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Determinants of holistic thinking in college demographics

Erin Stirgus

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Determinants of holistic thinking in college demographics

By

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in Industrial and Systems Engineering
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2019

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The current workforce climate has naturally led the way for wanting more systemic thinking individuals. This increasing complexity demands that universities train engineering students to be able to handle such difficulties amidst the interconnectedness of the world. This study aims to aid in understanding what will help the future leaders of the world become more equipped to handle these global and complex systems. College engineering students were the target population of this study. It was found that neither gender, educational level, grade point average, nor having an internship or co-op helped aid students to have higher systems thinking skills. However, employment status was found to affect the systems thinking skills scores. Laying the foundation for understanding engineering students' ability to be more or less holistic thinkers, this research aims to help evolve engineering education.

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CHAPTER I

INTRODUCTION

The world around us is constantly shifting, changing to accommodate for systems that are considered greater or improved. Systems have evolved from the first airplane to the first computer to the first conglomerate and so on. Increasingly dependent on systems that have come before the latter, the term complex system has been used to describe the most recent boom in relationships between various systems (e.g. internet, stock market, smart watch). From complex systems evolved Systems Thinking (ST) which has a wide variety of accepted definitions. The Business Dictionary defines ST as the practice of thinking that takes a holistic view of complex events or phenomenon, seemingly caused by myriad of isolated, independent, and usually unpredictable factors or forces (Business Dictionary). The Systems Thinker, a journal that ‘works to catalyze effective change by expanding the use of systems approaches’, defines ST as a perspective [that] includes the willingness to see a situation more fully, to recognize that we are interrelated, to acknowledge that there are often multiple interventions to a problem, and to champion interventions that may not be popular (Goodman). With this emerging discipline, determining which factors affect ST is important to establish more effective ways to increase student’s effectiveness and performance in the workforce environment. By showing what factors into a student’s foundation of ST, this will better accommodate students’ skillset in dealing with complex system problem domains which include, but is not limited to, the industrial, academic, healthcare, and military sectors.

Industrial Engineering, in particular, focuses on the design and improvement of systems to make products or provide services by applying a more systemic approach of what makes organizations work best (About ISE). This discipline is one of several disciplines that could benefit from a “bigger picture” perspective which translates, according to (Jaradat and Keating), to a higher ST score. The gap in the literature does not explore the factors that affect more holistic thinking in college-age students. This study aims to gauge what determinants affect higher systems thinking scores in college students, specifically Industrial Engineering (IE) students. The factors assessed include: gender, employment status, internship/co-op participation, level of education, and grade point average.

1.1 Related Literature

Related literature is divided into four sections. The first section provides some representative definitions of ST and briefly traces the history of ST since the word was first coined by Barry Richmond in 1987. The second section evaluates the application of ST that are, and have been, used in literature. The third section investigates previous factors that were analyzed in post-secondary students. The last section presents the current gap of the literature.

1.1.1 Overview of Systems Thinking (ST)

Noting that ST is at its simplest form ‘looking at the bigger picture’, but can be described as assessing how the broader system(s) is affected when interacting with different and variable parts, many applications of ST have come to fruition as specifically discussed in Table 2. Many works, perspectives, and studies are presented to describe exactly what ST has been interpreted as throughout current literature.

(Arnold and Wade) described ST as “.. a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects. These skills work together as a system.” They tested the ‘systemic fidelity’ of other ST definitions by which to figure out if the definitions presented in other works embody what ST is in Figure 1.1.

Figure 1.1 Systems Thinking Requirements

(Senge) mentioned that ST is “.. a way of thinking about, and a language for describing and understanding, the forces and interrelationships that shape the behavior of systems. [It] helps us to see how to change systems more effectively, and to act more in tune with the natural processes of the natural and economic world.” According to Senge, an organization is a system which is built by the presence and contribution of every member. The system cannot succeed if every member does not continually learn and improve (Senge).

Figure 1.2 addresses the steps (Rethmeier) found useful when modeling what ST was and how to implement its strategic advantage of higher order thinking.

Figure 1.2 ST Steps for Modeling (Rethmeier)

(Hopper and Stave) developed ways to assess the effectiveness of Systems Thinking interventions in the field of education by answering what ST was, what ST interventions were

being used in the current education models, and how has the effects of interventions been measured. Their definition uses the learning objectives depicted in Bloom's taxonomy to create their own proposed taxonomy as it pertains to ST (Bloom, Furst and Hill). This combined taxonomy can be seen in Table 1.1.

