ENABLING SYSTEMS THINKING TO ACCELERATE THE DEVELOPMENT OF SENIOR SYSTEMS ENGINEERS

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ABSTRACT

As engineering systems become more complex, the roles involved in developing and managing such systems also become more complex. Thus, there is increasing interest in educating and training engineering professionals to think more systemically. In particular, there is an increasing need to accelerate the development of senior systems engineers. As new educational degree programs in systems rapidly emerge and as companies scurry to establish systems training programs to meet this need, fundamental questions still remain about how systems thinking develops in engineers. Increased understanding of the mechanisms that develop systems thinking will enable effective and efficient development of senior systems professionals.

After reviewing related literature, an exploratory and inductive study was designed to gather data on enablers, barriers, and precursors to systems thinking development in engineers. In a field study conducted primarily in the United States aerospace sector, 205 interviews were conducted in 10 host companies. Senior systems engineers were studied to better understand how they developed systems thinking, and information was collected on company procedures for developing systems engineers. Using interview and survey data, comparisons were made of two control groups and senior systems engineers. Proven stellar systems thinkers were also interviewed.

To summarize the results, even though systems thinking definitions diverge, there is consensus on primary mechanisms that enable or obstruct systems thinking development in engineers. In order to reconcile the divergent definitions observed, a systems thinking framework, definition, and accompanying conceptual illustration are given. The data show that the primary mechanisms that enable systems thinking development include experiential learning, specific individual characteristics, and a supporting environment. This document defines the research space on this topic and suggests applications for the results. Better understanding of systems thinking development provides a foundation for educational interventions and employee development in systems thinking for engineering professionals across industry, government, and academia.

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EXECUTIVE SUMMARY

Engineering projects are growing in scale and complexity, government agencies in the United States are demanding improved systems engineering capabilities in contractors, and commercial companies are facing customer demands for more complex products. As engineering systems become more complex and as companies become more responsible for systems solutions, there is increasing interest in training engineering professionals to think systemically. In particular, there is an increasing need to accelerate the development of senior systems engineers.

To address this need to develop systems professionals, academia, industry, and government are reacting with a flurry of activity. As hundreds of systems professionals are being hired, new educational degree programs in systems are rapidly emerging. Companies are scurrying to establish systems training and development programs. Nonetheless, fundamental questions still remain about how systems thinking develops in engineers. Increased understanding of the mechanisms that develop systems thinking will enable effective and efficient development of senior systems professionals. There are questions both about what the requisite skills indeed are and how these skills develop. The type of thinking required by systems professionals is sometimes referred to as "*systems thinking.*" While systems thinking may be found throughout organizations, there is a specialized category of engineers called systems engineers who are charged with the responsibility to apply systems thinking to engineering systems.

The purpose of this research is to better understand systems thinking development and to better understand how senior systems engineers develop. Specifically, there are three key research questions: (1) What are enablers, barriers, and precursors to the development of systems thinking in engineers, (2) How do senior systems engineers develop, and (3) What are the mechanisms that develop systems thinking in engineers? There is not empirical evidence to show how systems thinking develops in people of all types, and it is not yet known if systems thinking develops differently in different disciplines. This research investigates only systems thinking in the engineering population. The terms systems professional and systems engineer are used interchangeably in this research.

After reviewing related literature, an exploratory and inductive study was designed to gather data on enablers, barriers, and precursors to systems thinking development in engineers. In a field study conducted primarily in the United States aerospace sector, 205 interviews were conducted in 10 host companies. After working with a point-of-contact to determine the company's interest in participating, the researchers worked with a point-of-contact to identify an "expert panel." This group consisted of approximately four individuals who are very familiar with the policies and practices of how that company develops senior systems engineers. Next, the Expert Panelists in each company were asked to identify subjects in three groups: (1) Senior Systems Engineers, (2) Junior Systems Engineers, and (3) Senior Technical Specialists. The selection of the follow-on subjects was dependent on the opinions of the Expert Panelists. Of course, the primary interest was in the characteristics, development histories, and opinions of the senior systems professionals. The other two groups were control groups.

In the survey, information was gathered on specific individual characteristics, assigned work roles, and educational interventions that inhibit or accelerate systems thinking development. The Expert Panelists were asked for formal company procedures for developing systems engineers. For all the subjects, the interview included questions about a definition for systems thinking, a reaction to a given definition of systems thinking, enablers and barriers to systems thinking, individual characteristics that predict the development of systems thinking, key steps to systems thinking development, etc. Additional interviews with proven stellar systems thinkers were also conducted. The study provides data to support and discredit existing heuristics on how senior systems engineers develop.

To summarize the results, even though systems thinking definitions diverge, there is remarkable convergence on mechanisms that enable and obstruct systems thinking development. The data show that the primary mechanisms that enable systems thinking development include experiential learning, various individual characteristics, and a supporting environment.

In order to reconcile the divergent definitions observed, an original systems thinking framework, definition and accompanying conceptual illustration are given. Synthesizing all the definitions considered, five foundational elements describe a systems thinking framework, which include the (1) componential, (2) relational, (3) contextual, (4) dynamic, and (5) modal elements. The resulting definition is that, "*Systems thinking* is utilizing modal elements to consider the componential, relational, contextual, and dynamic elements of the system of interest."

In addition to defining the research space on this topic, this document also suggests applications for this research. First, levels of intervention maturity are shown. Applications of research for government are: (1) Provide incentives to promote strong systems thinking, (2) adjust policies to emphasize experiential learning for systems thinking development, (3) change acquisition strategy to provide more programs and opportunities for engineers to develop systems thinking, (4) promote research on the mechanisms for effective systems thinking development, and (5) encourage systems programs that teach systems skills and systems thinking. The applications of the research for industry: (1) structure systems thinking interventions to emphasize experiential learning, (2) offer systems programs to teach systems skills and systems thinking, (3) filter and foster identified individual characteristics in systems organizations, (4) provide an environment supportive to the development of systems thinking, and (5) clearly communicate how strength of systems thinking is assessed. The applications of the research for academia are: (1) offer systems programs to teach systems skills and systems thinking, (2) use feedback mechanisms to continually improve systems programs and systems courses, (3) structure programs and courses to emphasize experiential learning, (4) structure courses and programs to promote systems thinking by emphasizing context and knowledge integration, and (5) continue research on the mechanisms for effective systems thinking development.

In the midst of the flurry of activity surrounding the currently urgent topic of systems, the results of this exploratory study demand that systems professionals step back to think. The mechanisms which develop systems thinking are not yet well understood, and the mechanisms that are currently being utilized are not necessarily the most effective. Before valuable resources are poured into systems development interventions, it is important to look at what the data in this study say about how systems thinking develops in engineers. Future research suggestions are given, since considerable work still needs to be completed in this area. Better understanding of systems thinking development provides a foundation for educational interventions and employee development in systems thinking for engineering professionals across industry, government, and academia.

