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Case Report

Systems Thinking Education—Seeing the Forest through the Trees

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Abstract: Systems thinking is an indispensable tool in comprehending and analyzing real-world phenomena. Observed processes are naturally composed of many interconnected components which ought to be studied jointly rather than individually. Engineering systems thinking is a very valuable skill, which helps to successfully execute multi-disciplinary projects. In high-tech companies that deal with complex and dynamic systems projects, the need for engineers with high systems thinking skills is growing. Engineers with high systems thinking skills are able to understand the big picture and the project in its entirety, both functionally and conceptually, without necessarily knowing all of the small details. Systems thinking enables understanding the entire system beyond its components, and clarifies the importance of the isolated component as part of the system as a whole. Systems thinking helps understand how sub-systems connect to one whole system, and provides solutions for the client's specifications and requirements. In addition, systems thinking enables perceiving the inter-relationships and mutual influence among the system's components and other systems. The current study examined the development of systems thinking among engineers and engineering students. In addition, the personality traits of engineers with high systems thinking skills were examined by the Myers-Briggs Type Indicator (MBTI) personality type test. This article also presents the initial results of the development of a new systems thinking study course, taught as a pilot course to industrial and management engineering students. It seems that engineers with certain personality traits can acquire or improve their systems thinking capabilities through a gradual, long-term learning process and by acquiring the necessary tools. Additionally, the study includes recommendations for the continuation of ongoing research on developing systems thinking.

Keywords: system thinking; systems approach; capacity for systems thinking; Myers Briggs Type Indicator (MBTI) personality type test

1. Introduction

Breaking down complex problems into constituent elements is often the accepted method of handling of complex assignments and questions. However, engaging in such deconstruction also often blurs perception of the problem's larger context. As stated by Senge [1]: "Systems thinking is a discipline for seeing wholes, a framework for seeing interrelationships and repeated patterns of events rather than just isolated incidences, seeing patterns of change rather than static "snapshots". It provides a scaffolding of principles, specifically tools and techniques developed in recent years, and is a discipline that seeks to discover the constructs underlying the complex, thus enabling a perception capable of discerning potential significant improvements possible with a minimum of effort (the principle of leverage). It offers us a language that expands, changes, and reshapes our ordinary ways of thinking regarding complex issues.

Clearly systems thinking will prove vital to students and graduates of technology management in their professional careers, helping them see and grasp multidisciplinary systems without necessarily being required to master the intricacies of each of their numerous parts.

2. Literature Review

The interrelationships of various system elements are the primary focus of the systems approach, as the discipline is founded on the understanding that such interactions are equally significant as the particular properties of the system components.

One of systems thinking's pioneers is Ludwig von Bertalanffy [2], a biologist who perceived systems thinking as a method of scientific investigation.

Bertalanffy [2] claimed that in order to understand what separates living matter from non-living matter, one needs to look not only at the microscopic particles, but also how they influence one another within the whole. Thereafter, he confirmed this viewpoint as a fundamental scientific approach, claiming that the only way to fully understand why a phenomenon arises and persists is to understand its parts in relation to the whole [3].

Bertalanffy [3] explained what systems thinking is: an approach that advocates viewing the issue at hand as a whole, emphasizing the interrelationships among its components rather than the components themselves, contrary to the traditional approach that understood a subject by analyzing its individual parts.

Bertalanffy [3] focused on formulating a general systems theory that could explain all systems in various fields of science since all systems are similar. The General Systems Theory (GST) contains a system of arguments, based on inter-disciplinary comparison. According to the GST, application of the theory to one specific scientific field helps solve problems and explain phenomena and processes in other fields [4].

Sterman [5,6] defined systems thinking as the ability to see the world as a complex system, in which we understand that 'you cannot just do one thing', that 'everything is connected to everything else'.

Senge [1] explained how to use the systems-thinking method in order to convert companies into learning organizations.