Table 1.1 Proposed Assessment Measures (Hopper and Stave)

Systems Thinking Levels	Indicators of Achievement A person thinking at this level should be able to:	Products, Assessment Tests
Recognizing Interconnections	<ul style="list-style-type: none"> - Identify parts of a system - Identify causal connections among parts - Recognize that parts make up the whole system - Recognize that the system is made up of the parts and their connections - Recognize emergent properties of the system 	<ul style="list-style-type: none"> - List of systems parts - Connections between parts represented in words or diagrams (concept map) - Description of how the parts of the system make up the whole - Description of how the whole breaks down into parts - Description of properties the system has that the components alone do not
Identifying Feedback	<ul style="list-style-type: none"> - Recognize chains of causal links - Identify closed loops - Describe polarity of a link - Determine the polarity of a loop 	<ul style="list-style-type: none"> - Representation of causality and loops in words or diagrams (causal loop diagram) - Diagram indicating polarity
Understanding Dynamic Behavior	<ul style="list-style-type: none"> - Describe problems in terms of behavior over time - Understand that behavior is a function of structure - Explain the behavior of a particular causal relationship or feedback loop - Explain the behavior of linked feedback loops - Explain the effect of delays - Infer basic structure from behavior 	<ul style="list-style-type: none"> - Representation of a problematic trend in words or graphs - Description of how problematic behavior arises from interactions among system components - Descriptions or representation of what will happen when one piece of the system changes - Description of how the causal structure likely generating a given behavior - Representation in words or graph of how polarity affects the behavior of systems (manufacturing task) - Representation in words or graph of the dynamic nature of systems

Table 1.1 (continued) Proposed Assessment Measures (Hopper & Stave)

Differentiating types of variables and flows	<ul style="list-style-type: none"> - Classify parts of the system according to their functions - Distinguish accumulations from rates - Distinguish material from information flows - Identify units of measure for variables and flows 	<ul style="list-style-type: none"> - Ability to move from a causal diagram to one that differentiates between the different types of variables - Table of system variables by type - Description of how and why the variables are different - Calculation of changing stock based on the flows (Bathtub, cash flow, and department store tasks) - Types of variables with units
Using conceptual models	<ul style="list-style-type: none"> - Use a conceptual model of system structure to suggest potential solutions to a problem 	<ul style="list-style-type: none"> - Representation or description of the expected effect of an action on a given problem - Justification of why a given action is expected to solve a problem - Paper and pencil simulation of a dynamic system
Creating simulation models	<ul style="list-style-type: none"> - Represent relationships between variables in mathematical terms - Build a functioning model - Operate the model - Validate the model 	<ul style="list-style-type: none"> - Ability to move from a paper and pencil simulation to a computer simulation - Simulation of a model - Running the model - Compare model output to observed behavior
Testing policies	<ul style="list-style-type: none"> - Identify places to intervene within the system - Hypothesize the effect of changes - Use model to test the effect of changes - Interpret model output with respect to problem - Design policies based on model analysis - Understand how to use model output to make real world recommendations 	<ul style="list-style-type: none"> - List of policy levers - Description of expected output for given change - Comparison of model output from different hypothesis tests - Policy design - Description of decisions made based on model output - Recommended policies for the real world based on model output

1.1.2 Applications of ST

Further literature has been evaluated for different applications of ST that have been used over the course of many years to ascertain the amount of ST an individual possesses. These applications are shown, for conciseness, in Table 2. This table provides a brief look into the

broad spectrum of applications that are seen in the literature and do not provide one superior or inferior application.

