Teaching Systems Thinking for Effective Problem Solving

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Abstract

The current industrial world has been, to a certain extent, limited by competing on technology. Technology has now become an available and affordable commodity. Effective problem solving is emerging as the pinnacle component of competitiveness in today's industry. Emphasis on data and business analytics is an illustration of such competition – knowledge is key. In today's global knowledge-based economy, intellect is the new form of capital. How to transform the knowledge into effective decisions through systems thinking and systems engineering is the challenge of complex problems solving. The intellectual capital, of systems engineers, is an intangible asset of information and knowledge processing. Those problem-solver-systems engineers who are adept at decision-making under uncertainty, managing big-data, and dealing with complexity will be best equipped for success.

This research focuses on the intellectual and intuitive requirements of systems engineers. The intellectual span of a Systems Engineer is measured by educational level, experience and knowledge of specific Systems Engineering concepts. The intuitive component of a Systems Engineer is the unconscious and rapid processing of information, which involves the perception of information in the form of recognized patterns and the generation of creative ideas and judgments. In a rapidly changing information environment, technical decision makers must accurately and promptly assess the best alternatives among a set of choices. This is most apparent during the development of complex mega systems. In the early stages of system development, where variance and risk are highest, there is much discovery needed when system information is incomplete.

The objectives of the research are to explore: 1) Styles of how Systems Engineers solve problems, and 2) The role of education and experiences in influencing problem solving. This paper presents analysis of a Systems Engineer's knowledge of systems engineering concepts, intuitive information and knowledge processing.

Keywords: Problem Solving, Intellect, Intuition, Knowledge, Systems Thinking

1. INTRODUCTION

A challenge for systems engineering education, in the global knowledge-driven economy, is keeping pace with an accelerated technological treadmill. In a rapidly changing knowledge-driven economy, systems engineers must accurately and promptly assess the best alternatives among a set of choices (Keller & Staelin 1987) (Keren, 2003). Rapid technological changes cause information and knowledge to quickly become obsolete. Therefore, well-informed decisions in a short time is essential. This is most apparent during the development of complex mega systems, where the system development lifecycle spans across multiple decades.

In the initial phases of the system development lifecycle (SDLC) there is uncertainty and a need for the discovery of information in order to understand the scope of the system being designed. The uncertainties are directly related to the variances associated with the characteristics of the system or system variables. Uncertainties and variances are highest during the conception and elaboration phases while the system functionality is still being explored. Given such uncertainties, it is the challenge of Systems Engineering early in the SDLC to bridge the gaps in information to develop a valid design. Systems Engineers accomplish the design and bridge the information gap by using many different engineering tools, research, experience and intuition.

The intellectual capital, of systems engineers, is an intangible asset of information and knowledge processing. The National Defense Industrial Association Systems Engineering Division (NDIA) Task Group Report of 2006 (National Defense Industrial Association Systems Engineering Division Task Group Report, 2006) states "The quantity and quality of systems engineering expertise is insufficient to meet the demands of the government and the defense industry." Intellectual capital is a critical resource of an enterprise, but it's the performance of the capital which equates to keeping pace with the technological treadmill and the gain of a competitive edge.

In the knowledge–based economy there is a need to rapidly process information and knowledge. Intuitive information and knowledge processing is being re-visited after decades of being ignored (Senge, 1994). An intellectual intuitive systems engineer innovates and integrates new knowledge effortlessly and instantaneously, elevating an organization's performance.

2. WHAT IS A SYSTEMS ENGINEER'S INTELLECTUAL CAPITAL?

Systems Engineers' apply their knowledge gained over their experience span For the purpose of this research the intellectual capital of systems engineers is limited to and measured in terms of the knowledge and understanding of five selected System Engineering concepts (Jain & Chandrasekaran, 2008) (Jain, Mercedes, McGrath, & Brockway, 2009) (Jain, Chandrasekaran, & Elias, Pedagogical Research on Understanding and Misconceptions of System Design, 2015). These are as follows:

Context: Conceptualizing beyond the multidisciplinary content contribution in engineering design to include how design is practiced in a context.

Interdiciplinarity: The integration of analytical strengths of two or more, often disparate, scientific disciplines to create a new, hybrid discipline.

Value: The intellectual content of realizing successful systems involves reasoning about the relative value of alternate system realizations to success critical system stakeholders, and the organization of components and people into a system that satisfies the value propositions of the success critical stakeholders.

Trade-offs: The purpose of evaluating different potential design concepts based on trade-offs such as, cost, time, performance, functionality etc., is to select the one that is most optimally suited to the task.

Abstraction: The ability to abstract a design concept independent of a solution requires that systems engineers are able to think of design concepts that are not dependent on specific solutions.

The assessment of a Systems Engineer's knowledge and understanding of the five systems engineering concepts is performed using a pilot system engineering concept inventory (SECI) tool. SECI is discussed in the survey and tools section of this paper.

3. WHAT IS INTUITIVE INFORMATION-KNOWLEDGE PROCESSING?

There are two information and knowledge processing approaches: intuitive and rational. Intuitive knowledge and information processing is the unconscious, fast and effortless processing of information. It involves the perception of information in the form of recognized patterns and the generation of creative ideas and judgments (Vaughan, 1979) (Agnor, 1989) (Salton, 2000) (Fields, 2001) (Epstein, 2003) (Dane, 2007). Intuition differs from the rational information processing system, which is a conscious and a much slower process. The rational system information processing is sequential, logical and analytical.