Senge [1] describes systems thinking as:

- A discipline for seeing wholes
- A framework for seeing interrelationships, for seeing patterns of change rather than static "snapshots"
- A set of general principles—distilled over the course of the twentieth century, spanning fields as diverse as the physical and social sciences, engineering and management
- A specific set of tools and techniques

Senge and his colleagues [7] claimed that a good systems thinker, particularly in an organizational setting, is someone who can see four levels operating simultaneously: events, patterns of behavior, systems, and mental models. It is systems thinking that brings the disciplines of personal mastery, mental models, shared vision and team learning all together.

According to Richmond [8], "Systems thinking is the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure".

Richmond [9] uses the paraphrase "forest thinking" to clarify the concept of systems thinking. According to Richmond [9], "forest thinking" involves a "view from 10,000 m rather than focusing on local trees" and "considering how the system influences systems on the other side of the line and how these latter systems influence the former system".

Richmond [10] presents four key questions about the term "systems thinking": What is it? Why is it needed? What works against its being adopted on a broader scale? And finally: What can we do to increase both the speed and breadth of its adoption?

In Richmond's [10,11] opinion, systems thinking is a continuum of activities that range from the conceptual to the technical. The adoption of systems thinking occurs when we are standing back far enough—in both space and time—to be able to see the underlying web of ongoing, reciprocal relationships, interacting cycling to produce the patterns of behavior that a system is exhibiting. You are employing a systems perspective when you can see the forest (of relationships), for the trees. You are not employing a systems perspective when you get "trapped in an event".

The term "thinking" combines learning and knowledge and includes various concepts such as: parallel thinking, holistic thinking, reductionist thinking, critical thinking, creative thinking, etc. The constructivism theory suggests that the human being is an active learner who constructs his/her knowledge of experience on his/her efforts to give meaning to that experience. In the study presented here, students were required to construct their knowledge by means of active experience and learning.

Social constructivism suggests that learners learn concepts or construct meaning about ideas through their interaction with others and with their world, and through interpretations of that world by actively constructing meaning [12].

One of the better-known researchers that refers to social constructivism theory is Vygotsky [12], who states that 'learners construct knowledge or understanding as a result of thinking and doing in social contexts'.

By implementing systems thinking, learners relate new knowledge to their previous knowledge and experience.

Systems thinking literature includes a vast range of areas of investigation, dealing mainly with the analysis of complex organizations [1,13–17], social systems, economics, curriculum design [18], social work, psychology, addiction therapy, the human body as a system, health, business, banking, personal interrelationships, the global state of affairs, environment [19], instruction methodologies for groups and teams [20,21], scientific and technological education [22], decision making [23], and project management [24].

Traditional linear thinking approaches work against an understanding of how the different parts of an organization or business work together and underplay or ignore the multifaceted nature of complex problems. It has become essential to change the nature of the curriculum to emphasize the interconnectedness of the various aspects of businesses and organizational systems as a whole [25].

It is clear that systems education, from informal learning to formal educational programs, is at the foundation of the key leverages to develop new ways of more holistic thinking to ensure systemic decision and policy making. The combination of capacity building with activities in which appropriate systems tools are being used by the end-users who will directly benefit is a critical success factor for long-term change in the way that management decisions and policy making can become systemic, rather than focusing on treating the symptoms [25,26]. Formal education in systems thinking has become essential. Many efforts are being put into ways to "infiltrate" the traditional teaching of disciplines as isolated units and to apply the systems approach in schools, universities and informal teaching programs (e.g., [25–30]). These programs can contribute significantly to the efforts of the systems community in making systems thinking and systems education become integrated into society.

Research literature presents evidence of efforts to develop systems thinking through task-oriented software, group dynamics, education, and training [31,32], demonstrating that systems thinking may be acquired or learned in a variety of ways.

Badurdeen et al. [33] presented developing and teaching a multidisciplinary course in systems thinking for sustainability. One of the reasons for using systems thinking to approach sustainability is because systems thinking is an appropriate education approach to complex problems and could be provided a kind of common language for students from different disciplines.

Another example is integrating systems thinking into sustainable manufacturing assessment.

Zhang et al. [34] presented a system of system methodologies grid in a sustainability engineering setting, where different sustainable manufacturing problems have been associated with system methodologies.