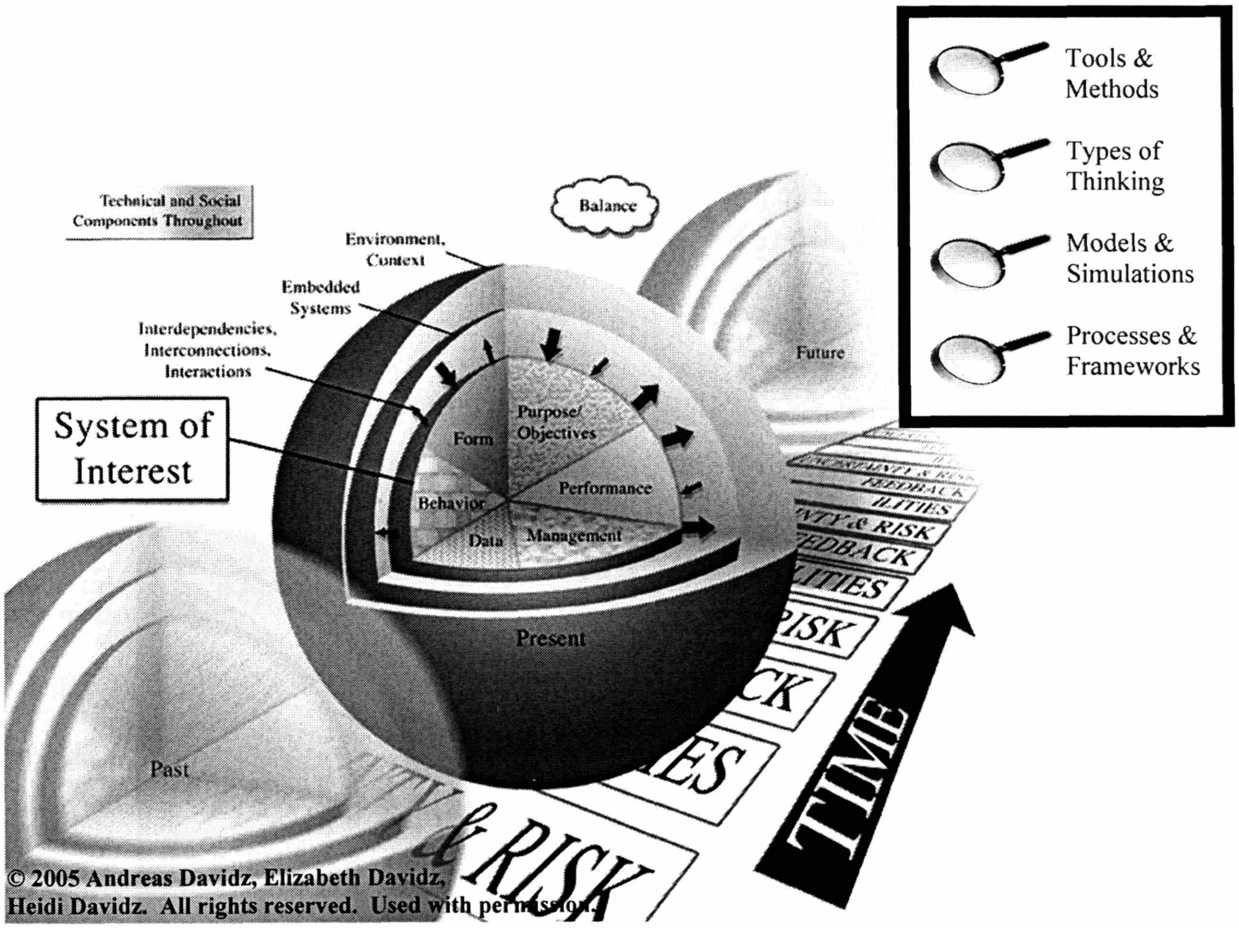

Figure ES-1: Conceptual Illustration of Systems Thinking

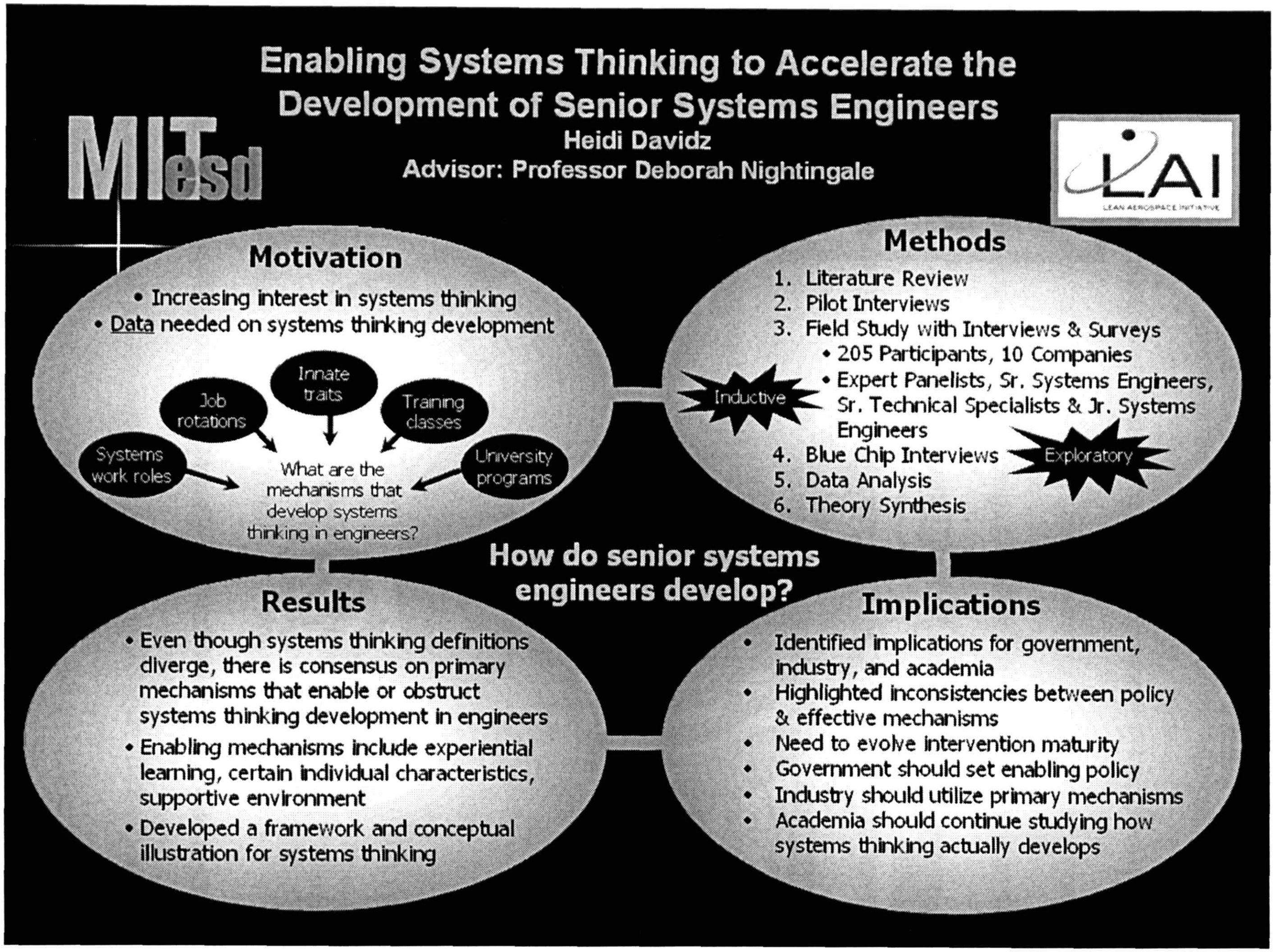

Figure ES-2: Research Summary

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List of Acronyms

ACQ	Acquisition
CONT	Contractor
DAU	Defense Acquisition University
DoD	Department of Defense
ESD	Engineering Systems Division
INCOSE	International Council on Systems Engineering
MDA	Milestone Decision Authority
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
PM	Project Management/Program Management
SAF/AQ	Secretary of the Air Force for Acquisition
SE	Systems Engineering
SEP	Systems Engineering Plan

1 Introduction

As engineering systems become more complex and as companies become more responsible for systems solutions, there is an increasing need to develop systems professionals. Engineering projects are growing in scale and complexity, government agencies in the United States are demanding improved systems engineering capabilities in contractors, and commercial companies are facing customer demands for more complex products. To address this need to develop systems professionals, academia, industry, and government are reacting with a flurry of activity. As hundreds of systems professionals are being hired, new educational degree programs in systems are rapidly emerging. Companies are scurrying to establish systems training and development programs. Accelerating the development of senior systems professionals is an immediate concern.

However, fundamental questions still remain about how these senior systems professionals develop the requisite skills to work these complex engineering challenges. There are questions both about what the requisite skills indeed are and how these skills develop. The type of thinking required by systems professionals is sometimes referred to as "systems thinking." While systems thinking may be found throughout organizations, there is a specialized category of engineers called systems engineers who are charged with the responsibility to apply systems thinking to engineering systems.

The purpose of this research is to better understand systems thinking development and to better understand how senior systems engineers develop. Specifically, there are three key research questions: (1) What are enablers, barriers, and precursors to the development of systems thinking in engineers, (2) How do senior systems engineers develop, and (3) What are the mechanisms that develop systems thinking in engineers? There is not empirical evidence to show how systems thinking develops in people of all types, and it is not yet known if systems thinking develops differently in different disciplines. This research investigates only systems thinking in the engineering population. The terms systems professional and systems engineer are used interchangeably in this research.

Designed as an exploratory and inductive study, this research utilized a series of interviews and surveys to gather data on the systems thinking development process in engineers. Information has been gathered on specific individual characteristics, assigned work roles, and educational interventions that inhibit or accelerate systems thinking development. Information has also been gathered on existing company practices to develop senior systems engineers.

Key Research Questions

1. **What are enablers, barriers, and precursors to the development of systems thinking in engineers?**
2. **How do senior systems engineers develop?**
3. **What are the mechanisms that develop systems thinking in engineers?**

Research Method

- **Exploratory and inductive study**
- **Literature review**
- **Pilot interviews**
- **Field study of 10 companies and 205 subjects using interviews and surveys**
- **Additional interviews with proven experts**
- **Data analysis**
- **Theory synthesis**

This document tells the story of this research project. First, the literature review discusses the motivation for this topic, the challenges of using "systems thinking" and "systems engineering" as research constructs, and literature that is related to the topic of systems thinking development in engineers. Next, the research methodology is explained, and the method of analysis is discussed. The results and conclusions are shown, and a discussion follows. Future research topics are given, and the applicable references are cited. The appendix includes copies of all the research instruments and detailed tables of the data gathered in this study.

This dissertation defines the research space on this topic while also providing preliminary information about current understanding and practice. In addition to informing curriculum design for education and training programs, enhanced understanding of systems thinking development in engineers provides a foundation for more effective employee development programs. The results of this research can help organizations enhance their interventions to accelerate the development of senior systems engineers across industry, government, and academia.

2 Literature Review

In order to explain the development of this research project, this section first discusses the motivation for this research topic. Next is a discussion addressing the challenges of using the constructs "systems thinking" and "systems engineering" in the study. Finally, there is a discussion of additional literature that informs the study of this topic. Unfortunately, there is not a well-established body of literature addressing the development of systems thinking in engineers, so the literature review covers a wide variety of topics. The unifying purpose is that the literature covered helps inform the study of systems thinking development in engineers.

2.1 Topic Motivation

It is important to understand why this topic is of interest. This section discusses both the importance of systems engineering and the importance of studying workforce issues related to systems engineering.

2.1.1 Importance of Systems Engineering

One sign of the importance of this topic is the degree to which it is identified in government and industry standards. The United States Air Force has set strict policy mandating systems engineering, and any contractor who hopes to do work with the USAF is obligated to comply. In Policy Memo 03A-005 "Incentivizing Contractors for Better Systems Engineering" (SAF/AQ 2003), the Assistant Secretary of the Air Force for Acquistion Dr. Martin Sambur says,

> "Ongoing Air Force transformation efforts strongly emphasize credible, agile acquisition processes. An immediate transformation imperative for all our programs is to focus more

attention on the application of Systems Engineering (SE) principles and practices throughout the system life cycle. Programs must elevate these disciplines to a level commensurate with other programmatic considerations such as cost and schedule.

A more robust SE environment can only be achieved through joint cooperative efforts with our contractors." I am therefore directing all PEOs/DACs/Single Managers to complete the following actions by 30 April 2003 for current programs:

Assess your ability to incentivize your contractors to perform robust SE, and report this information to the appropriate Milestone Decision Authority (MDA)...
As necessary, develop SE performance incentives appropriate to your program's life cycle phase, and insert into contractual Award Fee or Incentive Fee structures.
Include status of key SE processes/practices during all future program reviews."

Also in this policy memo, Dr. Sambur emphasizes that "SAMPs and ASPs that lack the necessary and sufficient attention to SE shall not be approved." Note that SAMP is Single Acquisition Management Plans and ASP is Acquisition Strategy Panel. This memo contains other details emphasizing the importance of systems engineering, but the point is that systems engineering is a mandated part of the acquisition process.

Additional policy documents also emphasize the importance of systems engineering. On February 20, 2004, Mr. Michael Wynne, the Acting Under Secretary of Defense, Acquisition, Technology & Logistics, issued a policy memo titled "Policy for Systems Engineering in DoD" (USD(AT&L)). In addition to emphasizing the importance of systems engineering, this memo also states that the Systems Engineering Plan (SEP) must be presented to the Milestone Decision Authority (MDA) at each Milestone review in the program, which repeatedly highlights the importance of systems engineering throughout the program. This memo states the following.

"Application of rigorous systems engineering discipline is paramount to the Department's ability to meet the challenge of developing and maintaining needed warfighting capability. This is especially true as we strive to integrate increasingly complex systems in a family-of-systems, system-of-systems, net-centric warfare context. Systems engineering provides the integrating technical processes to define and balance system

> performance, cost, schedule, and risk. It must be embedded in program planning and performed across the entire acquisition life cycle...
>
> All programs responding to a capabilities or requirements document, regardless of acquisition category, shall apply a robust SE approach that balances total system performance and total ownership costs within the family-of-systems, systems-of-systems context. Programs shall develop a Systems Engineering Plan (SEP) for Milestone Decision Authority (MDA) approval in conjunction with each Milestone review, and integrated with the Acquisition Strategy. This plan shall describe the program's overall technical approach, including processes, resources, metrics, and applicable performance incentives. It shall also detail the timing, conduct, and success criteria of technical reviews."

