides one of the most successful approaches in achieving this goal. Using an actual engineering project, a team of students can be guided to learn challenging skills and concepts. According to many literature reports, soft skills are best learned during practice, as an engineering project is carried out. System thinking is another example of a skill that is best learned while conducting an engineering project. Therefore, a hands-on project provides the best vehicle to achieve education of these two skillsets.**

Capitalizing on this knowledge, the study reported in this paper was set out to explore the correlation between soft skills and system thinking. The goal is to provide insight to educators that can help in designing better hands-on projects which integrate both skillsets holistically and efficiently. The fact that education of both skillsets uses the same vehicle of project based learning provided the motivation for this exploration. This exploratory study was conducted among a class of thirty high school students majoring in electronics and carrying out hardware-software combined projects. Students were asked to fill out two anonymous Likert-like questionnaires about their self-reported systems thinking and soft skills. The findings indicate a significant moderate positive correlation between the two skills, which may lead to both theoretical and educational implications. These results were employed in forming recommendations on integrating both system thinking and soft skills education in the set of activities carried out as part of accomplishing the technical project goals. Future work includes testing these recommended changes to finalize the formulation of an integrative approach to education that includes both of these skillsets.

Keywords*— *Systems thinking, Soft skills, Hands-on Projects, High school students

I. Introduction

A successful engineering team requires a set of qualifications that includes systems thinking and soft skills. Systems thinking indicates an ability to look at the whole rather than just one issue at a time, taking into account the interactions and relationships between a system and its environment [1]. Soft skills indicate, among other skills, the ability to interact effectively and harmoniously with others [2, 3]. These skills are crucial in all types of technical endeavors especially skills such as listening, communicating (within and with others), thinking (critically), and summarizing information. Therefore, many studies have focused on developing these two skills, separately, among engineering students due to their importance in engineering practice. [4, 5].

Although systems thinking and soft skills have each been dealt with separately, a possible relation between them has yet to be explored. This paper examines the correlation between systems thinking and soft skills among high school students carrying out projects that combine hardware and software. The theoretical contribution of this study is a quantitative characterization of the relationship between systems thinking and soft skills. The practical contribution would be to facilitate developing educational activities to promote a combination of systems thinking and soft skills using one vehicle for all levels of engineering students from high schools to universities.

The following parts begin with a review of project based learning (PBL), systems thinking, and soft skills. This is followed by the objective of the study and the research methodology. Next, a description of the work and a discussion of results are provided. Finally, conclusions are drawn with a view on future work.

II. Theoretical Background

A. Project Based Learning (PBL)

Project based learning (PBL) has its roots in Dewey's experiments with educational strategies at the University of Chicago Laboratory School [6]. The theoretical framework of the PBL builds on three main components:

1) Constructivism: which explains how students develop their understanding via PBL [7].

2) Social constructivism: which explains the importance of cooperative learning when team members work together to solve the problem posed [8].

3) Constructionism: which justifies turning students' understanding into a model, prototype, or an illustration [9].

Moreover, PBL is founded on the theoretical background of constructivism in which students are immersed in different components of problem solving, an interdisciplinary curriculum, open questions, hands-on activities, group work and interactive group activities [10, 11]. In fact, PBL has been used in education for a long time where it establishes an educational process driven by a demand and ended with a final product [12]. PBL is used in science education to engage students in research and to present, then try to solve, difficult social challenges [13, 14]. Project topics often arise out of students' interest and spread organically when students want to know more. Consequently, PBL can be described as a systematic method of teaching that directs students to acquire basic knowledge and life-enhancing skills through an advanced and student-influenced research process that is structured around complex questions, authentic, and carefully designed products and assignments [15, 16]. Moreover, PBL is also considered to be one of the most important factors in learning when it is designed to generate motivation among students [17].

B. *Systems Thinking*

Systems thinking is a way of seeing the whole, as a framework for examining relationships rather than isolated items, and for observing patterns of change rather than relying on static snapshots [1]. Additionally, system thinking ensures that an overall view is considered (or whole system performance), and all relevant factors are taken into account when implementing change. Therefore, solutions that are an aggregation of optimized subsystems can be avoided. Such solutions are ultimately ineffective due to lack of consideration of interactions among subsystems. Another explanation of system thinking states that systems thinking is the ability to represent and assess dynamic complexity (e.g., the behavior that results from a system's agents interacting over time) both textually and graphically [18]. The concept of systems thinking has been recognized since Ludwig von Bertalanffy's General Systems Theory [19], and it is likely that elements of systems thinking govern the creation of key project management outputs (e.g., network charts and Gantt charts). In fact, the importance of systems thinking is increasingly being recognized in industry, academia, and government.