4. INTUITIVE INFORMATION PROCESSING SYSTEMS

Decision Theorists have maintained that there is a trade-off between decision accuracy and decision speed (Dane, 2007). The rate and abundant amount of information generated in today's knowledge economy has created a need to understand how to make high quality decisions relatively quick. Most theorists define intuition as an unconscious human ability to synthesize information quickly and effectively (Epstein, 2003) (Betsch, 2008) (Sadler-Smith, 2004) (Hamm, 2008) (Dane, 2007). The decision theorists and cognitive scientists view intuition as the solution to the trade-off (Dane, 2007).

Intuition – "intuition is a natural attribute of an information processing style" (Fields, 2001) "our inborn ability to synthesize information quickly and effectively" (Dane, 2007); knowledge acquired without rational thinking (Kutz, 2008).

5. EFFECTIVENESS OF INTUITIVENESS

Decisions made by executives often involve time constraints, no previous precedents, and uncertainty (Agnor H, 1986). The use of rational and logical decision making in problem solving, in these types of situations, is time consuming and resource dependent. In a knowledge based economy, where the lifecycle of innovative ideas is shortened, and time to market is a critical factor, executives use intuitive decision making (Agnor H, 1986).

Table 1 shows research findings in diverse industries where executives score higher in intuition than non-manager types. Nurses are 50% rational versus hospital administrators who are 46% intuitive (Kalisch, 2006). Fifty-six percent of executives state their intuitive decision making is based on experience (Burke & Miller, 1999). Norwegian executives with an engineering education correlated positively with intuition. Executives educated in business correlated negatively correlation with intuition (Gisle, 2004).

6. KNOWLEDGE COMPETENCIES AND PERFORMANCE CAPABILITIES

"Competence" is a concept which gives an organization a competitive advantage in today's knowledge driven global economy. The business sector and employers are the primary drivers for defining and selecting key competencies (Rychen, 2000) which are specific to their market/industrial operating environment. Core competencies are composed of 1) core knowledge competencies and 2) performance capabilities.

Core knowledge competencies are intuitive and experiential knowledge which shapes how an individual perceives the world (Allee, 1997) (Rychen, 2000) (Nonaka, 2008). They are the technical "know-how" skills of an organization (Allee, 1997) (Nonaka, 2008). As organizations adapt to rapid changes, core knowledge competencies are continuously renewed, replenished, and expanded. Core competencies of knowledge are combined and recombined to create new knowledge, new technologies, and new products (Allee, 1997).

Society's views and beliefs of the world are what influence an organization's core knowledge competency. Today's societal worldview of technological advances is one of continuous change and complexity. To meet these societal challenges, core knowledge competencies, likewise, undergo continuous changes and adaptations. Technological advances in computer science changed the societal views and core knowledge of the industrial age, to the information age of today.

Performance capabilities are the mechanisms which transform core knowledge competencies into the creation of technical products (Allee, 1997). Long-term development and past performances formulate performance capabilities. Internal work processes are required to produce operational systems according to stakeholder requirements, product specifications, scientific formulas, etc (Nonaka, 2008). Core knowledge competencies define the core capabilities required to perform the activities of the internal work processes. Internal work processes performed by knowledge workers, with core performance capabilities, produces products according to design specifications. Performance capabilities of the workforce bring value to the development of products.

The dynamics of core knowledge competencies and performance capabilities are shown in the re-enforcing causal loop diagram, Figure 1. Core knowledge competencies define the performance capability needed to transforms core knowledge competencies into innovative technologies. Innovative expands technological core knowledge competencies and continuously redefines core performance capabilities.

7. SURVEYS AND TOOLS USED IN THE STUDY

A Systems Engineering Intellectual Intuitive Survey (SEIIS) tool (See Appendix B) was developed to assess a Systems Engineers' understanding of the selected Systems Engineering concepts and their capability to process information rapidly. SEIIS is a four-part survey composed of a demographics section, an intuitive personality preference inventory (AIM), an intuitive information\knowledge processing inventory (I-OPT) and a systems engineering concept inventory (SECI).

Part 1, Demographics - information about the characteristics of the systems engineering population such as gender, nationality, education, industrial and system engineering experience etc.

Part 2, Intuitive personality preference inventory (trade name AIM) - a validated instrument, developed by Weston Agnor (Agnor, 1989), to measure the intuitiveness of executives as part of his brain skills management program. The AIM inventory is a multiple choice survey of twelve closed-ended questions, which assesses an individual's intuitive and thinking information and knowledge processing style, where:

- **Intuitive** – "Prefers solving problems by looking at the whole, then approaching the problem through hunches"
- **Thinking** – "Prefers solving problem by breaking down into parts and then approaching the problem sequentially"

Scores of the AIM Survey are 0-12. Table 2 interprets the scores relationship to intuitive and thinking information-knowledge processing. For example: A systems engineer with an AIM score of 7 is 58% intuitive and 42% thinking personality preference. At 58%, intuition is the dominant preference.

Part 3, Information\Knowledge Processing Style (trade name I-OPT) – a validated instrument developed by Gary Salton (Salton, 2000), measures processing styles and patterns for the purpose of engineering organizational performance. The I-OPT inventory, based on information input and output, consists of 24 multiple choice closed-ended preference statements. Twelve of these statements are measures of different facets of input information and the remaining twelve statements measure different facets of output responses. I-OPT measures an individual's information processing style, based on the information process model {Input → Processor → Output} (Salton, 2000).