National Security Space Acquisition Policy also emphasizes the importance of systems engineering. In Policy Number 03-01 (NSS 2004) from December 27, 2004, section AP1.1.5, Systems Engineering (SE) states, "Robust SE is essential to the success of any program. Program offices must focus attention on the application of SE principles and practices including software-intensive systems management, throughout the system life cycle. Program offices must elevate these SE principles to a level commensurate with other programmatic considerations such as cost and schedule."

2.1.2 Importance of Systems Engineering Workforce Issues

Numerous high-level policy statements and presentations highlight the importance of enhancing the systems engineering workforce as well. In the Policy Memo 03A-005 "Incentivizing Contractors for Better Systems Engineering" cited above (SAF/AQ 2003), the Assistant Secretary of the Air Force for Acquistion Dr. Martin Sambur also says that, "We are identifying ways to improve SE throughout the acquisition process, including workforce issues such as education and training..."

In a presentation called "Implementing OSD System Engineering Policy" that Mr. Bob Skalamera gave at the Defense Acquisition University (Skalamera 2004), he states that we "need new ways to attract and develop systems engineers" and that we "need a better approach" to deal with the resource picture. He also says that, "Existing university/industry partnerships are not having enough impact." In this same presentation, the key elements of Systems Engineering Revitalization are given, as shown in Figure 2-1. One of these key elements is "Training/Education"; however, it is interesting to note that courses are the only interventions listed. Alternate inventions like experiential training programs and mentoring are not listed.

In a presentation in July 2005 by Mark Schaeffer, the Principal Deputy Director, Defense Systems and Director, Systems Engineering for the Office of the Under Secretary of Defense (AT&L), he said that one of the top five systems engineering issues is that, "adequate, qualified resources are generally not available within government and industry for allocation on major programs" (Schaeffer 2005). He goes on to say that the resources are outweighed by the challenges, that the "degreed workforce is a shrinking pool" and that we "need new ways to attract and develop system engineers."

In January 2003, a task group sponsored by the National Defense Industrial Association (NDIA) Systems Engineering Division identified five top issues in systems engineering in the defense industry complex (NDIA 2003). One of these top five issues was, "Adequate, qualified resources are generally not available within Government and industry for allocation on major programs." The report states that, "An experienced, trained workforce is in short supply." This again emphasizes the importance of systems engineering workforce issues.

The importance of studying both systems engineering and systems engineering workforce issues is apparent. Even though there are considerable methodological and theoretical challenges in studying the development of systems engineers and the systems thinking development process, the importance of this topic makes tackling the challenge worthwhile.

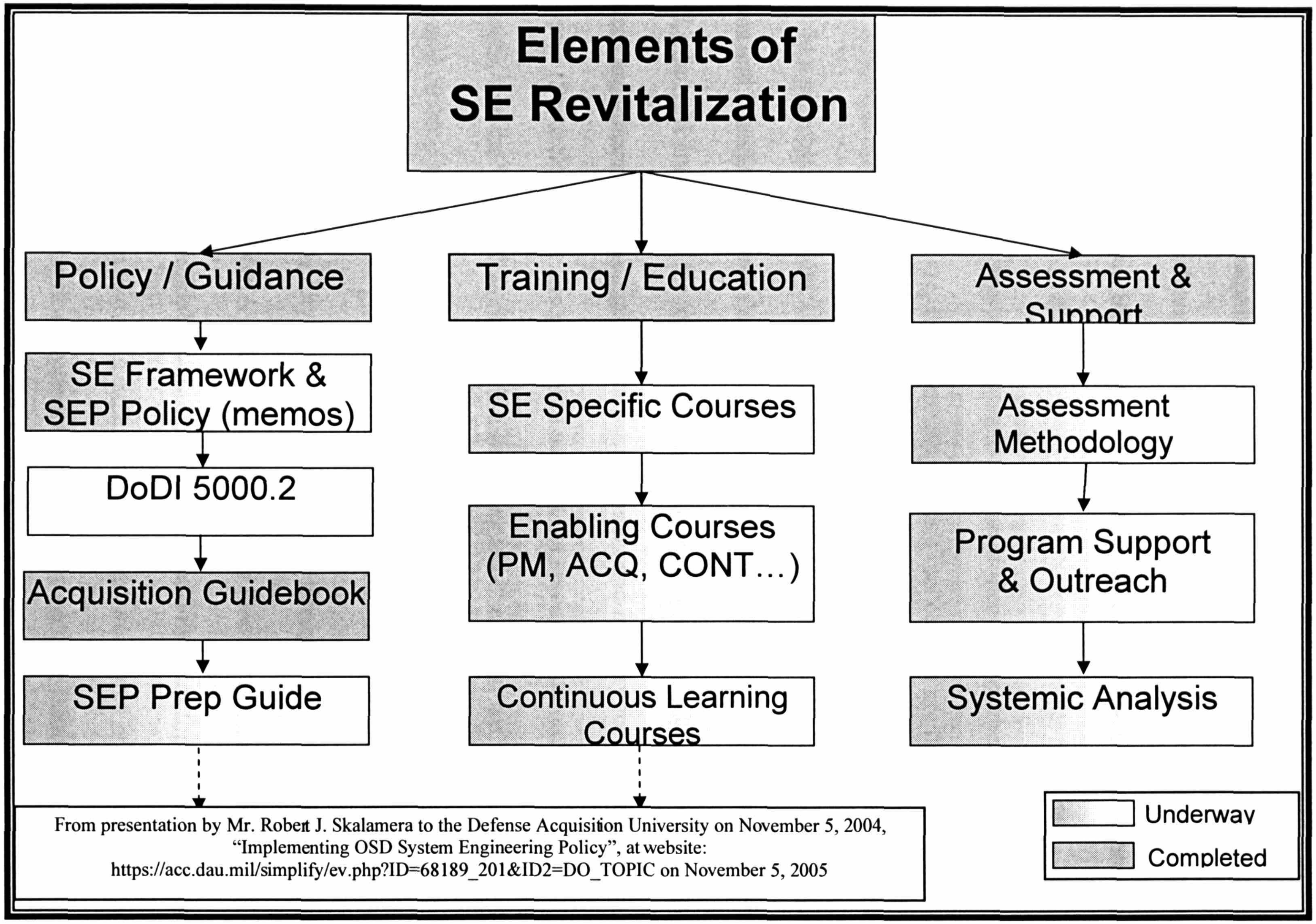


Figure 2-1: Elements of SE Revitalization from Mr. Robert Skalamera

2.1.3 Benefits of Systems Thinking for an Organization

Organizations benefit from developing systems thinking in their employees. The development of systems thinking expedites integration across the organization, which can enhance performance and increase value.

2.1.3.1 Benefits for the Organizational Elements

Systems thinking has benefits for an organization's elements of processes, stakeholders, technology, structure, and information. First, systems thinkers can optimize processes within the organization. Value stream mapping is one tool used to promote systems thinking. As employees map the processes of the organization, they can better understand what is considered waste in the system. Once identified, corrections can be made to eliminate waste, monuments, and misalignments in the organization. If systems thinkers are continuously thinking about the performance of the organization system, they may be drawn to continuously improving that system.

Systems thinking can help balance the needs of the organization stakeholders. Once the needs of the stakeholders are identified and valued by the organization, each stakeholder may benefit. Customers may receive better products and improved service. Employees may gain internal work motivation, growth satisfaction, and more experienced meaningfulness. Shareholders may benefit from increased profits due to efficient processes. While considering the value stream of the organization, systems thinkers may incorporate suppliers in the optimization of the system. Suppliers may benefit from smoother interfaces with the organization. Systems thinkers may consider the needs of the local community when making decisions that could affect the community. Benefits could include decreases in pollution, noise, traffic and job cuts, along with increases in community service volunteers and community service donations.

Systems thinkers may help expedite the development of technology by an organization. A functional design specialist trained in systems thinking may better understand the needs of the upstream and downstream functional specialists, which could help expedite the systems integration process. If a designer understands the concerns of manufacturing, some assembly problems may be avoided. In an extreme example, if a designer thinks systemically on the global scale, perhaps the designer could use recyclable or at least environmentally friendly materials in his or her design. This could help an organization if they are seeking the approval of stakeholders interested in environmental issues.

The organizational structure can also be impacted by systems thinkers. Systems thinkers could set up organizational forms to promote systems thinking. Systems thinking could help promote communication and learning across functional boundaries. If systems thinking could become a norm in an organization, a cycle could be established to continuously build and reward structures that promote systems thinking.

Systems thinking could also impact how information is shared across the organization. This could lead to increased sharing of information on a broader scale. Systems thinkers could establish efficient knowledge and information sharing tools. For example, a functional specialist with an optimization question could log-on to a central company website and ask an "optimization specialist" a question. Although that optimization specialist sits in a completely different division in a different country, the functional specialist could receive an answer in a couple hours to a question that could have taken a week to figure out. Organization systemic thinking can lead to information systems which expedite the transfer of information.

2.1.3.2 Benefits for Understanding Organizational Context

Systems thinking can also aid in the identification of changes in the context outside of the organization. These changes could be of a political, economic, environmental, or cultural nature. For example, in the aerospace industry, the end of the Cold War triggered changes in the acquisition environment (Murman, Allen et al. 2002). Systems thinkers can help an organization understand the macro cycles in which it is embedded.

2.1.3.3 Benefits for Organizational Value, Integration, and Performance

If employees in the organization understand where value is created in the organization, they can better understand how to best contribute to the creation of value. Systems thinking can help with the creation of overall organization value. However, organization value is also subjective for each stakeholder. If, in the past, a for-profit organization has optimized its performance only for shareholders, systems thinkers who may be incorporating the needs of other stakeholders, could decrease organization value for the shareholder. Pleasing employees, customers, and environmentalists may take away from profits. Nonetheless, improved performance due to efficient processes and improved integration may make up the difference. Systems thinking could increase the organization value for stakeholders not traditionally considered.

As senior managers consider the priorities of the organization, systems thinking can help with integration across the organization elements (stakeholders, processes, technology, organization, and information). Theoretically, they could look at the organization as a whole and balance the needs of the elements. Systems thinking could also help employees at lower levels in the organization see the whole organization, which could also help integration efforts. Integration of key organization elements could increase the agility and speed of the organization. Improved performance across all the elements of the organization, coupled with enhanced integration, could lead to improved performance for the overall organization.