Table 1.2 ST Tools and Methods

Contributor	General themes	Findings
Bloom (1956) (Bloom, Furst and Hill)	Development of a taxonomy systems for categorizing the outcome of student learning	The study arrived at a conclusion that in order to develop individual's level of thinking, it should follow the hierarchical (ascending) structure of taxonomy.; start with lower level of thinking processes and gradually grow to higher levels of thinking processes.
Science Curriculum Improvement Study (SCIS) (1960) (Garigliano)	Attempts to apply systems thinking in a school curriculum	This study introduced some fundamental perception of system element, interdependencies, and subsequent activities to the elementary school students in suburban of New Jersey.
Nancy Robert (1978) (Roberts)	Familiarization of dynamic feedback of system thinking in elementary school	This study aided to develop an educational curriculum for the secondary level students to gain a broader understanding of the system modeling concept.
Hopkins et al (1987) (Hopkins, Campbell and Peterson)	Incorporation of ST approach among the novice veterinary students and cardiovascular specialists	The general findings of the study implicated that students tended to understand the system in static anatomic terms while the specialists exposed a more consolidative and clear conceptualization than the students to recognize the relationship between system properties and corresponding system variables.
Mettes (1987) (Mettes)	Introduction of a model termed as "systematic approach" to problem solving to address complex system problems	Academic courses were developed at the Twente University of Technology in the Netherlands to leverage the models built in this study.
Sweeny and Sterman (2001) (Sweeny and Sterman)	Development of a list of ST characteristics to evaluate students' capability to understand the dynamic behavior of the complex problem	This research revealed that kids' have the inherent capability to be a natural systems thinker; from the very early age they can realize the uni-directional interaction and show their various expressions to catch the attention of surrounding individuals.

Table 1.2 (continued) ST Tools and Methods

Resnick (1996) (Resnick)	Verification of decentralized thinking capability among young students	Research embodied the idea that young students can explore the complex system problems more explicitly, but the mental model they develop to explore the complex system often becomes unsophisticated patterns of thinking.
Assaraf and Orion (2005) (Assaraf and Orion)	Examination of the system thinking skills among the junior high school level students	The outcome of research exhibited that ST competencies are developed level by level from scratch.
Frank (2000) (Frank)	Tests the cognitive aptitude and ST skills of a group of engineers	This study suggested that system thinking requires a higher degree of thinking aptitude. This advanced level aptitude enables the individual's capability to assess the complex problem more holistic perspective.
Hung (2008) and Lammi (2011) (Hung) (Lammi)	Tests the intellectual aptitude and ST skill of graduate students	This study used system modelling as a cognitive tool to appraise the intellectual aptitude and ST skill of the high school and graduate students.
Huang (2015) and Camelia and Ferris (2016) (Huang) (Camelia and Ferris)	Development of a ST instrument	These studies established a system thinking instrument to test the system thinking competencies of the undergraduate students.
Jaradat and Keating (2015) (R. M. Jaradat) (Jaradat and Keating) (Jaradat, Keating and Bradley)	Development of a ST skills instrument	These studies established a ST instrument that measures individuals' level of systems skills to deal with complex system problem domains.

1.1.3 Factors Assessed in College-Level Demographics

Previous studies have been conducted to explore different factors that affect college-aged students in different capacities. These factors were measured in terms of higher order thinking skills and academic performance. For example, (Budsankom, Sawangboon and Damrongpanit) measured and identified which factors affect the higher order thinking skills of college students.

They measured classroom environment, psychological characteristics, intellectual characteristics, and family characteristics (Budsankom, Sawangboon and Damrongpanit). The Meta-Analytic Structural Equation Modeling (MASEM) method was used to find the direct and indirect effects of higher order thinking skills in student success as it relates to the factors mentioned above. It was found that the classroom environment (i.e. classroom climate, teaching and learning methods, teacher behavior), psychological characteristic (i.e. attitude toward learning and achievement motivation), and the intellectual characteristic (i.e. intelligence quotient and reasoning abilities) all directly affect students' higher order thinking skills, whilst family characteristics (i.e. parenting style and parental support) do not. (Yigermal) studied the factors affecting academic performance of undergraduate students. The factors measured include the difference in gender, former academic performance levels, family education/income, and extracurricular activities outside of school. Ordinary least square and Pearson product moment correlation index were used to determine the value of parameters and the estimation of the model. Results showed that there is a significant relationship between gender differences and the university entrance exam and studying hours with academic performance.

1.2 Current Gap in the Literature

Factors affecting college students' ability to think less as a reductionist has not been delved into due to the many and varied definitions of what ST is and the past complications of measuring an individual's ST ability.

By using (Jaradat and Keating), this research aims to evaluate what benefits the students' ability to deal with multifaceted phenomena within an organization. Having not specifically targeted to look for how different factors are affecting students ST ability, which enables them to think more holistically, in past literature creates a gap in producing more 'work-ready' students.

There comes necessity for the recognizing and creation of proactive solutions for society's expanding need for people who can manage complex systems.