The I-OPT survey measures the following four information processing styles:

- **Reactive Stimulator (RS)** – Action-oriented: "the ability to act quickly and to be comfortable in making decisions with minimal information and detail."
- **Logical Processor (LP)** – Detailed-oriented: "the ability to define and execute programs, methodologies, and techniques in a disciplined fashion."
- **Hypothetical Analyzer (HA)** – Problem solver: "the ability to analyze and assess complicated problems and situations."
- **Relational Innovator (RI)** – Big picture: "the ability to rapidly generate new, often unusual ways of addressing a situation."

The four processing styles are configured, into four strategic profiles, based on a calculated formula of processing style ratings. The strategic profiles are conservator, perfector, performer, and changer. The changer strategic profile is I-OPT's equivalent to intuition (Fields, 2001). The changer is the dual style of the big picture idea-oriented relational innovator (RI) and the action oriented reactive stimulator (RS) (Salton, 2000).

Intuition (the changer) as a function of Reactive Stimulator (RS) and Relational Innovator (RI) processing styles is calculated by equation 1.1.

$$\textbf{Intuition} = (RS * RI)^{*}.5 \quad \{\text{Equation 1.1}\}$$

A Systems Engineer with an I-OPT Score of 18 and above is considered to have a dominant intuitive information\knowledge processing style.

Part 4, Systems Engineering Concept Inventory (SECI) – a validated instrument, developed by Dr. Rashmi Jain, to assess the intellect of system engineers in the domain of system design (Jain & Chandrasekaran, 2008) (Jain, Mercedes, McGrath, & Brockway, 2009) (Jain, Chandrasekaran, & Elias, Pedagogical Research on Understanding and Misconceptions of System Design, 2015). SECI measures a systems engineer's knowledge and understanding of five selected System Engineering concepts. SECI delivers eleven scores, representative of a Systems Engineer's understanding of the Systems Engineering concepts of context, interdisciplinarity, value, trade-offs, and abstraction. The scores are totaled for a final score, based on number of correct responses.

	Intuition AIM	Intuition I-OPT	Education
	Sample Size, N=72		
Education	.418**(.000)	.456**(.000)	1
Experience	.161(.089)	.098 (.207)	.050(.337)
Knowledge	.208* (.040)	.118 (.163)	.127(.143)

8. DATA COLLECTION

A sample pool is drawn from a population of an interdisciplinary technical population consisting of systems engineers, engineers, scientists, technical managers and practitioners. Sampling of the population is accomplished by survey and case study research methods.

Two hundred and fifty Systems Engineering Intellect and Intuitive Surveys (SEIIS) were distributed, with seventy-nine were completed by respondents – Table 3. The four parts, of SEIIS, namely, demographics, I-OPT intuition survey, AIM intuition survey and SECI, were distributed to government agencies, contractors, and the general systems engineering community. All findings reported in section 9 are between .80 and .90 sample power.

9. SUMMARY OF FINDINGS

Empirical results of this research support the following: Intuitive Systems Engineers are agile, and quick to adapt to changing and uncertain environments. Intellectual Systems Engineers are robust, and sensitive to factors causing variability.

Intuitive competencies encompass the abilities to be curious, innovative and create new ideas, to make decisions without optimal information, works comfortably in uncertain environments with short time horizons, to synthesize information quickly, possess a passion for solving complex and ambiguous problems, and to identify connections from separate elements of the project.

Our correlations between intuition measured with the AIM and I-OPT instruments and the predictors (Education and Knowledge) are significantly correlated. The results in the table below suggest with moderate to significant confidence "intuitive decision making is positively related to Education, Experience, and knowledge".

The coefficients of multiple correlations (R), the coefficient of multiple determinations (R2), and the standard estimated error are statistically significant. Variation analysis indicates that education, experience, and knowledge contribute to variations of intuitive decision making.

Intuitive information processing is an individual's unconscious perception of stimuli or cues in a domain specific environment and the unconscious reactions or judgment(s) to the stimuli. The outcome of intuitive information processing is intuitive decision making (Agnor H, 1986) (Fields, 2001) (Dane, 2007). The AIM and I-OPT survey instrument measures an individual's intuitive perceptions and intuitive judgment capabilities (McCaulley, 1976) (Agnor H, 1986) (Salton, 2000).

A Systems Engineer's levels of education, years of SE experience, and Systems Engineering knowledge of select Systems Engineering concepts increases a Systems Engineer's intuitive decision-making capability.

The positive multiple correlation coefficients(R) indicates variations of a Systems Engineer's intellectual span, namely, levels of education, years of SE experience, and Systems Engineer's knowledge of select Systems Engineering concepts contribute to the variations of a Systems Engineer's intuitive decision-making capability.

This research is designed to answer the question "What Makes a Systems Engineer a Systems Engineer?" by empirically measuring a Systems

Engineer's intellect and intuitiveness. In answer to "What Makes a Systems Engineer a Systems Engineer?" A significant finding was that "not all Systems Engineers are equal". The intellect and intuitiveness of Systems Engineers are contributors to the complexity of a Systems Engineer's, domain knowledge schema. A domain knowledge schema is a network(s) of encoded patterns which equates to environmental stimuli (Dane, 2007).

The domain knowledge schema, of Systems Engineers, is a function of a Systems Engineer's repetitive experience in a particular phase of systems development or functional areas of Systems Engineering and the tasks performed. Systems Engineers with repetitive experience in the concept development phase of new architectures are required to perform judgmental tasks in uncertain environments, with little or no information. Based on (Dane, 2007), the performance of judgment tasks influences intuition.

Systems Engineers with repetitive experience in the operation and maintenance phase perform tasks relative to system baseline procedures or standard operating procedures. The environment is less uncertain. The repetitiveness of performing judgmental tasks is less often. This would also be true for repetitive experience in the performance of tasks in different functional areas.