Zhang et al. [35] presented a novel approach using systems thinking principles to enhance sustainable manufacturing research and manufacturing system sustainability management. According to Zhang [35], this approach will not only benefit engineering management research by adopting systems thinking philosophies in emerging sustainable manufacturing research and practice, but will also assist enterprises in making strategic, tactical, and operational decisions by providing a deep understanding of the behavior change over time. It was also found that success in this process is of great importance to teachers/instructors/managers.

Students and graduates that demonstrate high levels of systems thinking are able to analyze customer needs and demonstrate an aptitude for coping with multidisciplinary problems in the business world.

For example, Kordova and Frank [27] conducted a capstone project with engineering students to examine whether such a multifaceted assignment discernibly improved systems thinking among participants. In this learning environment, the students constructed their own knowledge through active learning and interaction with their teammates and teaching staff. As such, the project-based learning environment supports the constructivist approach to teaching [27,36].

Some researchers refer to systems thinking as an innate ability. For instance, Hitchins [37] states that the human brain can see similarities of patterns between disparate sets of information, which presumably emanate from its drive to reduce perceived entropy, while Frank [38], Davidz and Nightingale [31] concluded that this ability is most likely a combination of innate talent and acquired experience.

Research Objectives

The research was conducted in two stages; the first stage examined factors that may potentially provide the greatest benefit in systems thinking for students and graduates of technology management. The main questions were as follows:

1. To what extent is it possible to train students and graduates for a systems-oriented position?
2. To what extent is the tendency towards systems thinking linked to personality traits?
3. To what extent is there a correlation between systems thinking capacity and supervisor evaluation?

The second stage of the study examined the extent to which it is possible to develop systems thinking capability within the framework of a designated course. Study questions were as follows:

1. To what extent is it possible to develop systems thinking capability through a designated course teaching the foundations and basic tools of systems thinking?
2. To what extent do differences exist in the ability to learn and develop systems thinking capabilities between people from different disciplines?

3. Methodology

3.1. Study Population

Stage 1:

The study population included two groups:

- The first group included 55 master's degree students from a management and technology faculty.
- The second group included 38 graduates involved in development projects in three companies that develop integrated systems for defense and homeland security applications.

Stage 2:

The study population included 21 industrial engineering and management students, 15 mechanical engineering students, and 12 psychology students.

3.2. Study Tools

Stage 1:

The first study tool was the CEST (capacity for engineering systems thinking) assessment questionnaire [39]. The capacity for engineering systems thinking characterizes the individual and can be evaluated and predicted.

The questionnaire was distributed to the first group in stage 1, before and after completing various graduate courses in systems engineering. It included 40 statement pairs, with items focusing on preferences, specifically likes and dislikes towards activities, jobs, professions, or other personality types. Respondents were asked to choose between the two statements according to their preference in each statement pair (*A* marking preference for the first statement and *B* for the second).

Here are two example items from the questionnaire:

- Item No. 17
    A. I think that every employee should gain interdisciplinary knowledge and general knowledge in several fields.
    B. I think that every employee should become an expert in his/her field. Learning more fields may lead to sciolism (to know a little about many subjects).
- Item No. 22
    A. I like to discuss the needs with the customer.
    B. B. I prefer to leave the contact with the customer to marketing experts.

The participants of the second group of stage 1 were asked to complete the CEST assessment questionnaire [39] and also the MBTI (Myers-Briggs Type Indicator) personality type test [40]. Additionally, supervisor evaluations were conducted to assess respondents' systems thinking capabilities [41].

The MBTI test is a tool to evaluate personality types using a psychometric questionnaire. The goal of the test is to help people identify their dominant preferences, tendencies, and personality traits. The questionnaire is based on the premise that people have four psychological functions through which they experience the world: Natural energy orientation, Way of perceiving or understanding and taking in information, Way of forming judgments and making choices and decisions, Action orientation towards the outside world (Lifestyle).

The result of this questionnaire is one of the 16 character archetypes, as shown in Figure 1.

The current study examined the connection between self-reported dominant personality traits (according to the MBTI research tool) and respondents' systems thinking capacity.