Another aspect of engineering systems thinking is that it allows seeing how the system works without revealing all the details, taking into account the system's interdependencies and synergies, as well as non-engineering factors, such as economic, societal, and organizational factors. The ability to evaluate technical and social relationships and exploit this information to design and manage complex systems is a challenge in modern systems engineering practice. During the last several decades, research efforts have explored both individual traits, skills, and attitudes as well as team properties that contribute to the capability for engineering systems thinking [20-24].

III. Soft Skills

During the spread of project management, "softer" or more people-centric issues came into focus, such as personnel management, motivation, team performance, team structure, stakeholder management, negotiation, communication management, and leadership [25]. The system thinking approach began moving from "hard systems" (product and technology-centric) to "soft systems" (people and process-centric) [25].

Soft skills include the ability to relate to others and encompasses not only relational skills, but also behaviors such as social responsibility, creativity, ethics, and emotional intelligence [3]. The soft skills of interpersonal skills (e.g., building rapport) and communication (e.g., adapting your message to the intended audience) are highly valued by organizations [26]. The importance of soft skills in engineering has recently been emphasized by a number of organizations including the National Academy of Engineering (NAE) and the Accreditation Board for Engineering and Technology (ABET).

Monarch Institute research shows that 85% of the skills required for employability are soft skills, whereas 15% are technical skills. This reinforces the importance of teaching soft skills during academic years. Researchers have shown that engineers should be able to adapt to new knowledge and express their ideas independently, critically, and proactively. As a member of the team, engineers need to build and maintain relationships and develop intrapersonal/self-management skills that enable them to manage impulsive tendencies, follow through on commitments, hold themselves accountable, and tolerate stress. Studies have also found that engineering students need to start developing innovative solutions to problems in the real world, to work in teams, manage interdisciplinary groups, and understand society. Students must take into consideration the ecological, ethical, and political implications of their actions [27, 28].

Caten and his colleagues suggest that the importance of soft skills is higher than that of technical skills for current and future engineers [29]. There are several examples of skills that go beyond technical competence which make professionals more capable of taking control of their career and adapting to market demands. These skills include leadership, creativity, communication, management, ethics, agility, resilience, and flexibility. The skills that are necessary for management and leadership positions post-university are those that develop based on humanities and social sciences, such as: showing passion and interest, accepting current roles and responsibilities while seeking continuous improvement; gaining experience in other projects and working groups, understanding and resolving organizational challenges; and self-assessment to learn from mistakes, cultivating values that promote trust [30].

IV. Research Goal

The goal of this study was to examine the relationship between systems thinking and soft skills during project-based education of pre-engineering high school students. The following research question was formulated: what is the correlation between systems thinking and soft skills among high school pre-engineering students performing project based learning?

A. *Participants*

Thirty senior high school students majoring in electronics took part in the study. Students worked on projects that combined hardware and software for two years

B. Procedure

Student teams worked on their final projects under the guidance of an experienced teacher and in teams of two students. For their final product, students had to design a hardware/software system based on an Arduino microcontroller board (programmable device). Several components, such as sensors, motors, and displays, were used in the design, which was tested using an oscilloscope and multimeter.

Final project examples:

1) A robot waiter serves food to a customer's table in a restaurant using an app installed on a customer's smartphone.

2) Fingerprint attendance system: In this system, an Arduino Mega 2560, a fingerprint sensor, and a touch-screen LCD detect employee entry and exit. In this system, an Arduino Mega 2560, a fingerprint sensor, and a touch-screen LCD detect employee entry and exit.

Indirect assessment instruments were used for evaluation of students' systems thinking and soft skills. These instruments included two anonymous Likert-scale questionnaires which were completed by each student. According to the statistical analysis performed, Pearson correlation coefficients were calculated between systems thinking scores and soft skills scores.