Environmental stimuli and the encoded patterns of domain knowledge schemas, are re-enforcing dynamic systems. A stimulus invokes a response from the domain schema which reinforces pattern recognition. If there is no response, then a new pattern is encoded and added to the domain knowledge schema.

The environmental stimulus a Systems Engineer is exposed to is dependent on the mission and business purpose of the work place. Organizations employ different strategies and approaches to select and identify core domain knowledge competencies required to meet the demands and tasks of the mission or business purpose (Rychen, 2000). The operational and cultural environment in which an organization or business functions, is a key driver in shaping an engineer's domain knowledge schema. Whereby, producing Systems Engineers who are not all equal.

Intuitive and agile Systems Engineering experts are quick to adapt to changing and uncertain environments. Intellectual Systems Engineering experts are knowledgeable about system engineering concepts. Robust Systems Engineering experts are sensitive to factors causing variability.

(Dane, 2007) and other cognitive researchers have identified domain knowledge factors which influence an individual's intellect and intuitiveness. This research study empirically supports the influencing factors of 1) domain-relevant schemas, 2) explicit learning, and 3) repetitive practice which is regarded as the intellectual span of Systems Engineers. The research also shows that there are other influencing factors. The exploration of other influencing factors goes beyond the scope of this research study.

10. CONCLUSIONS

The research presented in this paper, indicates through correlation analysis, that knowledgeable and educated Systems Engineers are intellectual and intuitive System Engineers. Intellectual and intuitive systems engineers are high performers. This finding supports furthering the educational initiatives in Systems Engineering.

System engineers who are current in SE concepts, intuitively processes information holistically in chunks or whole concepts (Simon, 1987). Likewise, systems engineers, because of explicit knowledge acquired, through education and experience are innovative problem solvers and decision makers comfortable operating in dynamic and unpredictable environments (Dane, 2007). Experienced systems engineers recognize patterns and cues in operating environments of uncertainty. All of these characteristics are what makes a Systems Engineer a Systems Engineer in the 21st century. Methods for intuitive information processing using holistic techniques should be applied to Systems Engineering curriculums. Further methods to teach innovative problem solving will benefit students looking to compete in global markets.

Today's societal worldview of technological advances is one of continuous change and complexity. Society's views and beliefs of the world is what influences an organization's core knowledge and performance competency (Rychen, 2000).To meet the societal challenges of globalization, core knowledge and performance competencies will undergo continuous change and adaptation.

To outpace the rapid changes and complexity of the technological curve, brought on by globalization, the innovation of systems development organizations must be unleashed. The whole brain theory states in order to innovate, the whole brain must be at use (Herrmann, 1991). Intellect and intuitiveness are 21st century systems development core knowledge and performance competencies. The whole brain must be put to work using both rational and intuitive information processing systems (Leonard, 1997)

Weston Agnor and Carl Salton, developers of the AIM & I-OPT intuition instruments, respectively, have provided thousands of industrial and government administrative organizations strategies to increase organizational performance through the design of teams based on information processing preferences.

The SEIIS tool will help identify the learning needs and capabilities of individuals to be effective systems thinkers. This would enable organizations to form teams with diverse strengths, thereby, developing interdisciplinary teams for effective problem solving. Based on information processing preferences, the tool will enable the strategic design of teams, aimed at reducing risk and variance inherent in the problem solving and decisions in system development lifecycle.

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Appendix A: Tables & Figures

Table 1 Research Areas of Intuition Effectiveness

Industry	Research	Population	Sample	Findings
Nursing	Information Processing of Nurses and Nurse managers (Kalisch, 2006)	Registered Nurses & Nursing Administrator	Nurses, N=344	50% Rational 12% Intuition
			Administrators, N=52	15% Rational 46% Intuition
Automotive Industry	The Use of Intuition in Management (Agnor H, 1986)	General Motors, Dow Chemical, Chrysler, Burroughs, Ford Foundation	Executives in the Top 10 Percent of Intuition scale, N=100	A vast majority of executives use intuitive decision making. Top managers scored higher then mid-level managers.
Aerospace / Engineering Industry	Intuitive Decision Making of Executives (Burke, 1999)	Space flight, Aerospace Engineering, Manufacturing, Communications,	Executives, N=60	56% Intuitive Decision Making based on experience
Norwegian Industry	Intuition and its Role in Strategic Thinking (Gisle, 2004)	Banking, Retail, Shipping, IT, Real Estate, Production etc.	Norwegian Executives, N=105	<u>Gut Feeling correlation</u> -.34(.01) for business educated +.28(.01) for Engineering educated
Engineering Education	Psychological Types in Engineering Implications for Teaching (McCaulley, 1976)	Engineering Students, Faculty, Practicing Engineers	Engineering Specialties, N=1060	<u>Intuitive:</u> 70% Nuclear, N=60 72% Aerospace, N=36 <u>Sensing:</u> 64% Industrial & Systems, N=60
Stock Market	Test of differences between rational and intuitive forecasts (Harteis, 2008)	Executives in Banking & Investment Domain	German Stock Index, N=32	<u>Actual Index Difference:</u> 21% Rational 18% Intuition
			US Exchange Rate, N=16	<u>Actual Rate Difference:</u> 12% Rational 1% Intuition
Medical Research	Right Brain Development During Child hood (Chiron, Jambaque, Nabbout, Lounes, Syrota, & Dulac, 1997)	Children 18 days to 19 years, N=39	Children and Toddlers	Infants are right brain dominant (Visuospatial) Shifts to left brain after three years (language abilities).