CHAPTER II

METHODOLOGY

Chapter 2 is broken down into three different sections as it pertains to the steps taken to research what factors are or are not significant to the level of holistic thinking in college-aged Industrial Engineering students. The first section investigates each factor and determines the meaning behind the terms/factors that were assessed in the study. The second section illustrates the means by which participants were given the instrument and discusses the validation of the instrument. The final section shows demographics of the participants that volunteered to take part in the analysis.

2.1 Academic/Demographic Factors

Five demographic factors were analyzed to find the significance of these determinants on the ability to deal with complex systems. These factors were chosen according to previous literature and are cited as affectors of college-aged-students' success.

2.1.1 Level of Education (Kovacic) (Wyatt and G)

Five levels of education were evaluated. These levels included freshmen (college students in first year of program), sophomores (college students in second year of program), juniors (college students in third year of program), seniors (college students in fourth year of program), and graduate students (college students who have an undergraduate degree and are currently enrolled in a graduate-level program).

2.1.2 Co-Op/Internship (Gault, Redington and Schlager) (Kuh, Jillian and A)

The two requirements that must be met if a student has been on a co-op (cooperative experience) or internship are: 1) if a student that has been paid for work (with money, volunteer hours, or educational experience) and 2) the opportunity has been established by an organization/company as an internship or cooperatively-working opportunity. This factor did not evaluate the types of Co-Op or Internship someone has been on nor did it distinguish between which (co-op or internship) the student has completed.

2.1.3 Grade Point Average (Pritchard and Wilson)

This factor evaluated how well a student has done in the classroom. Grade point average describes students' academic achievement over their time spent at one or more institutions. No evaluation distinguished between transfers and non-transfers in the study.

2.1.4 Outside Work (Marsh) (Pritchard and Wilson)

Outside work is the generalized term used for if a student is employed in any capacity. This factor did not take into account if the work is on or off-campus due to the complexity and variable elements that are associated with evaluating/grouping the different jobs. Outside work was deemed as excluding co-ops or internships, but inclusive of any work that pays a student to complete a task or tasks while attending school.

2.1.5 Gender (Okudan and Mohammed) (Khoje, E and Kremer)

Gender was asked of the participant via three options: male, female, or other. This subject-area was voluntarily given by the participant and is determined by which the participant identifies.

2.2 ST Skills Instrument

(Jaradat, Keating and Bradley) used a mixed method approach, Grounded Theory Coding, Monte Carlo Analysis, Exploratory Factor Analysis, and Confirmatory Factor Analysis to validate the instrument by which to measure the 7 dimensions of ST skills. Brief results of the reliability and validity tests are shown in Table 2.1.

Table 2.1 Reliability/Validity Tests and Results

Analysis	Test	Results
Exploratory factor analysis	KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy)	$0.74 > 0.5$
	Bartlett's test of Sphericity	$p\text{-value} < .001$
Confirmatory factor analysis	RMSEA	$0.029 < 0.08$
	GFI (Goodness of-fit index)	$GFI = 0.88; GFI > 0.80$
Reliability	Overall Cronbach	$0.87 > 0.8$
	Composite Reliability	$Overall\ 0.77 > 0.77$

The instrument, an online survey, was distributed to participants that consisted of two parts. The first part of the survey asked seven demographic questions that included questions about student status, internship/co-op opportunities, grade point average, and employment status. The second part of the survey employed the use of (R. M. Jaradat) (Jaradat, Keating and Bradley) Systems Thinking (ST) instrument (39 questions) to gauge how an individual deals with complex problems. One example of the instrument questions includes: Do you prefer to (a) organize a team to explore a problem (b) work individually on a specific aspect of the problem.

The instrument measures how holistically an individual handles complex problems and gives a score by analyzing 7 major dimensions of ST. These seven dimensions include complexity, integration, interaction, change, uncertainty, systems worldview, and flexibility. There were five questions allotted for each of the following dimensions: integration, systems worldview, and flexibility. However, the rest of the dimensions, including complexity, interaction, change, and uncertainty, had 6 questions a piece.

There are no good or bad profiles as it relates to the results of the instrument. In contrast, the instrument paints a picture on a continuum of each individual's predisposition toward dealing with complex phenomena. The profile contains 14 main letters that translate to two letters per dimension. This can be seen in table 4. The profiles determine if an individual is a more holistic or more reductionist thinker with the employ of these letters for simplicity by dimension.