We examined a different kind of reliability and validity of the CEST (capacity for engineering systems thinking) assessment questionnaire. Two types of reliability were calculated: inter-judges reliability and alpha coefficient reliability. Four types of validity are presented: content validity, concurrent validity, contrasted group validity, and constructed validity.

Stage 2:

As a continuation of stage 1 of the study, we examined the extent to which it is possible to develop systems thinking capability through engaging in a designated course aimed at teaching systems thinking foundations and basic tools.

The course was based on Senge's book *The Learning Organization* [1], and on Richmond's approach [8,9] to thinking skills. The course included basic foundations of systems thinking and the five disciplines of a learning organization (personal skills and personal vision, mental models, creating a shared vision, group learning, and systems thinking).

The course stresses the ways in which changes in thinking are created and the use of the systems prototypes.

The Function		
Natural energy orientation	**Extraverted (E)** Usually open to and motivated by outside world of people and things	**Introverted (I)** Motivated internally, Prefer one-to-one communication and relationships
Way of perceiving or understanding and taking in information	**Sensing (S)** Like clear and concrete information; dislike guessing when facts are "fuzzy"	**Intuitive (N)** Comfortable with ambiguous, fuzzy data and with guessing its meaning
Way of forming judgments and making choices and decisions	**Thinking (T)** Instinctively search for facts and logic in a decision situation	**Feeling (F)** Instinctively employ personal feelings and impact on people in decision situations
Action orientation towards the outside world (Lifestyle)	**Judging (J)** Plan many of the details in advance before moving into action	**Perceiving (P)** Comfortable moving into action without a plan

Figure 1. MBTI character archetypes.

The 14-week course was conducted with two separate classes, comprised of students studying industrial engineering and management and who were also employed in the industry during their studies.

During the course, the students were exposed to the theoretical approach at the base of systems thinking and, in addition, practiced analyzing events and processes using the classic Senge prototypes [1]. Moreover, the students presented examples from their personal experience at work and from their daily reality. These examples were also examined using the systems tools.

The research hypothesis was that by integrating systems thinking tools in analyzing systems processes, the students will acquire systems thinking skills, and improve their system thinking abilities when faced with a complex problem in their organization.

Table 1 shows some examples of how to use the prototypes to analyze events.

Table 1. Examples of using the classic Senge prototypes.

Event	Tools for Analysis
An enterprise is interested in dealing with a high percentage of defective products in the production line by enlarging the required production quantities instead of establishing a process that minimizes defective products. As a result, a situation in which surplus inventory which cannot always be sold occurs.	"Moving the problem" archetype—instead of solving it examines the shifting of a specific problem to other solutions because the problem is unclear or because dealing with it comes at a high price. This is what happens when only symptoms of the problem are addressed and not the root cause. The problem can than re-occur, in the same form but also in another department.
Conflict between consumption and savings	"Success to the Successful" archetype—in which resources are allocated to the most successful activity, which makes the unsuccessful ones even more unsuccessful because they receive fewer resources. This is not necessarily the best policy for the long term.

The same CEST questionnaire distributed during stage 1 was also distributed twice in the second stage of the study—before embarking on the course and after completing it.

4. Results and Discussion

Stage 1:

Table 2 presents the comparative average scores of graduate management and technology students before and after the systems engineering course. The course lasted two semesters, and respondents completed the Frank questionnaire at three stages: at the beginning of the course, the end of the first half, and the end of the second half.

Table 2. Paired samples test.

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		*t*	*df*	Sig. (2-Tailed)
					Lower	Upper			
Pair 1	total_pre–total_post1	−2.63889	6.50069	1.53223	−5.87161	0.59383	−1.722	17	0.103
Pair 2	total_post1–total_post2	18.12500	32.75583	7.32443	2.79480	33.45520	2.475	19	0.023
Pair 3	total_pre–total_post2	18.19444	34.45805	8.12184	1.05886	35.33003	2.240	17	0.039

The results of stage 1 are first shown in IEEM 2015 [26].