C. Tools

The self-reported questionnaires on systems thinking and soft skills were based on the characteristics of systems thinking [22,31] and soft skills [32] of engineers, adjusted for high school students. Those characteristics were validated by two experts in engineering education and four electronics teachers highly experienced in leading projects that combine hardware and software.

Systems thinking self-reporting Questionnaire: was based on a five-level Likert scale, ranging between "highly agree" and "highly disagree", consisted of 32 statements concerning systems thinking. Thus, for example, the statement "when I am involved in an engineering project, it is important that I understand how a component fits into the overall product" indicates relatively low systems thinking. The questionnaire was validated by two engineering education experts. The internal consistency of the statements that focused on systems thinking (Cronbach's a = 0.751) was acceptable. Samples from the systems thinking questionnaire are provided in table I.

The soft skills self-reporting questionnaire was based on a five-level Likert scale, ranging between "highly agree" and "highly disagree", and consisted of 50 statements concerning soft skills. Thus, for example, the statement "when I am involved in an engineering project, I tend not to ask questions or get help from others" indicates relatively low soft skills. The questionnaire was validated by two engineering education experts. The internal consistency of the statements that focused on soft skills (Cronbach's a = 0.833) was acceptable. Samples from the soft skills questionnaire are provided in Table II.

V. Findings

Table III shows the mean score M, ranging between 20 and 100, and the standard deviation SD for systems thinking and soft skills as measured by both questionnaires.

TABLE I. SELF-REPORTING QUESTIONNAIRE: SYSTEMS THINKING (SAMPLE STATEMENTS)

Statement	**Systems Thinking**
When I am involved in an engineering project, It is important that I understand how the component fits into the overall product	High
It is important for me to have knowledge in engineering subjects that I do not study as part of my major (for example, if I major in electronics and computer science, it is important for me to have knowledge in mechanical engineering as well).	High
When I am involved in an engineering project, I prefer to let another student in the team engage in the interactions (relationships) between a component and other components in the product.	Low
When I am involved in an engineering project, I prefer not to deal with unclear issues or situations	Low

TABLE II. SELF-REPORTING QUESTIONNAIRE: SOFT SKILLS (SAMPLE STATEMENTS)

Statement	**Soft Skills**
When I am involved in an engineering project, I solve problems quickly and effectivly	High
When I am involved in an engineering project, I act straightforward and honest when dealing with others	High
When I am involved in an engineering project, I tend to avoid asking questions or getting help from others	Low
When I am involved in an engineering project, I don't tolerate stress very well	Low

Pearson correlation coefficient between systems thinking and soft skills was found to be positive, moderate and significant ($r = 0.530$, $p < 0.01$).

TABLE III. SELF-REPORTING QUESTIONNAIRES: SCORES

	M	***SD***
Systems thinking	78.50	5.59
Soft Skills	74.45	7.90

VI. Discussion

Despite the fact that systems thinking and soft skills share the same vehicle of education, which is PBL, both types of thinking have been characterized separately so far. This study examined the correlation between these two skillsets and according to what has been reported so far it is the first study to indicate a significant moderate positive correlation between the two skills. This correlation was obtained through indirect assessment instruments consisting of self-reporting questionnaires.

The results found may have both educational and theoretical implications. Accordingly, from a theoretical perspective, it is possible that both skills share a cognitive behavior, which could help students in learning and mastering both skillsets. Educationally, it may be more beneficial to have programs that develop both skills simultaneously than those that focus on each separately. These results open doors to a more informed approach as project are being designed for PBL where instructors can capitalize on this learning vehicle to deliver both skillsets in a cohesive and more effective manner. This study is planned to continue to the next phase where applications will be introduced and tested. One major application would be to redesign the project used for PBL so it can deliver both skillsets.

It is to be mentioned that this study has two main limitations: (a) the relatively small number of participants, and (b) the fact that the participants were high school students carrying out projects that combined hardware and software. However, it is believed that a study of this scope can contribute to theory as well as practice. In addition to the potential contributions explained previously, another theoretical contribution of this study is the quantitative characterization of the relationship between systems thinking and soft skills.

VII. Conclusion

A positive, moderate, and significant correlation was found between the two skillsets: systems thinking and soft skills. This correlation might lead to better design and delivery of a project for PBL which is the common vehicle for delivery of both skillsets. This will consequently improve engineering students' education and preparation for the real word.

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