(Jaradat, Keating and Bradley) scores participants by giving 1 point for a more systemic response and 0 points given for a more reductionist response. By adding the individual's points up by dimension and then dividing by the total number of total questions of that respective dimension, a final score for each participant was calculated for each dimension. That score is then converted to a percentage for easier understanding (score between 0 and 100). The 14 main letters are then determined by if the individual has a score between 0 and 49 (more reductionist, left letter), of 50 (neither reductionist or holistic, both letters), between 51 and 100 (more holistic, right letter). Table 2.2 is indicative of the letters, and definitions of each letter, by dimension.

Table 2.2 14 Letters by Dimension (Jaradat and Keating)

Less Systemic (Reductionist)	Dimension	More Systemic (Holistic)
Simplicity (S): Avoid uncertainty, work on linear problems, prefer best solution, and prefer small-scale problems.	Level of Complexity: Comfort with multidimensional problems and limited system understanding	Complexity (C): Expect uncertainty, work on multidimensional problems, prefer a working solution, and explore the surrounding environment.
Autonomy (A): Preserve local autonomy, trend more toward independent decision and local performance level.	Level of Independence: Balance between local level autonomy versus system integration	Integration (G): Preserve global integration, trend more toward dependent decisions and global performance.
Isolation (N): Inclined to local interaction, follow detailed plan, prefer to work individually, enjoy working in small systems, and interested more in cause-effect solution.	Level of Interaction: Interconnectedness in coordination and communication among multiple systems	Interconnectivity (I): Inclined to global interactions, follow general plan, work within a team, and interested less in identifiable cause-effect relationships
Resistance to Change (V): Prefer taking few perspectives into consideration, over specify requirements, focus more on internal forces, like short-range plans, tend to settle things, and work best in a stable environment.	Level of Change: Comfort with rapidly shifting systems and situations	Tolerant of Change (Y): Prefer taking multiple perspectives into consideration, underspecify requirements, focus more on external forces, like long-range plans, keep options open, and work best in a changing environment.

Table 2.2 (continued) 14 Letters by Dimension (Jaradat & Keating)

Stability (T): Prepare detailed plans beforehand, focus on the details, uncomfortable with uncertainty, believe work environment is under control, and enjoy objectivity and technical problems.	Level of Uncertainty: Acceptance of unpredictable situations with limited control	Emergence (E): React to situations as they occur, focus on the whole, comfortable with uncertainty, believe work environment is difficult to control, and enjoy subjectivity and non-technical problems.
Reductionism (R): Focus on particulars and prefer analyzing the parts for better performance.	Systems Worldview: Understanding system behavior at the whole versus part level	Holism (H): Focus on the whole, interested more in the big picture, and interested in concepts and abstract meaning of ideas.
Rigidity (D): Prefer not to change, like determined plans, not open to new ideas, and motivated by routine.	Level of Flexibility: Accommodation of change or modifications in systems or approach	Flexibility (F): Accommodating to change, like flexible plan, open to new ideas, and unmotivated by routine.

2.3 Study Sample

Table 2.3 is indicative of the 53 total number of participants that took part in the online survey. The research was vetted through the internal review board at Collage State University before being distributed. Participants include undergraduate and graduate engineering students from a college university. Classes were asked to participate, after explaining the background of the research, under the pretense of knowing that the survey was completely voluntary and anonymous. There was no specific time or place that the study was conducted.

After gathering the data needed for the study, three surveys were taken out due to being completely blank. Incomplete surveys were evaluated using the aggregate mean as the total score across the dimensions and as a whole. The demographics can be seen in Table 2.3.

The sample size that was gathered included 50 participants. The full overview of the demographics can be seen in Table 2.3.

Table 2.3 Demographics

Demographic	Category				
Gender	Female	Male			
	24	26			
Education level	Freshman	Sophomore	Junior	Senior	Graduate
	0	0	9	27	14
Internship/Co-Op	Yes	No			
	25	25			
Employment Status	Yes	No			
	23	27			
GPA	Below 2.00	2.00-2.50	2.51-3.00	3.01-3.50	3.51-4.00
	1	1	15	13	20

*Grey boxes indicate categories that were not evaluated further due to limited participation.