Table 2 shows no significant difference between average scores of respondents at onset of the course and the end of the first semester (Sig. = 0.103). There was a significant difference between the mean score of respondents at the end of the first semester when compared to the end of the course (Sig. = 0.023). A significant difference was also found between the average score of respondents at onset and course conclusion (Sig. = 0.039).

These results were first presented at IEEM 2015 [28] and are in line with previous studies such as [27,31,32,38].

From these results, we can conclude that the second course provided more systems thinking tools than the first course.

One explanation for this is the nature of the course given in the second semester, which mainly dealt with systems content, as opposed to the course given in the first semester, which focused on specific content.

According to these studies, engineers or managers can report about themselves or others—that they notice details or immediately see the big picture.

Stage 1 of this study supports these findings. A significant correlation was found between supervisor ranking of systems thinking capabilities and average scores of filled-in Frank questionnaires (Sig. = 0.000, $r = 0.855$).

The respondents were asked to provide self-reports on their personal desire to engage in systems-related projects; a significant correlation was found between this evaluation and the results of the Frank questionnaire (Sig. = 0.000, $r = 0.763$).

In contrast to these findings, no correlation was found between capacity for engineering systems thinking and years of employment experience.

The established possibility of distinguishing engineering systems thinking capacity, even after only a few years of work experience, proves that apparently there are additional factors that strengthen systems thinking acquisition. Among these factors, there is also the notion of inherent potential—which seems to be an inseparable part of those candidates who received high systems thinking scores, even with little work experience (measured in years).

In addition to all of the findings mentioned above, respondents were divided into personality groups according to the MBTI questionnaire.

Study findings also support Meade's results [42], according to which 57.9% of respondents belong to the STJ (Sensing, Thinking, Judging) group. Character archetype distribution is presented in Figure 2. This finding emphasizes the fact that a significant percentage of respondents belong to particular personality groups with unique traits.

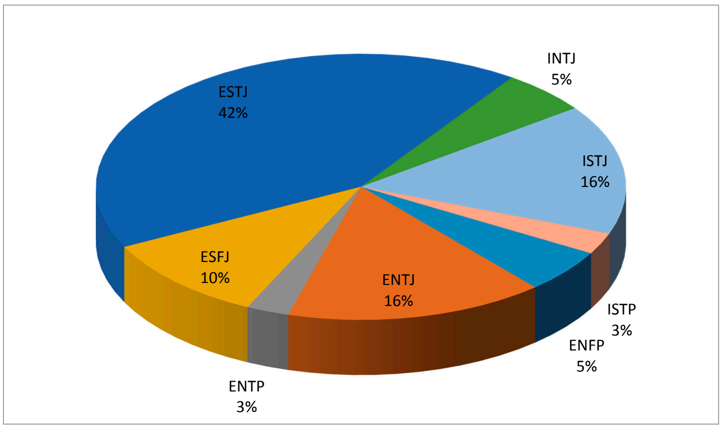

Figure 2. Character archetype distribution according to MBTI questionnaire.

Stage 2:

Analysis of questionnaire results showed no significant difference between average scores before the designated systems thinking course (Time 1) and after its completion (Time 2) ($t = -0.61$, Sig. = 0.5476).

Table 3 illustrates independent samples t-test outcomes.

Table 3. t-Test Outcomes.

Time	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	21	54.00	8.69	1.89	39.00	66.00
2	18	55.67	8.37	1.97	36.00	72.00
Diff (1-2)		−1.67	8.54	2.74		
Time	**Mean**	**95% CL Mean**		**Std Dev**	**95% CL Std Dev**	
1	54.00	50.04	57.95	8.69	6.65	12.55
2	55.67	51.50	59.83	8.37	6.28	12.55
Diff (1-2)	−1.67	−7.23	3.89	8.54	6.96	11.05
Method	**Variance**	**DF**	**T Value**	**Pr > |t|**		
Pooled	Equal	37	−0.61	0.5476		

Figure 3 shows the normal theoretical quantiles at both time points (course onset on the left and course completion on the right). According the results of the Q-Q plots, the difference scores were not normally distributed.