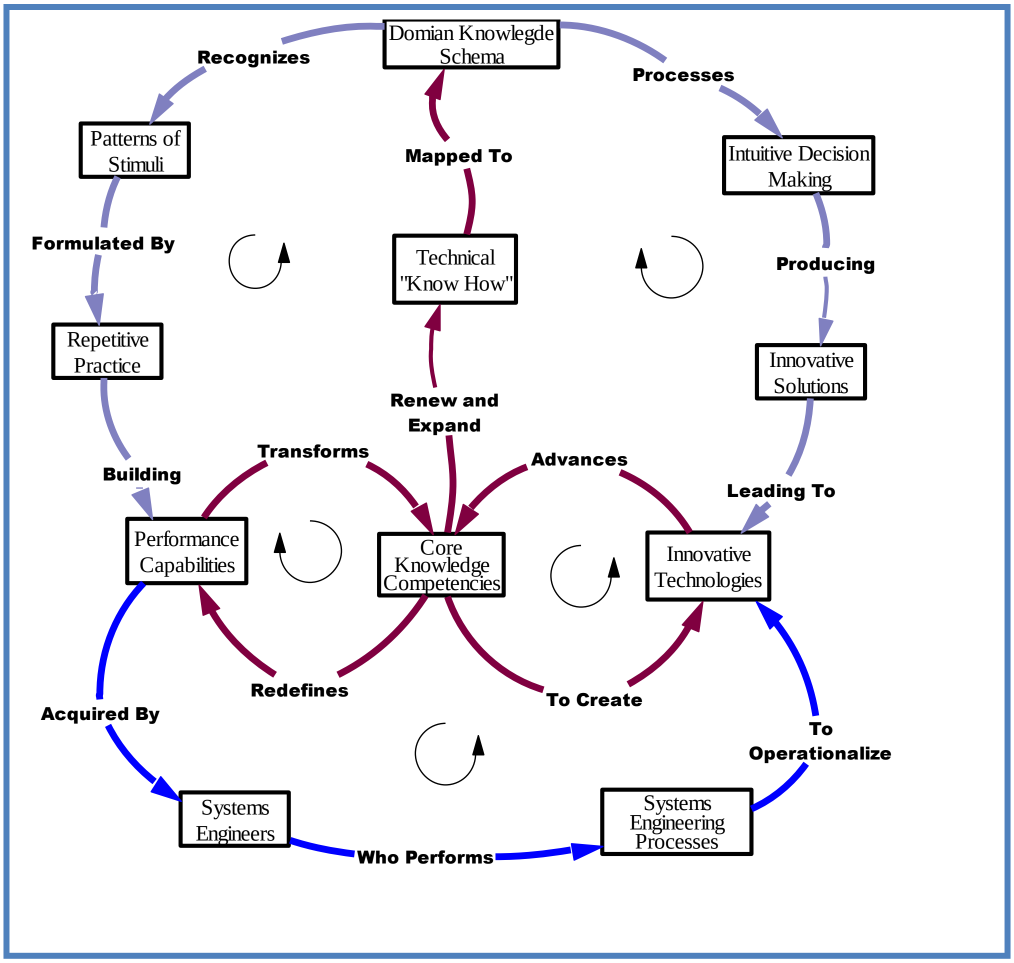

Figure 1 Casual Loop: Core Knowledge Competencies & Performance Capabilities

Table 2 AIM Survey Scale (In Percent)

AIM Scale	12	11	10	9	8	7	6	5	4	3	2	1	0
Intuitiveness	100%	92%	83%	75%	67%	58%	50%	42%	33%	25%	17%	8%	0%
Thinking	0%	8%	17%	25%	33%	42%	50%	58%	67%	75%	83%	92%	100%

Dominant Thinking **Integrated Intuition & Thinking**

Table 3 SEIIS Respondents

Industry	Demographics	I-OPT	AIM	SECI
Company A	10	10	10	10
Company B	6	6	6	6
Company C	6	6	6	6
Company D	6	6	6	6
Other	49	49	49	49
Total	79	79	79	79

Appendix B: SEIIS Survey

SEIIS Survey instructions

Please, read the information and instructions provided below before responding to the questions.

Purpose of the Study

The purpose of this study is to better understand the intuitive information processing styles of Systems Engineers. The overwhelming and abundant amount of information that organizations are confronted with makes it necessary to seek out alternative means of processing information. Information processing is the underlying principle of an organization's decision-making, problem solving, solution generation etc. Because there is a need to rapidly process information, intuition in management is being re-visited after decades of being ignored.[1]

The assessment of the intuitive information processing styles of system engineers provides organization with insight into underutilized capabilities and competencies. The outcome of the research will provide an organization a tool to strategically engineer, a higher performing, system development workforce.

Survey Process

Your participation in this research study will require the completion of a five part survey.

Part # 1 Demographic Information
Part # 2 Personality Preference Inventory
Part # 3 Information Processing Style
Part # 4 System Design Concept Inventory

Please follow the instructions given for each part of the survey. The survey will be administered to a global community of Systems Engineers. The survey will take approximately 25 minutes to complete.

[1] Senge, Peter M, The Fifth Discipline, Currency Doubleday1990, pg168

SEIIS: Part # 1 Demographic Information

Part 1: System Engineering Intellectual Intuitiveness Survey (SEIIS)
Your Demographics

Thank you for participating in this study! Please complete the following survey by entering the appropriate information in the blank spaces provided or clicking-on the appropriate box:

1. Company Name: ☐ Anonymous Identity: ☐

2. What is your gender? ☐ Female ☐ Male

3. What is your current country and state/province of residence? ☐

4. Please indicate your highest degree obtained by checking the appropriate box:

☐ Technical certificate or Diploma (2 years post-secondary)

☐ Bachelor's degree or equivalent (4 years post-secondary)

☐ Graduate Certificate (5 years post-secondary)

☐ Master's Degree (6 years post-graduation)

.