2.4 Research Hypothesis

H1: *There is a significant relationship between engineering students' impacting factors, including gender (H_a), education level (H_b), internship/co-op status (H_c), employment status (H_d), and GPA (H_e) and their systems-thinking skills.*

H0: *There is not a significant relationship between engineering students' impacting factors, including gender (H_a), education level (H_b), internship/co-op status (H_c), employment status (H_d), and GPA (H_e) and their systems-thinking skills.*

Figure 2.1 below shows theoretical model which includes: five independent variables, the dependent latent variable, and the dependent observed variables from the study. This model investigates the potential relationship(s) between the impacting factors and engineering students' ST skills.

Figure 2.1 Theoretical Model

CHAPTER III

ANALYSIS

The following chapter reviews, in detail, the conclusions that have been drawn from the statistical analyses performed on the dataset. Descriptive and inferential statistics were performed on the dataset. The independent variables that were evaluated during the study included: gender, employment status, education level, internship/co-op status, and GPA. The dependent variable was their overall Systems Thinking level/score.

3.1 Descriptive Statistics

Descriptive statistics were conducted following the identification of the demographics. The dimension, including its respective definition, can be seen in Table 3.1 showing what the aggregate score and standard deviation of the participants scored in each dimension.

Table 3.1 7 ST Dimensions

Dimension	Definition	Spread Percentage of Group	Systems Skills percentage
Complexity	Comfort with multidimensional problems and limited system understanding	23.0	57.8
Integration	Balance between local level autonomy versus system integration	25.4	55.8
Interaction	Interconnectedness in coordination and communication among multiple systems	25.0	59.4
Change	Comfort with rapidly shifting systems and situations	20.2	38.3
Uncertainty	Acceptance of unpredictable situations with limited control	23.7	35.5
Hierarchical Worldview	Understanding system behavior at the whole versus part level	27.2	43.8
Flexibility	Accommodation of change or modifications in systems or approach	24.8	66.8

The following bar chart shows the overall systems skills percentage, as seen above, for clearer visual representation.

Figure 3.1 Overall ST Scores by Dimension

The following figures show descriptive statistics of the results by each independent variable evaluated.

Figure 3.2 Employment Status

Figure 3.3 Gender

Figure 3.4 Education Level

Figure 3.5 Internship/Co-Op

Figure 3.6 Grade Point Average

3.2 Post- Hoc Test Results

This section evaluates the significance of each group (independent variable) as it relates to the ST score (dependent variable). Table 7 is indicative of coefficient correlations and covariance.

Table 3.2 Coefficient Correlations and Covariance

Coefficient Correlations ^a								
Model		EduQulaity	Employed	Gender	GPA	Intern	EduLevel	
1	Correlations	EduQulaity	1.000	.012	-.062	.258	.051	-.307
		Employed	.012	1.000	.131	.150	.184	.041
		Gender	-.062	.131	1.000	.076	-.139	-.088
		GPA	.258	.150	.076	1.000	.020	-.354
		Intern	.051	.184	-.139	.020	1.000	.040
		EduLevel	-.307	.041	-.088	-.354	.040	1.000
	Covariances	EduQulaity	6.006	.119	-.604	1.377	.504	-2.417
		Employed	.119	16.578	2.141	1.331	3.004	.539
		Gender	-.604	2.141	16.050	.661	-2.234	-1.135
		GPA	1.377	1.331	.661	4.759	.171	-2.486
		Intern	.504	3.004	-2.234	.171	16.055	.510
		EduLevel	-2.417	.539	-1.135	-2.486	.510	10.343

a. Dependent Variable: Total Score

Figure 3.7, a structural equation model, shows the strength of relationships between the factors evaluated. The latent variable is the oval, whilst the observed variables are rectangles. Seven dimensions of ST were loaded on the latent variable (called Systems skills) and serves as the dependent variable. Five academic and demographic factors serve as the independent variables, including Education Quality, GPA, Employment, Gender, internship, and Education

level. The numbers corresponding to the arrows represent path coefficients for the observed variables and factor loadings for the latent variable. The factor loadings are indicating what dimensions are most representative when interpreting the overall systems thinking score.

Systems Worldview, Complexity, Uncertainty, and Interaction (i.e. particular factor loadings) are found to affect the overall systems skills more than the other three dimensions. The strongest relationship can be seen between employment status and overall systems skills and the strongest factor loading can be seen between systems worldview and overall systems skills.

Figure 3.7 SEM Model

Table 8 is indicative of the full analysis of the model that was presented. Significance was found in the employment status category and can be seen highlighted below.