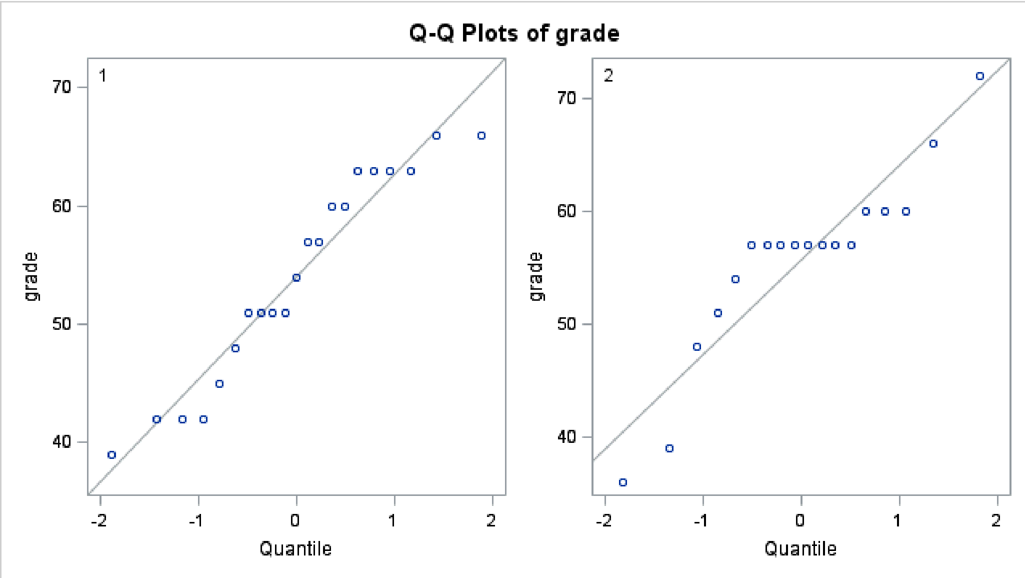

Figure 3. Q-Q Plots.

Since normal distribution was not met, we used the Wilcoxon non-parametric test to compare the scores before and after the course.

The results of Table 4 clearly illustrate no significant difference between scores at both time points (Sig. = 0.6881).

This result may be explained in several ways:

1. Small sample size. It is necessary to examine a larger group of students in order to draw stronger and more established conclusions.
2. The present course format/curriculum failed to help develop participant systems thinking capabilities; it might be necessary to revise the course curriculum and/or teaching methods.
3. The course was given to industrial engineering and management students. Perhaps these students have intrinsically high systems thinking capabilities and the course induced no improvement in their systems thinking.

Table 4. Wilcoxon two-sample test.

Wilcoxon Two-Sample Test	
Statistic (S)	374.5
Exact Test	
Two-Sided Pr >= |S − Mean|	0.6881

In order to examine the last hypothesis, questionnaires were distributed to two groups whose members did not study the course: one group of students studying mechanical engineering and a second group of students studying towards their bachelor's degree in psychology.

Table 5 presents the analysis of variance when comparing total questionnaire scores among mechanical engineering, industrial engineering and management, and psychology students. This comparison was carried out during Time 1 only.

Table 5. ANOVA comparing total score among three groups (Time 1 only).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model Error Corrected Total	2 45 47	1777.65 4971.60 6749.25	888.82 110.48	8.05	0.0010
R-Square	**Coeff Var**	**Root MSE**	**Grade Mean**		
0.263	22.30	10.51	47.12		
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Group	2	1777.65	888.82	8.05	0.0010

Table 5 shows a significant difference exists between the three groups in total questionnaire scores at Time 1 (Sig. = 0.0010). Figure 4 indicates that the average scores of industrial engineering and management students were higher compared to those of mechanical engineering and psychology students.