☐ Doctoral Degree

5. What engineering discipline was your major(s)? Please check what applies.

☐ Systems Engineering

☐ Aerospace Engineering

☐ Electrical Engineering

☐ Mechanical Engineering

☐Civil Engineering

☐ Chemical Engineering

☐ Nuclear Engineering

☐Architecting

☐ Engineering Management

☐Other Explain (Mathematic, Chemistry etc): ☐

6. What industry do you currently work?

☐ Nuclear
☐ Aerospace
☐ Agricultural
☐ Pharmaceutical
☐ Energy
☐ Intelligence
☐ Health
☐ Education
☐ Arts, Entertainment & recreation
☐ Transportation
☐ Mining
☐ Utilities
☐ Construction
☐ Automotive
☐ Housing
☐ Telecommunications
☐ Scientific & Technical
☐ Other Explain

7. How many years have you worked in this industry? ☐

8. In the following classifications, what Systems Engineering position have you held and the number of years? Click-on the appropriate box.

☐ System Engineering Manager - Group Leaders, Department Managers & Senior Engineering Management
☐Less than 5 years ☐5-10 years ☐1 0 – 15 years ☐Greater than 15 yrs

☐Senior Systems Engineer - Responsibility for all Technical aspects of Project.
☐Less than 5 years ☐5-10 years ☐1 0 – 15 years ☐Greater than 15 yrs

☐Junior Systems Engineer - A system engineer with 5-10 years
☐Less than 5 years ☐5-10 years ☐1 0 – 15 years ☐Greater than 15 yrs

☐Specialty Engineer - An engineer functioning as a System Engineer during a specific program phase, focused on a specific technical discipline
☐Less than 5 years ☐5-10 years ☐1 0 – 15 years ☐Greater than 15 yrs

☐Other, Explain
☐Less than 5 years ☐5-10 years ☐1 0 – 15 years ☐Greater than 15 yrs

9. Have you participated in any in-house (internal to your company) Systems Engineering Training program? ☐ Yes

☐ No

If yes, Please check appropriate box below:

☐ Less than 40 hours

☐40 hours

☐Greater than 40 hours

☐Other

SEIIS Part # 2 Personality Preference Inventory

Part 2: System Engineering Intellectual Intuitiveness Survey (SEIIS)/AIM[2]
Personality Preference Inventory

Instructions: Select the response that first appeals to you most. Place an "X" in the box next to your response. Complete as quickly as you can.

1. When working on a project, do you prefer to:
☐ Be told what the problem is, but left free to decide how to solve it?
☐ Get very clear instructions about how to go about solving the problem before you start?

2. When working on a project, do you prefer to work with colleagues who are:
☐ Realistic?
☐ Imaginative?

3. Do you admire people most who are:
☐ Creative?
☐ Careful?

4. Do the friends you choose tend to be:
☐ Serious and hard working?
☐ Exciting and often emotional?

5. When you ask a colleague for advice on a problem you have, do you:
☐ Seldom or never get upset if he/she questions your basic assumptions?
☐ Often get upset if he/she questions your basic assumptions?

6. When you start your day, do you usually:
☐ Seldom make or follow a specific plan to follow?
☐ Make a plan first to follow?

7. When working with numbers, do you find that you:
☐ Seldom or never make factual errors?
☐ Often make factual errors?

[2] Source: "AIM" survey developed by Weston H Agor, a public domain tool

Part 2: System Engineering Intellectual Intuitiveness Survey (continued)

8. Do you find that you:
☐ Seldom daydream during the day and really don't enjoy doing so when you do it?
☐ Frequently daydream during the day and enjoy doing so?

9. When working on a problem do you:
☐ Prefer to follow the instructions or rules when they are given to you?
☐ Often enjoy circumventing the instructions or rules when they are given to you?

10. When you are trying to put something together, do you prefer to have:
☐ Step-by-step written instructions on how to assemble the item?
☐ A picture of how the item is supposed to look once assembled?

11. Do you find that the person who irritates you the most is the one who appears to be:

☐ Disorganized?
☐ Organized?

12. When an unexpected crisis comes up that you have to deal with, do you:
☐ Feel anxious about the situation?
☐ Feel excited by the challenge of the situation?

SEIIS Part # 3 Information Processing Style

Part 3: System Engineering Intellectual Intuitiveness Survey (SEIIS)/ IOPT[3]

Information Processing Style

Instructions: Please provide your preference to all (A through X) statements. For each statement, read choices then click on the box next to the letter, for the dropdown menu. Select the number of the single phrase that best describes you. There is no right or wrong answers, just preferences.

A. 0
1. I complete things I start
2. I respond fast
3. I make plans
4. I imagine things

B. 0
1. I plan before
2. I do things that are different
3. I change easily
4. I like clear instructions

C. 0
1. I react fast
2. I like to have others finish what I start

I. 0
1. I like to take chances
2. I like to follow the rules
3. I find and fix problems
4. I get into things totally

J. 0
1. I like my own ideas best
2. It is easy for me to stay on task
3. I am very careful
4. I sometimes do things before I think through

K. 0
1. I take chances
2. I adjust easily

Q. 0
1. I use things at hand to solve the problems
2. I look for more than one way to solve things
3. If things are tough I will change ideas
4. I like to get things done the way they are supposed to get done

R. 0
1. I like to start things
2. I tell others what I think
3. I get things done
4. I don't always know how things are going to end up

S. 0
1. I decide things easily
2. I stir up action

[3] Source: "I OPT" survey developed by Organizational Engineering and used with their approval, copyright 1989-1999, Professional Communications Inc. all rights reserved.