How much systems education and training should each member in the organization receive? Even if an employee is acting as a functional specialist, it is important for that employee to understand the larger systemic context. No matter how technical the work, scientific activity does not happen in isolation (Latour 1987). There are always interfaces and contexts involved in technical work. Certainly, systems education and training will resonate more with some employees than others. Not all members of the organization are tasked to the same role in the organization system, and some employees should receive more systems education and training than others. Nonetheless, it is important for all employees in the value stream to understand the organization as a system.

2.2 Construct Challenges

2.2.1 Construct Definition

It is important to note that the goal of this research study is not to generate yet another definition for systems thinking. The goal of this research is to understand enablers, barriers, and mechanisms to develop systems thinking. Definition discussions are necessary in the process, but the definitions are NOT the goal of this research.

2.2.1.1 Variety of Systems Definitions

The definition of the word "system" is relative. There are a plethora of definitions and understandings for this word, and Table 2-1 shows multiple definitions for this word. Since the definition for "systems thinking" follows from the definition for "system", there is likewise a morass of misunderstanding surrounding this phrase as well. In addition, the phrase "systems engineering" has different definitions and actualizations in different communities of practice.

The original intent of the study was to understand how engineers develop systems thinking, using a very broad definition of systems thinking. By studying complex engineering systems, the Engineering Systems Division (ESD) at the Massachusetts Institute of Technology (MIT) aims to broaden engineering practice to include the context of each technical challenge as well as the consequences of technological advancement. The ESD understanding of a system includes interactions, interrelationships, and interdependencies that are technical, social, temporal, and multi-level. This system definition was the original basis for this study.

Table 2-1: Variety of Systems Definitions

	INCOSE Systems Engineering Handbook (INCOSE 2004)	**NASA Systems Engineering Handbook (NASA 1995)**	**DAU Systems Engineering Fundamentals Guide (DAU 2001)**	**MIT ESD Internal Symposium Committee Overview (ESD 2002))**
System	"An integrated set of elements that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements."	"A *system is* a set of interrelated components which interact with one another in an organized fashion toward a common purpose. The components of a system may be quite diverse, consisting of persons, organizations, procedures, software, equipment, end 'or facilities."	"Simply stated, a system is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective.	"A set of interacting components having well-defined (although possibly poorly understood) behavior or purpose; the concept is subjective in that what is a system to one person may not appear to be a system to another"
Systems Engineering	"An interdisciplinary approach and means to enable the realization of successful systems. (The above definition of Systems Engineering is recommended by the INCOSE.)"	"*Systems engineering is* a robust approach to the design, creation, and operation of systems...""	"Systems engineering consists of two significant disciplines: the technical knowledge domain in which the systems engineer operates, and systems engineering management… Three commonly used definitions of systems engineering are provided by the best known technical standards that apply to this subject…" (proceeds to cite MIL-STD-499A, EIA Standard IS-632, and IEEE P1220)	"A process for designing systems that begins with requirements, that uses and/or modifies an architecture, accomplishes functional and/or physical decomposition, and accounts for the achievement of the requirements by assigning them to entities and maintaining oversight on the design and integration of these entities…"

It is important to remember the embedded nature of systems. What is considered a holistic, systems view is considered a reductionist view when the boundaries of the system are redrawn. Considering an aircraft engine, a "system" could be a part (a set of compressor blades called a compressor stage), a component (a compressor), a sub-system (an aircraft engine), a product system (an aircraft), a group of design engineers (advanced compressor design group), a business (GE Aircraft Engines), a nation (the U.S.A.), a sector (the aerospace sector), or the global system (sustainable air transportation). The definition of a system is driven by the end-state or application of interest. This is a reality in many fields. For example, in social psychology, one may focus work at the individual level of analysis, remembering there are also contributions from the other levels of analysis, such as the group and organizational levels of analysis.

There are phrases using the term "system" which have very specific meanings. "System dynamics" is a specific area of study especially concerned with temporal feedback. This is the program of study pioneered by Jay Forrester and now led by John Sterman, Nelson Repenning and others (Society 2005). Note that in classical control theory the same phrase "system dynamics" relates to very different subject content, the modeling and response of physical systems. The subject "systems engineering" traditionally relates how components in a product interact with each other, though this is evolving. In contrast, the current term "engineering system" relates to how technical and social components interact with the broader enterprise.

2.2.1.2 *Thinking*

In a study of the development of systems thinking, it is important to understand the construct of thinking. This begins with understanding the nature and workings of the brain. A discussion of the physiology of thinking provides a foundation for understanding the relevant modes of thought in the human brain. In addition, a key question is whether systems thinking is innate or if it can be taught, and better understanding of the physiology involved in systems thinking may answer this.

The brain is a vast complex of brain cells, called neurons, which may receive impulses from hundreds of thousands of connecting brain cells every second. Tony and Barry Buzan explain that, "As a given message, or thought, or re-lived memory is passed from brain cell to brain cell, a biochemical electromagnetic pathway is established. Each of these neuronal pathways is known as a 'memory trace'" (Buzan and Buzan 1993). Repetition eases these memory traces.

> "Every time you have a thought, the biochemical/electromagnetic resistance along the pathway carrying that thought is reduced. It is like trying to clear a path through a forest. The first time is a struggle because you have to fight your way through the undergrowth. The second time you travel that way will be easier because of the clearing you did on your first journey. The more times you travel that path, the less resistance there will be, until, after many repetitions, you have a wide, smooth track which requires little or no clearing. A similar function occurs in your brain: the more you repeat patterns or maps of thought, the less resistance there is to them. Therefore, and of greater significance, repetition in itself increases the probability of repetition. In other words, the more times a 'mental event' happens, the more likely it is to happen again."

The two hemispheres of the cerebral cortex are sometimes referred to as the "right brain" and "left brain". The right brain dominates rhythm, spatial awareness, gestalt (wholeness), imagination, daydreaming, color, and dimension. The left brain dominates words, logic, numbers, sequence, linearity, analysis, and lists. However, both hemispheres have the capacity for all areas, and these skills are distributed throughout the cortex. Though common understanding is that individuals have a preference for either right brain or left brain thinking, Buzan and Buzan challenge this.

> "The current fashion for labeling people either left- or right-side dominant is therefore counter-productive… Saying 'I am bad at or do not possess mental skill X' is both an untruth and a misunderstanding. If one is weak in any skill area, the correct statement must be 'I have yet to develop mental skill X.' The only barrier to the expression and application of all our mental skills is our knowledge of how to access them."

Some individuals are considered more whole-brained and equally proficient at both modes. One opinion is that systems thinkers are whole-brained. However, depending on the characteristics of the "systems thinking" desired, this may or may not be true. For example, if gestalt (wholeness) is desired, right-brain dominance would be desired. If logical, sequential tracing of requirements is desired, left-brain dominance would be desired. If both gestalt and logical thinking are desired, whole-brained dominance would be desired. The desired brain dominance depends on the mode of systems thinking desired.

Various adjectives often accompany the term "thinking." These include logical thinking, lateral thinking, parallel thinking, radiant thinking, holistic thinking, reductionist thinking, critical thinking, creative thinking, etc. It is premature to claim that "systems thinking" is a combination or subset of any of these types of thinking without understanding the context of the use of the phrase "systems thinking."

When interventions are being designed to develop systems thinking, it is valuable to keep the psychology of learning and remembering in mind. Buzan and Buzan also state that, "the human brain primarily remembers the following:

- Items from the beginning of the learning period ('the primacy effect')
- Items from the end of the learning period ('the recency effect')
- Any items associated with things or patterns already stored, or linked to other aspects of what is being learned
- Any items which are emphasized as being in some way outstanding or unique
- Any items which appeal particularly strongly to any of the five senses
- Those items which are of particular interest to the person."

The most effective systems thinking interventions could be designed considering these elements. People who are inherently interested in system level issues would then be more likely to remember systems knowledge. Systems thinking interventions that include work experiences or life experiences engage more of the five senses and establish a pattern of systems learning, so these interventions are more likely to be remembered.

2.2.1.3 Variety of Systems Thinking Definitions

The phrase "systems thinking" has a plethora of definitions and understandings. Table 2-2 shows a variety of systems thinking contributions and Table 2-3 shows a variety of systems thinking definitions. These are just a sample of the systems thinking interpretations in the broadly dispersed literature on the topic.

Peter Senge views systems thinking as the fifth discipline in a learning organization (Senge 1990) (Senge, Kleiner et al. 1994). Senge says that the core of a learning organization is based upon five learning disciplines, which are lifelong programs of study and practice. The disciplines are personal mastery, mental models, shared vision, team learning, and systems

Table 2-2: Examples of the Variety of Systems Thinking Contributions

Reference	Contribution	Key Concepts
Peter Checkland	Soft Systems Methodology	"Hard" versus "soft" systems thinking, process for examining management situations, action research
Jamshid Gharajedaghi	Iterative Design	Simplify complexity, manage interdependency, understand choice in organizational systems
Barry Richmond	Advances in system dynamics	System dynamics, applying seven critical systems thinking skills simultaneously
Peter Senge	The Learning Organization	System dynamics, feedback
Ludwig von Bertalanffy	General System Theory	Open systems theory, equifinality, teleology

thinking, and it is systems thinking that brings the disciplines together. He uses the basics of systems dynamics to emphasize the concepts of feedback and dynamic complexity, where cause and effect are not always closely related in time and space and small changes can produce big results.

A biologist named Ludwig von Bertalanffy was the creator of general system theory, a theory which seeks universal principles applying to systems in general (von Bertalanffy 1968). As Bertalanffy states, "General system theory, then, is scientific exploration of 'wholes' and 'wholeness' which, not so long ago, were considered to be metaphysical notions transcending the boundaries of science." The theory of open systems is part of general system theory. Open systems are systems which are not considered to be isolated from their environment. The theory of open systems has led to the principle of equifinality, where the same final state may be reached from different initial conditions and in different ways. Open systems may also import entropy which may well be negative, so "living systems, maintaining themselves in a steady state, can avoid the increase of entropy, and may even develop towards states of increased order and organization." Contrary to one-way causality, open systems display teleological or directed behavior, where feedback is used to seek and maintain a final goal using circular causal chains.