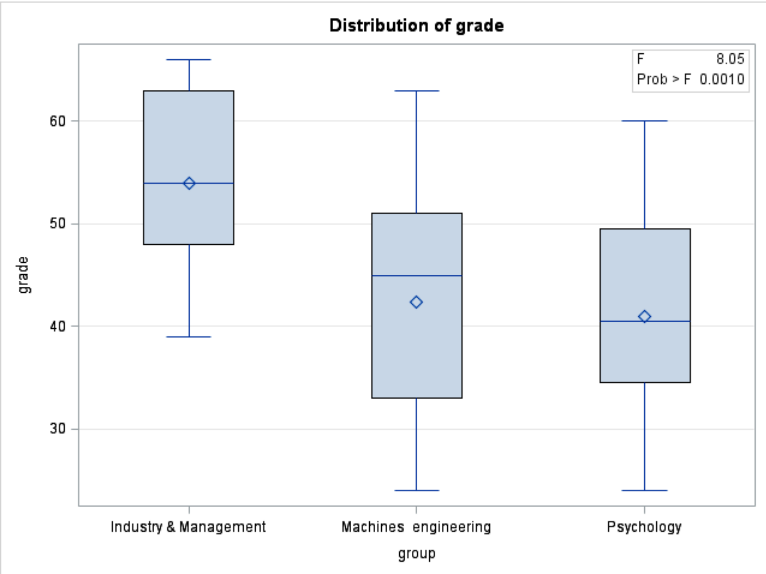

Figure 4. Grade distribution of the three groups.

Multiple comparisons were carried out to determine whether significant differences exist in total scores among the three groups, as presented in Table 6.

Table 6. Tukey studentized range (HSD) test.

Means with the Same Letter Are Not Significantly Different			
Tukey Grouping	**Mean**	**N**	**Group**
A	54.0	21	Industrial engineering
B	42.4	15	Mechanical engineering
C	41.0	12	Psychology

Since normal distribution was not met, we also used a Kruskal-Wallace non-parametric test to compare the three groups' total scores. Table 7 shows that a significant difference was found among the three groups (Sig. = 0.0028).

Table 7. Kruskal-Wallace Test (Time 1 only).

Group	N	Sum of Scores Wilcoxon Scores	Expected under H0	Std Dev under H0	Mean Score
Industrial	21	678.00	514.50	47.96	32.28
Mechanical	15	290.50	367.50	44.81	19.36
Psychology	12	207.50	294.00	41.86	17.29
Kruskal-Wallis Test					
Chi-Square	11.76				
DF	2				
Pr > Chi-Square	0.0028				

Figure 5 presents score distribution among the different groups. Industrial engineering and management students demonstrated an innate tendency for higher levels of systems thinking capability compared to mechanical engineering and psychology students.

One possible explanation for this finding may be related to the structured differences between industrial engineering and management students and those students who study other fields. It is reasonable to assume that among people who have a systems thinking approach, there is a tendency to choose a multi-disciplinary profession which, by its very definition, requires systems thinking. This means that people with an innate systems thinking approach will prefer a profession that is systems-oriented, such as industrial engineering and management, while those whose natural tendency is to see details will choose a profession that requires paying attention to the small details. Similar findings to these results were also presented is Kordova's previous study [28,36].

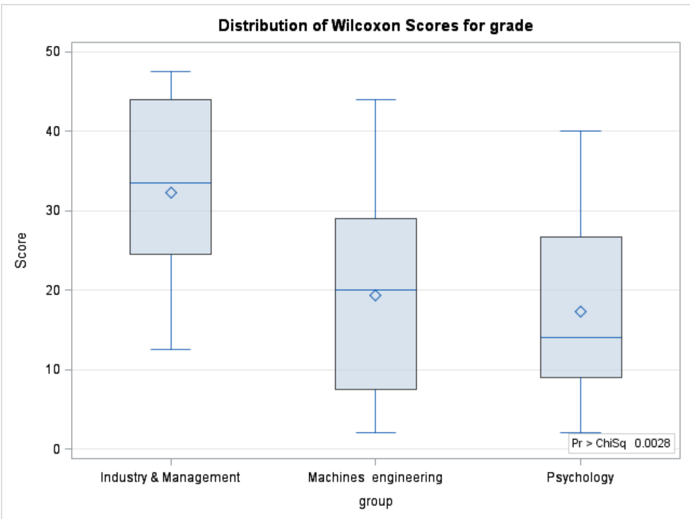

Figure 5. Grade distribution of the three groups—Time 1.