3. I do things that are new and different
4. I get things done

D. 0
1. I see into the future
2. I like things clear and direct
3. I am an organizer
4. I change ideas a lot

E. 0
1. I have complicated ideas
2. I think of new ways to do things
3. I solve things pretty easily
4. I like things to be easy to understand

F. 0
1. I follow direction
2. I predict what's going to happen
3. I am quick to respond
4. I have many ideas

G. 0
1. I pay attention to every detail
2. I have quick solutions
3. I like things my way
4. I like to follow directions

H. 0
1. I know what I want to do
2. I know how I want to get things done
3. I am pretty good at planning details
4. I have suggestions faster than others

3. I do not like changes
4. I make things happen

L. 0
1. I like to analyze
2. I like to get things decided
3. I am easily distracted
4. I like to see ideas grow

M. 0
1. I really do not like rules
2. I like things "just right"
3. I like to get things done
4. I sometimes forget detail

N. 0
1. I forget things easily
2. I pay close attention to details
3. I go along with the crowd
4. I get others doing

O. 0
1. I like things to be exact
2. I am playful
3. I get unusual ideas that I need to explain
4. I like to follow a schedule and be on time

P. 0
1. I like directions
2. I like to invent things
3. I like adventure
4. I want to be exact

3. I am steady as a rock
4. I am "out of sync" with others

T. 0
1. I am thoughtful and deliberate
2. I like to think about lots of things
3. I do not like interruptions
4. I like to look at different ways to get things done

U. 0
1. I am careful
2. I like a fast pace
3. I like to complete all the details
4. I see unusual connections between things

V. 0
1. I'm a daredevil
2. I'm interested in getting results
3. I'm logical
4. I ignore details

W. 0
1.I like to be in the "here and now"
2. I think about how thinks might be in the future
3. I like facts
4. I act on the spur of the moment

X. 0
1. I like things to be clear and easy to understand
2. I can predict things in the future
3. I do things according to a "system"
4. I like things to happen "right now"

SEIIS: Part # 4 System Design Concept Inventory

Part 4: System Engineering Intellectual Intuitiveness Survey (SEIIS)
System Engineering Concept Inventory

Instructions: Please select from the choices under each term to describe it as you understand it. If you do not find the choices appropriately describing the term add your description of the term in the section called "In your words".
<u>Choose all that apply</u>:

1. Context of a system

.☐ Context of a system is how the system fits into its environment
.☐ Context of a system shows the external interfaces of the system, the inputs and outputs of the system, and how the system interacts with other systems.
.☐ Context of a system is the functionalities and capabilities of a system (will perform or use of system).
.☐ Context of a system is a means of simplifying a system development effort to enable a more efficient focused, approach by the engineering team.
.☐ Context of a system is the scope of the system, where it will operate, and what it will do.
.☐ Context of a system is a system with a group of components that work together to accomplish some purpose.
.☐ Context of a system is the system's main function.

In your words: ☐

2. Context Diagram

☐ Context diagram shows the interaction between the system and its external systems
☐ Context diagram is a standardized illustration to simplify a system development effort to enable a more efficient and focused approach for the engineering team.
☐ Context diagram is a simplified diagram showing the main stakeholders and the input/output functionality.
☐ Context diagram is a basic picture of your system.
☐ Context diagram shows the transition of data between the system and its stakeholders.
☐ Context diagram is a pictorial reference of the system and all the external actors to the system.
☐ Context diagram is the highest level of a system overview, graphically presents all the inputs and outputs

In your words: ☐

3. External Systems Diagram

☐External systems diagram shows the interaction of the system and its environment.
☐External systems diagram shows the flow of inputs and outputs between the system and its external systems.
☐External systems diagram gives information about all the systems interfering with the main system to understand the complete functionality of the system.
☐External systems diagram identifies the various functions of a system and their interactions.
☐External systems diagram shows the external systems that interact with the system.
☐External systems diagram shows all the inputs and outputs of the system and where they go and come from.

In your words: ☐

4. Difference between stakeholder requirements and system requirements

☐Stakeholder requirements deal with the needs of the individuals, users and other systems that use the system at hand.
☐System requirements are the requirements needed to accomplish the functionality of the system.
☐System requirements are derived from stakeholder requirements.
☐Stakeholder requirements are based on the stakeholder/customer needs (what they want).
☐System requirements are the requirements that pertain to the system and the capabilities that the system will do (including the constraints and the boundaries).
☐Stakeholder requirements are "what" the system has to do (suppose to do) and System requirements specify "how" the system has to do the "what".
☐System requirements describe what the system is.
☐System requirements are written by system engineers for all other engineers.
☐System requirements are more detailed requirements that are generated to accomplish the stakeholders' objectives from the refined high-level stakeholder requirements.
☐System requirements are MTBF, MTTR, and MTBF….
☐Stakeholder requirements are what the system must do. They include input and output requirements.
☐Stakeholder requirements are the minimum set of requirements that stakeholders set as the goal of the system

☐ System requirements specify the technical details about a component.
☐ System requirements serve the purpose of achieving stakeholder requirements.