Table 2-3: Examples of Systems Thinking Definitions

Reference	Term	Definition
Eberhardt Rechtin (Rechtin 2000)	System (or systems) approach	"A management process in which virtually all decisions in all elements and subelements are made based upon the effects on the system and its functions as a whole."
Peter Checkland (Checkland 1999)	Systems thinking	"An epistemology which, when applied to human activity is based upon the four basic ideas: emergence, hierarchy, communication, and control as characteristics of systems. When applied to natural or designed systems the crucial characteristic is the emergent properties of the whole."
Jamshid Gharajedaghi (Gharajedaghi 1999)	Systems thinking	"It puts the system in the context of the larger environment of which it is a part and studies the role it plays in the larger whole."
Peter Senge (Senge, Kleiner et al. 1994)	Systems thinking	"A way of thinking about, and a language for describing and understanding, the forces and interrelationships that shape the behavior of systems."
ESD Symposium Committee (ESD 2002)	System thinking	"includes holism, an ability to think about the system as a whole; focus, an ability to address the important system level issues; emergence (see below), recognition that there are latent properties in systems; and trade-offs, judgment and balance, which enable one to juggle all the various considerations and make a proper choice"
John Sterman (Sterman 2000)	Systems thinking	"the ability to see the world as a complex system, in which we understand that 'you can't just do one thing' and that 'everything is connected to everything else."
Pegasus Communications Systems Thinking Newsletter (http://www.thesystemsthinker.com)	Systems thinking	"Systems thinking is a way of understanding reality that emphasizes the relationships among a system's parts, rather than the parts themselves. Based on a field of study known as system dynamics, systems thinking has a practical value that rests on a solid theoretical foundation."

As Peter Checkland sought to apply the systems engineering approach to management situations, he developed a new approach he termed the Soft Systems Methodology. In his book "Systems Thinking, Systems Practice," he discusses the application of this approach (Checkland 1999). One of the key ideas is the differentiation of "hard" systems thinking versus "soft" systems thinking. In "hard" systems thinking, systems are viewed as entities in the world which can be engineered. The term "soft" systems thinking is the process of inquiry, the process of dealing with the world. As Checkland says, "Thus the use of the word 'system' is no longer applied to the world, it is instead applied to the process of our dealing with the world. It is this shift of systemicity (or 'system-ness') from the world to the process of inquiry into the world which is the crucial intellectual distinction between the two fundamental forms of systems thinking, 'hard' and 'soft'." A misunderstanding is that "hard" refers to technical systems and "soft" refers to social systems. Checkland clarifies this.

> "In the literature it is often stated that 'hard' systems thinking is appropriate in well-defined technical problems and that 'soft' systems thinking is more appropriate in fuzzy ill-defined situations involving human beings and cultural considerations. This is not untrue, but it does not define the difference between 'hard' and 'soft' thinking. The definition stems from how the word 'system' is used, that is from the attribution of systemicity."

In his book "Systems Thinking: Managing Chaos and Complexity, A Platform for Designing Business Architecture," Jamshid Gharajedaghi presents a methodology to simplify complexity, manage interdependency, and understand choice (Gharajedaghi 1999). As the author states, "This systems language, by necessity, will have two dimensions. The first will be a framework for understanding the nature of the beast, the behavioral characteristics of multiminded systems. The second will be an operational systems methodology, which goes beyond simply declaring the desirability of the systems approach and provides a practical way to define problems and design solutions." Gharajedaghi uses five systems principles to define the characteristics and behavior of an organizational system. These are: openness, purposefulness, multidimensionality, emergent property, and counter-intuitiveness. This author also has an interesting perspective of the evolution of systems thinking.

> "…systems thinking has already gone through three distinct generations of change. The first generation of systems thinking (operations research) dealt with the challenge of interdependency in the context of mechanical (deterministic) systems. The second generation of systems thinking (cybernetics and open systems) dealt with the dual challenges of interdependency and self-organization (neg-entropy) in the context of living systems. The third generation of systems thinking (design) responds to the triple challenge of interdependency, self-organization, and choice in the context of sociocultural systems."

In an effort to separate his work from that of Jay Forrester, Barry Richmond uses the term "systems thinking" as a replacement for the term "system dynamics" (Richmond 1993). Nevertheless, his definition of "systems thinking" is similar to the contemporary understanding of the phrase "system dynamics" now used by John Sterman at MIT. Barry Richmond suggests seven critical systems thinking skills, and he suggests that good "systems thinking" means operating on at least seven thinking tracks simultaneously. He considers the seven critical systems thinking skills are as follows.

- Skill 1: Dynamic thinking is the ability to see and deduce behavior patterns rather than focusing on, and seeking to predict, events.
- Skill 2: Closed-loop thinking is the ability to look to the loops themselves (i.e., the circular cause-effect relations) as being responsible for generating the behavior patterns exhibited by a system.
- Skill 3: Generic thinking is the ability to apprehend the similarities in the underlying feedback-loop relations that generate cycles.
- Skill 4: Structural thinking requires people to think in terms of units of measure or dimensions. The distinction between a stock and a flow is emphasized

- Skill 5: Operational thinking is closely linked to structural thinking. Thinking operationally means thinking in terms of how things really work.
- Skill 6: Continuum thinking involves working with simulation models that have been built using a continuous, as opposed to discrete, modeling approach.
- Skill 7: Scientific thinking encompasses rigorous hypothesis-testing. It has more emphasis on quantification than on measurement. People thinking scientifically modify only one thing at a time and hold all else constant.

In his book, "Rethinking the Fifth Discipline: Learning Within the Unknowable," Robert Louis Flood compares and contrasts Ludwig von Bertalanffy's open systems theory, Stafford Beer's organizational cybernetics, Russell Ackoff's interactive planning, Peter Checkland's soft systems approach, and C. West Churchman's critical systemic thinking (Flood 1999).

Table 2-3 shows examples of the diversity of systems thinking definitions. Although there are multiple systems thinking perspectives, there are commonalities. These commonalities include feedback, temporal concerns, complexity, structure, relationships, behavior, interdisciplinary knowledge, multidisciplinary knowledge, elements making up a whole, and practical implementation.

2.2.1.4 Lack of Central Discussion

One key limitation of the systems thinking literature is that there is not a central, ongoing discussion. The systems thinking literature is found in disparate fields and journals, from systems dynamics to systems engineering to general philosophy. Additional insights can be gained from social psychology, personality psychology, organizational behavior, cybernetics, biology, history, anthropology, and other bordering literatures. A clear reason for this detached discussion is that the definition of systems thinking is still quite elusive. As the definition of "systems thinking" evolves, it is questionable whether existing research results are generalizable to a broader definition of systems thinking.

For example, using the work of Richmond, the simultaneous application of his seven critical systems thinking skills may not be applicable to a broader systems thinking definition. Depending on the scale of the system considered, the system might be open-loop. In addition, rigorous hypothesis-testing might be limiting if the objective is to synthesize the creation of a new system where multiple factors are modified simultaneously. Certainly, these thinking skills each have specific times when they are valuable; however, the simultaneous application of all seven critical systems thinking skills is valid for only a limited system application.

2.2.1.5 Moving Beyond Philosophy

Another problem is that some of the writing on this topic lacks analytic rigor and supporting data or models. Various writings about systems thinking are philosophies, heuristics, lay theories, and opinions. One interpretation of systems thinking may be as valid as the next. Unless control cases are used, there is no way to know if the application of one systems thinking methodology is more helpful than the application of another systems thinking methodology. Thus, various writing in this field remains at the level of philosophical treatises. If "systems thinking" is as important as industry and government representatives claim, there is a need for resources to develop this literature in an analytically rigorous and relevant way where broad claims then undergo evaluative research testing.

2.2.1.6 Applications for this Research

The ambiguous state of this nomenclature is not going to be resolved in this dissertation. However, the research must be designed in a way to acknowledge the breadth of interpretations possible for these terms. Likewise, the data analysis must also accommodate varying interpretations. The compensations for these varying definitions are discussed in detail later in this document.

2.2.2 Linking Systems Thinking to Systems Engineering

There has been some question as to whether "systems thinking" and "systems engineering" are related constructs. Those ideas are discussed here.

2.2.2.1 Scope

As the scope and complexity of engineering systems grow, the thinking skills of systems professionals must also evolve. Systems professionals are needed to address a new generation of problems, and this arena has been referred to as systems-of-systems, complex systems engineering, enterprise systems engineering, or engineering systems. An example program is the Future Combat System, which is envisioned by the United States Army as an elaborate network of manned and unmanned systems, connected by a common and robust network, to provide each node enhanced, real-time information (Army 2005). This very large, complex engineered system is the type of system of interest to MIT's ESD. Ideally, the hope for this research would be to see how the systems professional's thinking skills develop to support this type of system. However, the official job classification for this professional does not exist in many organizations, so this is hard to operationalize. Thus, the operationalized focus of this research is on the "senior systems engineer", since this is a formal job position and a recognizable term in most of the organizations studied.

Nonetheless, the role of the "senior systems engineer" has varied across organizations. In some of the organizations studied, systems engineers did indeed work at the level of systems-of-systems and complex systems engineering. On the other hand, a person who is considered a senior systems engineer in one company may be considered narrow and inadequate by the standards of another company. What is considered a holistic, systems view is considered a reductionist view when the boundaries of the system are redrawn. Senior systems engineers work at all levels of system boundaries. Efforts of the International Council on Systems Engineering (INCOSE) to establish a Professional Certification Program address this problem, since this type of certification provides a formal method for recognizing that a person has achieved competency in certain skills (INCOSE 2005).

2.2.2.2 Adequacy

Although "systems thinking" is necessary for senior systems engineers, it is not sufficient. In addition to systems thinking ability, these individuals must also execute and perform to be successful systems engineers. Nonetheless, in order to accelerate the development of senior systems engineers, one could first enable and expedite the development of "systems thinking."

2.2.2.3 Systems Thinking

The thinking utilized by senior systems engineers is thus the type of "systems thinking" examined in this study. For this research, the original working definition of systems thinking was, "analysis, synthesis, and understanding of interconnections, interactions, and interdependencies that are technical, social, temporal, and multi-level." As discussed previously, the definition of the word "system" is relative, and it is important to remember the embedded nature of systems. Senior systems engineers work at all levels of system boundaries, and the definition of a system is driven by the end-state or application of interest.

As perceived by the employer, the aptitude of a systems engineer is not always independent of the system in which that professional is working. Although the required skills for a senior systems engineer vary across organizations and across expanding system definitions, there is a common thinking about interconnections, interactions, interdependencies and feedback that persists.

2.2.3 Level of Analysis

The term "systems thinking" is somewhat a paradox, since this phrase combines words that imply individual and multi-actor concepts into one research construct. This creates difficulties in selecting the unit and level of analysis. Following is a discussion of considerations when choosing the unit and level of analysis for the study of systems thinking. In addition, key issues at the individual, group, organizational, and institutional levels of analysis are discussed, and these are summarized in Table 2-4.