5. Summary and Conclusions

This study examined whether it is possible to train engineers and graduates for a systems-oriented position in a formal teaching environment such as systems engineering courses or systems design. The different courses teach the engineering design process, and during the course, a systems model is built; a model based on a structure related to requirements, functions, components and tests. The full model also includes systems scenarios, material and design interfaces, as well as outputs and inputs.

The main goals of these courses are: to provide knowledge about product design and development processes; to provide knowledge about different technologies in different business environments; to learn about methodologies and tools used for product and services design and development; to give students self-confidence in their personal ability to initiate and design new products/services, as well as to present and "sell" their ideas and products to clients for design and development projects.

These subjects are a main part of systems engineering studies; however, according to the results of the first part of the study, these courses focused primarily on specific engineering design processes and did not provide sufficient tools for developing systems thinking skills among the course participants. One of the study groups participated in an engineering design course, which was taught over a two-semester period as part of the master's degree program for systems engineering. The course lasted two semesters, and respondents completed the CEST questionnaire [39] at three different time points: at the beginning of the course, the end of the first semester, and the end of the second semester.

The results showed that there was no significant difference between systems thinking skills before the course and after the first semester. However, a significant difference was found between the students' average score at the end of the first semester and their average score at the end of the course. In addition, a significant difference was found between the students' average score before the course and their average score at the end of the second semester.

From these results, we can conclude that the second part of the course provides systems thinking tools to a greater extent than the first part of the course, which mainly focused on specific engineering design.

These results also show that it is necessary to create a systems thinking study course that deals with specific methodologies and systems thinking tools. These findings are in line with the results of Davidz and Nightingale [31] and Kasser [32], which showed that it is possible to acquire systems thinking through education and training.

The study also examined the systems thinking skills of systems engineers as opposed to other engineers who are partners in systems projects. It was found that the systems engineers' score on the systems thinking questionnaire was significantly higher than the other engineers' scores (Sig. = 0.000).

In addition, these engineers' managers were asked to evaluate the engineers' tendency towards systems thinking and to rank them on an ordinal scale. A significant correlation was found between this ranking and the score on the questionnaire that evaluated the engineers' system thinking ($r = 0.855$, Sig. = 0.000).

In contrast to these results, no correlation was found between the systems thinking score and number of years' experience acquired by the engineer.

These findings stress that systems engineers with high systems thinking skills are capable of understanding the general/big picture—functionally and conceptually—even without understanding all of the small details.

The study findings show that despite the difficulty to define systems thinking, people know how to evaluate the systems thinking skills of their work colleagues, and to identify those who immediately see the big picture compared to those who tend to look at the small details.

The finding that shows no correlation between systems thinking skills and number of years' experience may indicate that additional factors exist which foster this ability.

The fact that it is often possible to distinguish a capacity for engineering systems thinking, even after only a few years of work experience, proves that apparently there are additional factors that strengthen systems thinking acquisition. Among these factors, there is also the notion of innate potential—which seems to be an inseparable part of those candidates who received a high CEST score, even though they had little work experience (in years) [28].

This finding supports Frank's claim [38] that systems thinking is a combination of an acquired ability and an innate talent.

The current study found that a link exists between personality type and systems thinking skills. The study found that 57.9% of the engineers in the sample belonged to the sensing, thinking, judging (STJ) personality type, according to the MBTI questionnaire. This finding emphasizes that a large percentage of engineers have unique personalities and traits.

The second part of the study presented a preliminary attempt to develop a systems thinking study course. Since this is a pilot course, additional studies are needed with diverse sample groups in order to strengthen the claim that this type of course is likely to improve its participants' systems thinking skills.

Author Contributions: S.K.K. was the main researcher of this study who prepared the literature review, developed the study design and analyzed the results. M.F. developed the CEST (capacity for engineering systems thinking) assessment questionnaire and conducted several studies for assessing the reliability and validity of the questionnaire. A.N.M. conducted the pilot course presented at this paper. The main goal of this course was to develop systems thinking capability.

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