In your words:

5. Functional Decomposition
☐ The functional decomposition of a system is a breakdown of the overall function (goal) of the system into sub functions that must be completed in order to complete the overall function.
☐ Functional decomposition is the decomposition of the main function into sub functions that support all the operating scenarios.
Functional decomposition is the decomposition of the main function into sub functions that support all the operating scenarios.
☐ Functional decomposition shows all the aspects of the system.
☐ Functional decomposition gives a clear understanding of different questions and input-output correlated with that (How the output of one function can be the input of other function can be understood by this decomposition).
☐ Functional decomposition is the process of reducing the system functionality into constituent parts in such a way that the original functionality can be reconstructed.
☐ Functional decomposition is a hierarchy of functions that accomplish system objectives.
☐ Functional decomposition is the process of breaking down high level functions so they can be understood. The more complex functions are decomposed.

In your words:

6. Different aspects of Value of a system
☐ Value can be cost, reliability, functionality, ease of use, maintainability, etc.
☐ The value of a system varies based on the perceptions of the individual stakeholder.
☐ Different aspects of Value of a system are performance, scalability, responsiveness, and modularity.
☐ Different aspects of Value of a system are derived from the interactions between its components in the form of emergent properties.
☐ Different aspects of Value of a system are dependent on the stakeholder. Each stakeholder has his/her own set of values for the system, which should be expressed in the stakeholder requirements.
☐ Value looks at how well the system is designed.
☐ Different aspects of Value of a system are cost, and 'ilities' such as reliability, availability, maintainability, commonality, usability, operability, etc…
☐ Value of the system is provided by its success

In your words:

7. Tradeoff:
☐ Tradeoff is giving up functionality in one area to gain functionality in another area. For example there can be tradeoffs between quality vs. cost, and feasibility vs. cost.
☐ Tradeoff is an opportunity given up for another opportunity, for example, time and cost.
☐ Tradeoff is what happens when there are conflicting requirements and something must be given up or compromised in order to achieve another goal.
☐ Tradeoff is comparing designs.
☐ Tradeoffs are items that are considered during the system design. One item may be good but it will affect another item in a negative way.
☐ Tradeoff is choosing between system functionalities, balancing system as a whole and giving up certain functionalities to gain better overall system performance.

In your words:

8. Tradeoff Analysis
☐ Tradeoff analysis quantifies the losses and benefits of tradeoffs.
☐ Tradeoff analysis is a method for giving up - A failure to find a means of achieving multiple objectives simultaneously.
☐ Tradeoff analysis is the process used to determine what tradeoffs to make to a system in developing a system.
☐ Tradeoff analysis analyzes what you don't implement.
☐ In tradeoff analysis minimum change option is recommended.
☐ Tradeoff analysis is a systemic approach to balancing the trade-off between time, cost and performance.
☐ Tradeoff analysis uses a methodological approach to determine which option is the most acceptable.
☐ Tradeoff analysis is the process of considering what/which functionality can be cut/gained to increase overall system performance.

In your words:

9. Factors evaluated during tradeoff analysis
☐The factors evaluated during tradeoff analysis are performance, cost, and schedule
☐The factors evaluated during tradeoff analysis are the impacts of tradeoffs on acceptance criteria, requirements, and ultimately commercial viability.
☐The factors evaluated during tradeoff analysis are effect on system performance, effect on cost, effect on functional architecture, effect on physical architecture, effect on overall changes of the system.
☐The factors evaluated during tradeoff analysis are value, use, cost, and ilities such as supportability, reliability, etc.
☐The factors evaluated during tradeoff analysis can change for every tradeoff.
☐The factors evaluated during tradeoff analysis are those that contribute to the overall benefit of the system.

In your words:

10. Decision making in Systems Engineering
☐Decision making in systems engineering is evaluating positive and negative aspects of options.
☐Decision making in systems engineering is looking at requirements vs. functionality of many things via Pugh matrix.
☐Decision making in systems engineering is a structured approach to achieve decisions with an emphasis on the impact of bad decisions on a holistic level; focusing not on deciding between options on their merits alone, but on how each decision will impact (and ultimately benefit or damage) the greater context.
☐Decision making in systems engineering is setting up a design that can be realized and be successful.
☐Decision making in systems engineering is based on different parameters mainly physical architecture, functional architecture, tradeoff analysis, sensitive parameters, and objectives hierarchy.
☐Decision making is one of the most important steps in systems engineering. It is the last step after you gather requirements, create functions and perform tradeoff analysis.
☐When designing a system, tradeoffs must be made, and this is because there is a lot to consider when implementing systems, and not every item can be applied. So decision making plays a major role.
☐Decision making in systems engineering is always based on analysis such as tradeoff analysis. Weighted items are considered to achieve the best system.

In your words:

11. Inter-disciplinarity in Systems Engineering (SE)
☐Inter-disciplinarity in SE takes into account the variety of stakeholders utilizing the system and performing functions within the system.
☐Inter-disciplinarity in SE is an incorporation of different technologies.
☐Inter-disciplinarity in SE is crucial. System architects need to consult with many engineering disciplines in order to gather requirements, needs, constraints, and design systems. . This makes sure that there are fewer errors and surprises as the design goes forward.
☐Inter-disciplinarity in SE is interfacing with the customers (non technical) and translating their design needs such that the designers/developers can understand.
☐SE can be applied in any discipline to improve or create a system. When designing any system, a proper architecture should be analyzed prior to manufacturing. The purpose of SE is to make processes more efficient.
☐It is very important in SE to have inter-disciplinary teams because it is impossible for one individual to possess all of the expertise necessary to complete a system design.
☐Inter-disciplinarity in SE includes the coordination of the different inter-disciplinary aspects of a system to provide input for SE decision making.

In your words:

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