Table 2-4: Factors Affecting Systems Thinking Development at Each Level of Analysis

Level of Analysis	Factors Affecting Systems Thinking Development
Individual	Personality
	Aptitude
	Task Assignment
	Affect
	Experience
Group	Diversity of Group
	Group Skills
	Group Task
	Emotional Contagion
	Group History
Organizational	Strategy
	Time
	Structure
	Function
Institutional	Government acquisition standards
	Government certification standards
	Professional Associations
	University Departments
	Industry Career Paths

2.2.3.1 Unit of Analysis

A unit of analysis is the entity being described or analyzed during a research study. A typical unit of analysis could be an individual person, a social role, a relationship, a social grouping like a family, an organization, a city, or even a social artifact like a book (Singleton and Straits 1999). Four standard levels of analysis in social science are individuals, groups, organizations, and environments. The individual, group, organizational, and environmental lenses are of key importance in this research topic. Individual characteristics, group dynamics, organizational culture, and surrounding environment may all affect the development of systems thinking. Multi-level interactions may also impact this development.

2.2.3.2 Individual Level of Analysis

At the individual level of analysis, "systems thinking" involves the thinking of one individual about the system's interactions, interrelationships, and interdependencies of a technical, social, socio-technical, or multi-level nature. This is an individual thinking about the "whole system". Factors that explain the phenomenon of systems thinking at the individual level of analysis include: personality, aptitude, task assignment, affect, and experience. All the factors listed are measured in an individual, which is why they are classified at the individual level of analysis. These are characteristics for one person at any particular time when a study might be initiated. With varying levels of proof, these characteristics promote systems thinking at the individual level.

It is important to note that each individual-level construct is simultaneously affected by multi-level dynamics and temporal state. At any given time, any construct at the individual level of analysis is simultaneously influenced by constructs at the group, organizational, and institutional levels of analysis. In addition, any construct at the individual level of analysis at any given time is simultaneously influenced by past and future states. Using the "experience" construct as an example, a worker with thirty years of work experience at the time the study is initiated once had no work experience, which is the temporal condition. The previous organizational and group multi-level dynamics during each state of those thirty years all contribute to the current state of the construct "experience."

Furthermore, the threshold to the classification of "systems thinker" is relative. When is a person's thinking considered "reductionist" and when is a person's thinking considered "systems thinking"? This is relative to the system in which the person is embedded. One level's "systems thinker" might be considered a "reductionist thinker" at the next level of a series of embedded systems.

2.2.3.2.1 ***Personality***

Personality characteristics may contribute to systems thinking. Cross and Vick use a construct called the interdependent self-construal, which is when individuals define the self in terms of relationships (Cross and Vick 2001). Though measures of the interdependent self-construal are scarce, the authors use the Connectedness Scale designed by Rude and Burnham to measure the construct of interdependent self-construal. Women in the U.S. culture are generally socialized to construct an interdependent self-construal, and men are socialized to be more independent and autonomous. Nonetheless, in their study linking self-construal to persistence in engineering, the authors found that female engineers were less interdependent than the other women in the sample. The authors point out that, "Members of many ethnic minorities, such as Hispanics, African Americans, and Asian Americans tend to define themselves in terms of close relationships and interdependence with others." Though it seems logical to say that those who define themselves in terms of their relationships with others will be strong systems thinkers, one could also test if high scores on the Connectedness Scale predict strong systems thinking performance.

Toshima has produced an integrated aptitude test for system engineers, which includes intellectual abilities and personality factors (Toshima 1993). This test relates specifically to system engineers in the information processing context. From this point of view, "the task of the system engineer (SE) is basically to analyze transactions and business functions through Electric Data Processing operations. Thus it can be said that the function of the SE is to integrate and unify various functions so as to establish a complete information processing system." Again, this application refers to a specific, not general, view of systems thinking. Nonetheless, Toshima has linked personality to systems engineering aptitude.

2.2.3.2.2 ***Aptitude***

Certainly, aptitude affects systems thinking. Of course, if a person is formally trained in systems thinking and has developed an aptitude for the subject, that person is more likely to think systemically. People who can cognitively handle more complexity may also be more prone to high quality systems thinking (Hirschi and Frey 2002). In addition, the systems professional role requires spanning multiple disciplinary boundaries. The more knowledge an individual can amass in each area, the better the understanding of the system. Though it requires omniscience to completely understand a complex system with all the corresponding dynamics, individuals with superior intellect and aptitude have an advantage.

Social aptitude may also be important. In order to understand the social interdependencies and interactions in systems, social perception and social cognition may be needed. Individuals differ in their social perception and social cognition abilities. Social perception is also influenced by prior expectations, biases, and schemas of the perceiver (Fiske and Taylor 1991), (Carroll 1993).

2.2.3.2.3 ***Task Assignment***

Assigned work tasks affect systems thinking. A managerial position may force one to think more systemically, particularly regarding social interdependencies in the system. Working in a test or manufacturing environment also enables systems thinking, since the daily work tasks require coordination across disciplines and departments. Of course, being assigned responsibility for the performance of a system forces a person to develop systems thinking.

2.2.3.2.4 ***Affect***

The affective state of the individual may also contribute to systems thinking performance. Compared to people in negative or neutral states, people who experience positive emotions tend to choose global configurations (Fredrickson 2003). On global-local processing tasks, they tend to see the "big picture" instead of focusing on smaller, local details. Assessed by self-report or electromyographic signals from the face, positive emotions broaden an individual's momentary mindset.

2.2.3.2.5 ***Experience***

The amount of work experience may also contribute to the level of systems thinking. Senior employees may be more prone to better systems understanding (Crawley, de Weck et al. 2004). Perhaps those employees have learned the importance of systems thinking from earlier work roles. In the case of systems thinking about a particular system, the amount of experience with that specific system may improve the level of systems thinking. Limited perspective taking and naïve realism (Ross and Ward 1996) may also prevent systems thinking. This may also be linked to the amount and type of experience an individual has had.

2.2.3.3 Group Level of Analysis

Thinking is generally considered an individual concept, but the collective thinking of a group is not a new concept. Janis' concept of "groupthink" is one of the more popular examples (Janis 1983), though it signifies a dynamic that is often counter to systems thinking. At the group level of analysis, systems thinking is the collective thinking of a group about a much larger multi-actor system. With a group, this involves both the thinking of individuals *and* the communication of those thoughts in the group. Collective systems thinking is produced by the communication and dynamics of the group. With the right group dynamics, the systems thinking produced by the group may be much greater than the contribution by any of the members.

This leads to the extensive literature on group dynamics. The most brilliant systems thinker contributes nothing to the group's level of systems thinking if he or she does not, or cannot, influence the group. On the contrary, minority influence may also be factor. Perhaps a systems thinker is more influential than other team members, since the systems thinker may understand the concerns of multiple team members and lead the reconciliation of differences. Communication and group dynamics dictate the level of systems thinking produced by a group.

Factors at the group level of analysis that explain the phenomenon of systems thinking include: diversity of the group, group skills, group task, emotional contagion, and group history.

All the factors listed are measured for a group, which is why they are classified at the group level of analysis. These are characteristics for one group at any particular time when a study might be initiated. As in the case of individual level constructs, it is important to note that each of these constructs is affected by multi-level dynamics and temporal state.

2.2.3.3.1 ***Diversity of Group***

The amount of diversity in the group may contribute to systems thinking. This could be either ethnic or substantive diversity. Although a direct correlation between diversity in groups and systems thinking has not been proven, there are indications in the group literature that there may be a connection. Ethnic diversity improves creativity in small groups on brainstorming tasks (McLeod, Lobel et al. 1996). Janis shows that too much cohesion in a group can lead to excessive concurrence-seeking (Janis 1971) which might limit the contributions of a group member who knows about a part of the system that others in the group do not. Increased diversity is also associated with increased conflict, which can have a constructive or a destructive impact on systems thinking by individuals in the group.

2.2.3.3.2 ***Group Skills***

The collective skills in the group can contribute to the level of the group's systems thinking. In general, groups combine the output of individuals in five ways: by disjunctive, conjunctive, additive, compensatory, and configural processes (Hackman 2003). Further research may indicate how the group's systems thinking develops, but for now, all categories are considered since it is not clear which category fits a systems thinking task. A disjunctive process is where the group's performance is a function of how well the best member in the group performs. In a disjunctive process, if one key member of the group is well-trained or experienced in systems thinking, the group's systems thinking can be improved. In a conjunctive process, the group functions at the level of the least competent member. In this case, it may be appropriate to ensure that the least competent member of the group is sufficiently trained in systems thinking. In an additive process, the group's productivity is a sum of the individual's contributions. If many of the members in the group are well-trained or experienced in systems thinking, the group's systems thinking may be improved. In a compensatory process, the group decision is better than any individual's since errors cancel each other. A configural process is a combination of the other processes.

2.2.3.3.3 ***Group Task***

The task that is assigned to the group can affect systems thinking. If the group is called to lead the management of a large, complex, engineered system, hopefully the group's level of systems thinking will be superior. The complexity of the task at hand may draw the group to improved levels of systems thinking.

2.2.3.3.4 ***Emotional Contagion***

Emotional contagion may also promote systems thinking at the group level. Groups experiencing positive emotional contagion experience improved cooperation, decreased conflict, and increased perceived task performance (Barsade 2002). Improved cooperation may include improved cooperation in the sharing of ideas, which could positively affect the level of systems thinking in the group.

2.2.3.3.5 Group History

The history of the group may also contribute to the level of systems thinking of the group. Discussing learning in groups, Edmondson develops the idea that psychological safety is a shared belief held by members of a team that the team is safe for interpersonal risk taking (Edmondson 1999), (Edmondson 1996). Perhaps in groups where psychological safety exists, group members will be less reluctant to voice minority opinions, which may expand the breadth of the group's thinking.

2.2.3.4 Organizational Level of Analysis

When considering the organizational level of analysis, it is important to consider both the systems thinking of the organization as a whole and the interactions between this level of analysis and the other levels of analysis. Not only does an organization set the context for the creation of systems thinkers, but the systems thinkers in the organization also impact the performance and value created by that organization. The causal arrow can point both ways. The first section here addresses how systems thinking might be studied at the organizational level of analysis. The subsequent sections discuss various organizational aspects which impact the creation of systems thinkers. These aspects can be grouped in four general categories: strategic, temporal, structural, and functional.