Table 3.3 Full Model of Analysis

Coefficients ^a												
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
Constant	50.953	18.130		2.810	.008	14.310	87.595					
EduLevel	1.531	3.216	.079	.476	.637	-4.969	8.031	.149	.075	.071	.808	1.238
Intern	.602	4.007	.023	.150	.881	-7.497	8.700	.061	.024	.022	.937	1.068
Employed	-7.413	4.072	-.282	-1.821	.076	-15.643	.816	-.291	-.277	-.270	.913	1.095
Gender	-1.559	4.006	-.060	-.389	.699	-9.656	6.538	.009	-.061	-.058	.938	1.066
GPA	.475	2.182	.036	.218	.829	-3.934	4.884	.083	.034	.032	.823	1.215

a. Dependent Variable: Total Score

Since significance was found in the employment status category, one-way ANOVA, seen in Table 9 with a 95% CI, was performed to determine which specific dimension, of the 7, within

ST affected that significant result the most. The two groups that were compared were employed students and unemployed students. The Complexity and Autonomy dimensions seem to be affecting the significance of the overall ST score. Table 3.4 shows the results in more detail.

Table 3.4 ANOVA Analysis Between/Within Groups

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
Interaction	Between Groups	.079	1	.079	.000	.991
	Within Groups	29387.180	46	638.852		
	Total	29387.259	47			
Autonomy	Between Groups	2027.188	1	2027.188	3.290	.076
	Within Groups	28339.478	46	616.076		
	Total	30366.667	47			
Change	Between Groups	.431	1	.431	.001	.975
	Within Groups	18845.659	45	418.792		
	Total	18846.090	46			
Uncertainty	Between Groups	391.201	1	391.201	.691	.410
	Within Groups	25493.964	45	566.533		
	Total	25885.166	46			
Complexity	Between Groups	6230.174	1	6230.174	15.462	.000
	Within Groups	18131.706	45	402.927		
	Total	24361.879	46			
Worldview	Between Groups	229.479	1	229.479	.305	.584
	Within Groups	33881.159	45	752.915		
	Total	34110.638	46			
Flexibility	Between Groups	342.291	1	342.291	.552	.461
	Within Groups	27878.986	45	619.533		
	Total	28221.277	46			
TotalScore	Between Groups	682.551	1	682.551	4.177	.047
	Within Groups	7352.511	45	163.389		
	Total	8035.062	46			

Education level was found to have a high correlation to GPA, therefore further evaluation was performed to see the p-value results with Tukey HSD post-hoc multiple-comparisons for the seven ST dimensions and total ST score. The following shows significance was found only in the Systems Worldview dimension when comparing juniors to graduate students on the 90% CI.

Table 3.5 Education Level P-Value Results

Comparisons	<i>Junior-Senior</i>	<i>Junior-Grad</i>	<i>Senior-Grad</i>
Complexity	0.823	0.642	0.879
Independence	0.393	0.555	0.981
Interaction	0.855	1	0.81
Change	0.98	0.999	0.96
Uncertainty	0.712	0.793	0.997
Systems worldview	0.731	0.077	0.577
Flexibility	0.99	0.483	0.363
Total ST Score	0.955	0.626	0.654

CHAPTER IV

DISCUSSION

The analysis shows significance in only one determinant studied: employment status. This information is important because of the insignificance of the other factors. This section provides more details for each of the factors and discusses the importance of the analysis conducted and the results found.

4.1 Gender

No significance was found in the gender category. One of the reasons for no gender being more likely to be more holistic thinkers could be because of the generation that is currently enrolled into college programs. Past literature has been cited for men having the advantage in engineering curriculums, but generational advancements throughout the current paradigm within the modern family could be the culprit (Felder, Gelder and Mauney). Women are more likely to be on the same level as their counterparts in terms of ST due to more access and progressiveness within the field. This access can be determined from more parents of students being better educated, the increasing of enrollment between both genders, and improved access to materials that support all student (e.g. internet, networking, etc.)

4.2 Education Level

No significance was found in the education-level category. This conclusion is noteworthy due to the fact that as students progress through the Industrial Engineering program, they are not

becoming more likely to be holistic thinkers once they get out into the workforce. Because of the nature of the degree, this is important because Industrial Engineers are more likely to be dealing with complex problems/systems and put into leadership positions once they join the workforce. More effort by Industrial Engineering programs should be made to broaden the thinking of engineering management skills while also learning the technical aspects of the engineering discipline, so that students will be better equipped once they enter into their career.