2.2.3.4.1 Systems Thinking of the Organization

Numerous standards and process models have been developed to assess the systems capabilities of an organization. The Systems and Software Consortium has studied the frameworks relevant to companies that build software-intensive systems, and they have documented the standards and process models that apply to the software development industry in what they call "The Frameworks Quagmire" shown in Figure 2-2 (SSC 2001). This figure is used with permission from the Systems and Software Consortium.

It is difficult to use these standards and process models as a measure of quality of systems thinking for this study. There is disagreement on the appropriateness and adequacy of these standards and process models as true measures of quality of systems capability. For example, many organizations currently pride themselves in their CMMI® level. However, in a presentation at the National Defense Industrial Association 4th Annual CMMI® Technology Conference in 2004, Mr. Mark D. Schaeffer, the Director of Systems Engineering for the Office of the Under Secretary of Defense (AT&L), cites the negative effects of CMMI® levels (Schaeffer 2004). He says, "Level "X" companies often do not perform at that level on all programs" since "not all programs are appraised." In addition, "Once an organization achieves a desired level, the tendency is to let the baseline erode." He says that, "We created 'level-mania' instead of continuous improvement." That raises doubts as to the reliability of CMMI® level as an indicator of quality of systems engineering throughout an organization.

Although this figure was developed for software development, many of the standards and process models shown relate to the general systems engineering community. Some of the standards that address systems engineering include the following: (a) CMMI®, which stands for

Capability Maturity Model® Integration (CMMI), Version 1.02b published in December 2001; (b) International standard ISO/IEC 15288, Systems Engineering—System Life Cycle Processes, published in October 2002, (c) MIL-STD-499B, a draft military standard titled Systems Engineering which was never officially released; (d) SECAM, the Systems Engineering Capability Assessment Model, published in July 1996 (Version 1.5) by the International Council on Systems Engineering (INCOSE), and (d) SE-CMM, the Systems Engineering Capability Maturity Model, published in November 1995 (SSC 2001).

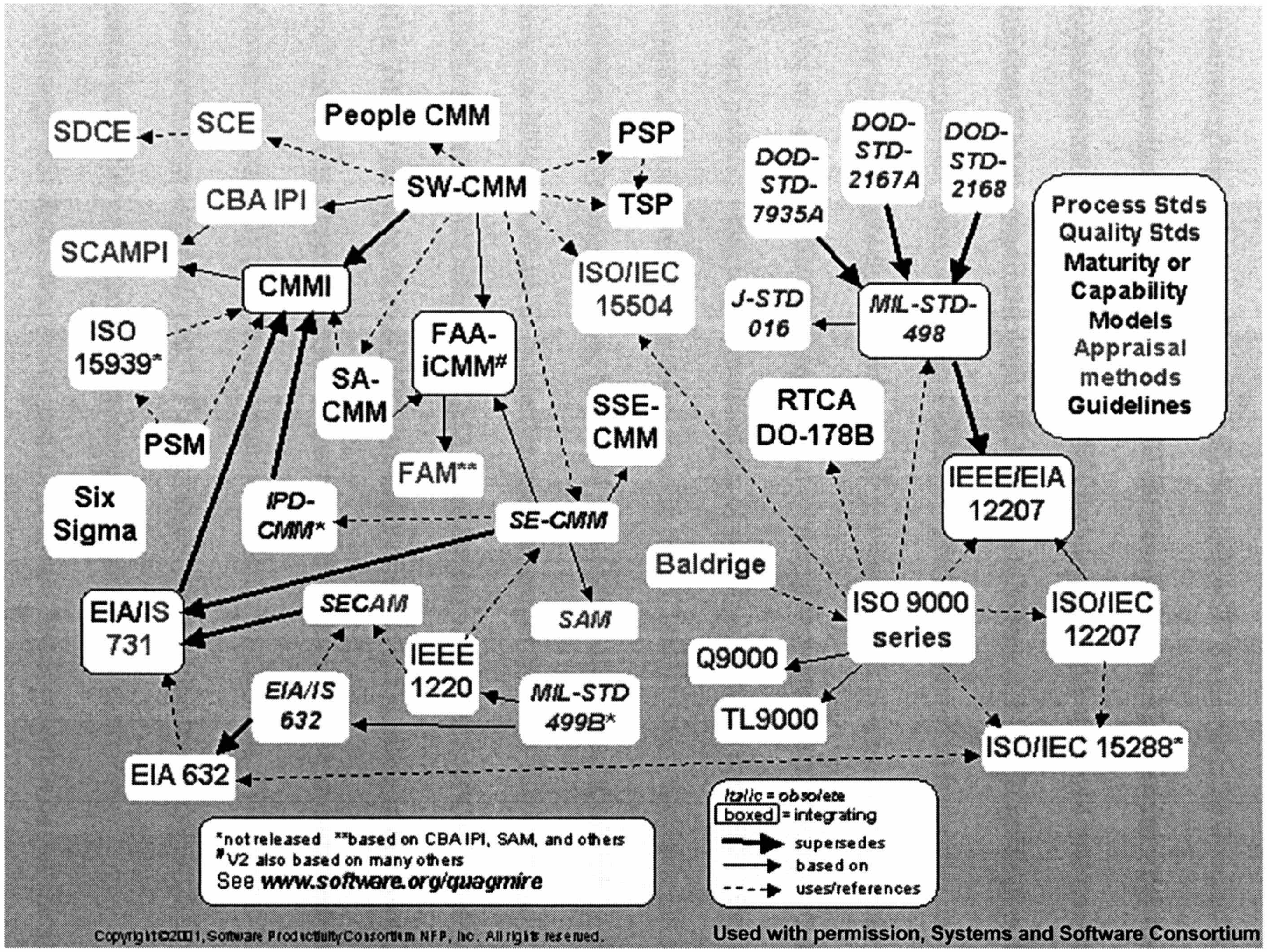


Figure 2-2: The Frameworks Quagmire Developed by the Systems and Software Consortium

2.2.3.4.2 ***Strategic Impact***

Senior management sets the strategy for the organization, and this strategy may or may not enable the creation of systems thinkers in the organization. If the chief executive officer (CEO) says that the company will only promote employees who have served as a lean change agent or a Six Sigma Blackbelt, the incentive is set for many employees to serve in these roles. At Southland Furniture Company, process improvements led to the ability to schedule and produce furniture more quickly; however, the senior executives needed to intervene to change the strategy regarding which customers they were serving (Hout and Carter 1995). Systems thinking and process improvement developments can be undermined if the company's strategy is disconnected from these efforts.

If the direction senior management sets for the company is compelling for systems thinkers, systems thinkers will be drawn to that organization. As Peter Drucker has pointed out, "the best and most dedicated people are ultimately volunteers, for they have the opportunity to do something else with their lives," state James Collins and Jerry Porras (Collins and Porras 1996). It is important for senior management to set a direction compelling to systems thinkers. As more systems thinkers are embedded in an organization, systems thinking can become a norm.

Senior managers can also set the core values and core purpose for the organization. Depending on how these values are incentivized in the organization, core values that consider multiple stakeholders or the broader system can be a mechanism to promote systems thinking in the organization. James Collins and Jerry Porras list the core values of Merck as, (1) Corporate social responsibility, (2) Unequivocal excellence in all aspects of the company, (3) Science-based innovation, (4) Honesty and integrity, and (5) Profit, but profit from work that benefits humanity (Collins and Porras 1996). Depending on how seriously these core values are held within the company, these core values could encourage thinking about the larger system in which the corporation is embedded. Although this may seem idealistic, some organizations do enforce their core values and core purpose. It is possible for organizations to establish and enforce core values and core purposes that promote systems thinking through their personnel and promotion practices.

2.2.3.4.3 Temporal Impact

An organization has a temporal impact on its employees. Deborah Ancona applies the concept of entrainment to organizational behavior (Ancona and Chong 1996), (Ancona and Chong 1999). Originally a concept from the natural sciences, entrainment is when the pace or cycle of one activity adjusts to match or synchronize with that of another. Not only do macro cycles "capture" the pace and cycle of organizational activities, but the organization also sets the pace and cycle for work of its employees. A public organization may be paced by the fiscal year, while an employee in the organization may be paced by internal deadlines and meetings. The pace of the organization may be just too frantic to train new employees in any type of systems thinking. Organizations can incorporate mechanisms in the yearly cycle to encourage and motivate systems thinking in the organization.

Another key idea from Ancona is that windows of opportunity come and go. Also supporting this theory, Connie Gersick showed that at the midpoint of a group's task, the group is most open for radical and innovative change (Gersick 1988), (Gersick 1990). Depending on the pace and cycle in an organization, perhaps there are specific points in time when employees are most open to the development of systems thinking skills. Perhaps this is during a visible crisis or a "burning platform." One preliminary respondent in this study emphasized how "teachable moments" are times when employees and students are most open to revolutionary breakthroughs in their thinking. An organization can have a systems thinking team prepared to seize the opportunity when burning platforms and teachable moments appear in the organization.

2.2.3.4.4 ***Structural Impact***

The organizational structure of the organization can enable the development of systems thinking. Cross-functional teams and matrix organizations can help employees think outside of traditional, functional roles. At Chrysler, senior managers hold formal positions that combine functional and product-line responsibilities. "These dual responsibilities not only embody the tension between product lines and functions, they are also the chief mechanism for managing such tension. All the senior executives know that they have to accomplish two conflicting tasks," states Thomas Hout and John Carter (Hout and Carter 1995). When the organization is structured with non-traditional links, employees may think more broadly.

Training programs can also be used to promote systems thinking. Rotational training programs can help employees gain appreciation for other areas of the organization. Although they do not address larger scale systems thinking, systems engineering training programs can help employees think more broadly. Process improvement training programs can help develop systems thinking as it relates to the broader organization.

An organization can also establish a supportive infrastructure for systems thinking. The physical surroundings and architecture in which the organization is housed could promote interaction and communication across functional groups (Allen 1977). Interaction and communication across functional groups can help employees understand and empathize with the concerns of other groups in the organization. Physical facility layout can also be used to evoke an affective response. Passing by an airplane hanger or a manufacturing line on the way to the office may remind employees that their work is part of a bigger system. If an organization has an end-product or end-service that is glamorous or moving, that functional system can trigger emotional contagion to inspire systems thinking. As Sigal Barsade shows, positive emotional contagion can improve cooperation, decrease conflict, and increase perceived task performance (Barsade 2002).