4.3 Internship/Co-Op

No significance was found in the internship/co-op category. An internship is noted by Mississippi State University to be beneficial due to the experience gained in relation to your field of study, the chance to see classroom theory in action, the opportunity to grow professionally and personally, etc (MsState). None of those benefits, however, increased the chance of broadening an individual's thinking to become more socially, politically, and systemically more conscious of the organization around them. One reason for this could be due to the job-specific roles the engineers-in-training are in during the internship or co-op. Employers tend to give the students more jobs that are considered more tedious (e.g. time studies, data analytics, etc.) and do not give the student the ability to expound upon the knowledge learned during school to solve problems and/or increase efficiency/effectiveness of a system.

4.4 Employment Status

Significance was found in the employment status category. If an individual had a job outside of school, they tended to be more holistic-thinking than their counterparts who are not employed outside of school. Systemic thinking was measured across 7 dimensions. Being employed outside of school has an impact on 2 of those dimensions: Complexity and Autonomy.

Juggling schoolwork and having other responsibilities outside of one area could be the contributing factor behind scoring higher in the complexity dimension. Also, the reason behind most students having jobs is because they need, rather than want, the money due to limited or no help from family/friends. Because of this, a certain level of autonomy is assumed to handle the increased amount of responsibility whilst in college which could contribute to the significance in that dimension.

This conclusion is significant to the literature because it moves forward the narrative that students should be better-rounded to accommodate for an ever-changing society that will continue to grow in size and complexity. The natural paradigm of society has called for an increase in individuals that can grow and learn from dealing with multiple phenomena that deals in the uncertainty of which direction to partake. Because of this, having a job outside of school is one way to prepare students to be more equipped to multi-task effectively and efficiently once they step into their career. Since complexity and autonomy were the dimensions that affected the significant result, more emphasis should be placed on advocating for more participation in extra-curricular activities for higher overall ST scores.

4.5 Grade Point Average (GPA)

Grade point average was found to not be significant in the study. From the three categories measured, having a higher or lower GPA was found to not have an impact on an individual's ability to deal with complex problems. As stated above, this is significant to current research as scoring well in Industrial Engineering classes does not indicate a lesser or higher ability to see how and why systems interact or will interact. Because of this analysis, to better equip the students with more business-oriented acumen, the discipline could benefit by finding more robust ways to broaden the focus of students to show how entities interrelate.

CHAPTER V

CONCLUSION

This study was conducted to analyze the determinant(s) that may or may not affect the ability of a student to be a more or less holistic-thinker. The results found that only one determinant analyzed, employment status, had a significant effect on Systems Thinking. Students who had a job outside of school tended to be more likely to have a higher ST score than students who did not have a job outside of school. This result is indicative of how having a more well-rounded life can be helpful when later trying to solve complex phenomena. Descriptive and inferential statistical analysis was used to determine and interpret the results obtained by the study. The main takeaways are summarized below:

- Having an outside job allows individuals in college to be better equipped to deal with complex problems.
- Education level does not affect Systems Thinking scores. Holistic thinking is either not being taught or is not being registered as they progress through the Industrial Engineering program.
- Employment status significantly affects the overall Systems Thinking score of the engineering students' study sample.
- Gender, grade point average, level of education, nor having/not having an internship/co-op affects the Systems Thinking score significantly.

The flexibility dimension is the most cultivated amongst the 7 dimensions when looking at the descriptive statistics on engineering students at a university.

CHAPTER VI

FUTURE RESEARCH

This study was limited in a variety of ways. The most pressing concern was the limited population size that was used to gather and determine results. In the future, more emphasis should be placed on gathering a larger sample size to be more accurate when determining results. Other main ways to improve this study are summarized below:

- Improving the evaluation of factors that increase an Industrial Engineer's ability to be a systems thinker could be expounded upon in later research to validate the results.
- Explore if the co-op and internship category should be broken up to see the differences between the groups. Also, explore if outside work should be broken up by amount of hours the individual works could be further evaluated.
- Alpha level was reduced due to limited participation, therefore alpha can be evaluated at the 95% confidence interval with larger participation.
- Further research could involve more Industrial Engineers at differing Universities or add in other Engineers from different departments to validate the results.
- Research could delve into how other extra-curricular activities besides having a job might affect a student's ST ability. These extra-curricular activities could include, but are not limited to: playing a sport, being involved in an organization (e.g. student government), volunteering, etc.

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