2.2.3.4.5 ***Functional Impact***

On the other hand, to promote systems thinking, one could tell an employee whose job it is to carry bricks, that they are building a cathedral, that they are part of a much larger and grander system. But at the end of the day, when that employee's back hurts, he or she may realize, "I'm not building a cathedral, I'm carrying bricks!" Role definition does matter. The design of the work itself can shape motivation and behavior (Hackman and Oldham 1980). When an employee has a job which requires systems thinking, either the employee develops systems thinking or finds a new job. Organizations can design more jobs which require systems thinking.

As Hackman and Oldham state, there are various approaches to change and work redesign (Hackman and Oldham 1980). Four widely used approaches are: (1) Change the people who do the work, through improved selection, placement, and training procedures, (2) Change other people, specifically supervisors, by improving supervisory selection and training practices, (3) Change the context in which the work is performed by adding workplace amenities, and (4) Change the consequences of work by altering the contingencies that determine the benefits (and costs) to employees. These four approaches could also be used to promote systems thinking in organizations. People could be changed by selecting systems thinkers, placing them in key roles, or training people in systems thinking. Other people could be changed by placing only proven systems thinkers in supervisory roles or training all supervisors in systems thinking. The organizational context could be changed to promote systems thinking. Last, the consequences could be altered to promote systems thinking.

2.2.3.5 Institutional Level of Analysis

Above the organizational level of analysis is the institutional level of analysis. Factors that affect systems thinking development at the institutional level of analysis include government acquisition and certification standards, professional associations such as INCOSE, university departments, and industry career paths. By setting incentives and priorities, government acquisition standards promote or obstruct the development of systems thinking in organizations. One unlikely option is that the government could institute a formal systems engineering certification process, such as the existing certification process architects undertake to become officially licensed. Professional associations such as INCOSE promote systems thinking development by providing a community in which to debate and develop systems engineering knowledge. The existence of systems studies in university departments enables systems thinking development. In addition, trends in industry career paths can inhibit or enhance systems thinking development. For example, if career opportunities in the aerospace industry are limited, high potential or experienced systems professionals may exit the industry altogether, which adversely affects the systems thinking of the organization.

2.2.3.6 Selecting the Appropriate Level of Analysis

This discussion has several implications for engineering systems research design in general and for this research study in particular. First, multi-level theories are needed. "Systems thinking" itself is a multi-level construct. At the individual level of analysis, this is an individual thinking about a multi-actor system. At the group level of analysis, "systems thinking" is the collective thinking of a group about a multi-actor system larger than the group. Either level of analysis leads to cross-level theories. Every one of the concepts leading to the phenomenon of systems thinking has multi-level influences. Personality, aptitude, task assignment, affect, and experience are all influenced by groups, organizations, and environments either simultaneously or in the past. Diversity of group, group skills, group task, emotional contagion, and group history are all influenced by individuals, groups, organizations, and institutions either simultaneously or in the past.

It is important to note that a group may be required to understand and manage a large, complex, engineered system. This type of system is probably not managed by an individual acting alone. Even a systems superstar may not be able to comprehend the vast complexity and detail of a large, complex, engineered system (Hirschi and Frey 2002). Even if a systems superstar could accomplish that, that superstar would probably have a team of advisors or system analysts. Thus, evaluating the systems thinking of the group may be more important than evaluating the systems thinking of an individual. In addition, to get a truly holistic view of a system, many perspectives may be needed. Multiple stakeholders and specialists from many different disciplines may be needed to get a picture of the entire system. If one person cannot comprehend the vast complexity and detail of a large, complex, engineered system, then it is up to a group to merge their systems understandings. Thus, evaluating the systems thinking of the group may be more important than evaluating the systems thinking of an individual.

Nonetheless, there are multiple reasons why the individual level of analysis may be an appropriate starting point for research on the development of systems thinking. First, studying this topic at the individual level of analysis is more straightforward than studying this topic at the group level of analysis. Also, as discussed, the systems thinking of the group is dependent on the collective systems thinking skills of the individuals in the group. Although studying the development of systems thinking at the group level of analysis may be more important, more work is needed to first understand the development of systems thinking at the individual level of analysis. Finally, systems thinking interventions such as training programs and education programs are designed to improve the systems thinking of the individual. If this research is to directly affect change in these systems thinking interventions, it is appropriate to focus this work at the same level of analysis, the individual level of analysis.

2.2.4 Construct Validity

In the study of systems thinking, construct validity is a major obstacle. When it comes to research design and methods in the area of complex engineering systems, there are serious concerns about convergent validity, discriminant validity, internal validity, and external validity (Singleton and Straits 1999). Ambiguity of terminology makes it hard to replicate studies. In addition, many of the systems studied are so complex that it is hard to find a parallel case to use as a control case. The complexity of the systems also makes it hard to isolate variables or standardize treatments. Many of these complex engineering systems are also one-time systems, so it may be hard to replicate results. These are issues that must be addressed in any study of systems thinking.

2.2.4.1 Convergent Validity

The first issue is convergent validity. If two people are asked to rank a set of ten people they both know on the quality of their systems thinking, would the two people agree on their rankings? If people cannot converge on an understanding of systems thinking, then the construct is not valid.

2.2.4.2 Discriminant Validity

Another problem is discriminant validity. If people are asked to rate an individual on quality of systems thinking, are they indeed rating systems thinking, or are they rating another construct, such as leadership, creativity, openness, or eminence in the engineering field? If it is not possible to discriminate between systems thinking and these other constructs, then systems thinking is not a valid construct.

2.2.4.3 Internal Validity

Another concern is internal validity. Internal validity is when a study can plausibly demonstrate the causal relationship between treatment and outcome (Robson 1993). This is when a study rules out extraneous variables that may be responsible for the observed outcome. Studies eliminate rival explanations in two ways. Singleton and Straits explain this clearly as follows (Singleton and Straits 1999), "First, effects of prior differences between subjects, such as personal qualities and experiences, are 'neutralized' by randomly assigning subjects to treatment and control groups, thus initially assuring approximate equivalence of the groups. Second, aside from the introduction of the experimental variable, treatment and control groups are treated exactly alike, thus assuring equivalence of the groups during the experiment." Though this quote is from the experimental literature and the approach used in this study is inductive and exploratory, this quote demonstrates how internal validity may be addressed.

Internal validity can be a serious problem when studying the development of systems thinking. The time scale required to develop systems thinking may be much longer than the time scale possible for a controlled intervention. In addition, the idea behind systems thinking is seeing a holistic view. Depending on the system definition, the "whole system" could include anything in the surrounding environment, and this could make it difficult to design the treatment and control groups.

The development of systems thinking may also be a cumulative process. If systems knowledge could be assessed, two people who have acquired the same amount of systems knowledge most likely arrived at that point by following very different paths. Different combinations of treatments and events may have developed each individual's systems thinking knowledge, which makes it hard to draw valid comparisons. When studying the development of advanced systems thinkers, it is difficult to control for personal characteristics, experiences, or equal treatment.

There are serious problems with internal validity when studying systems thinking development. The time frame required to develop strong systems thinking may be too long for a controlled intervention, no two people have undergone the same cumulative systems thinking intervention series, there are not standardized assessment tools for the dependent variable, and it is the variance in personal characteristics and experiences that is of interest.

2.2.4.4 External Validity

There are difficulties with systems thinking and external validity as well. As stated by Singleton and Straits, "External validity is basically a problem of generalizability, or what the experimental results mean outside of the particular context of the experiment (Singleton and Straits 1999). The research sample and setting must be representative of the population of interest in order to have external validity. External validity may be a problem if one seeks to generalize from what people say in a survey to what people actually do, since there is a notorious lack of relation between attitude and behavior (Robson 1993).

Quality of systems thinking may be linked to context, which could be a problem for generalizability. Excellent systems thinking about a specific engineering system might be related to familiarity with that particular system, not inherent skill. An experienced systems thinker may perform splendidly in one specific context, but if that person is moved into a different engineering system or a broader role in an engineering system, the individual's "systems thinking" may be quite poor. This is the unresolved problem of quality of systems thinking. On the other hand, strong performance on a decontextualized systems thinking test may indicate strong nonspecific systems skills, but it may not predict ability to perform in a real, contextualized setting. A real-life setting requires cognitive ability to comprehend technical and social context and the ability to decipher and react to social cues.

In addition, "thinking" is being assessed. Many measures or assessments of thinking may not reflect what a subject is actually thinking. Systems thinking also is a not a well-defined construct. There are many interpretations of what is included in systems thinking. Much of the current debate on systems thinking has been hosted by the military-industrial complex. Extrapolating this literature to the wider population may be problematic.

There are things that can be done in the selection of unit and level of analysis to help external validity. These methods could include sampling randomly, replicating results in a different setting, or using a field research setting. In this research study, external validity is addressed by utilizing field research. In addition, the results were replicated in a non-aerospace company outside the United States, which provides a data point from a very different setting.

2.3 Related Literature

2.3.1 Construct Assessment at the Individual Level of Analysis

This leads to the next problem, which is the assessment of systems thinking. How does one determine the *strength* of systems thinking? As previously noted, there is theoretical systems thinking, which may be distinct from practical, tactical systems skills. A person could excel at thinking about systems theoretically, but have no ability to operate in a real-life system. Considering the specificity of systems thinking, a subject may perform poorly on a decontextualized systems thinking test, but yet be an outstanding systems manager in practice. Similarly, a person could excel in a specific, real-life systems setting but not be able to transfer those skills to a different systems context. It would be difficult to rank these possible cases against each other on one scale of strength of systems thinking, since different capabilities are being compared.

2.3.1.1 Certification for Systems Engineers

As mentioned previously, the International Council on Systems Engineering (INCOSE) established its Professional Certification Program as a formal method to recognize the knowledge and experience of systems engineers (INCOSE 2005). As the website states, "The title of the baseline recognition of personal certification is 'Certified Systems Engineering Professional.' Certification is valid for three years from the date awarded, and may be renewed in three-year intervals. Certification is a formal process whereby a community of performing skilled representatives, such as INCOSE, warrant that a person has achieved competency in certain skills." There are four components to this certification which include: (1) Experience, shown by a minimum of 5 years of systems engineering work experience; (2) Education, which much be a Bachelor's degree or equivalent in a technical field from an accredited institution; (3) Systems Engineering References, which is a minimum of 3 technical references that confirm experience and recommend certification; and (4) Systems Engineering Knowledge, which is shown by passing an examination. As the INCOSE website states, "The examination is two hours long. It consists of 120 multiple-choice questions. Typically, each question will have about five possible answers of which three are correct. All correct answers to a question must be selected to receive credit for a successful response; no credit is given for a partially correct answer to a question." Even if permission would be granted to utilize this tool, this examination would be too lengthy to utilize in this research project. However, future studies might use this certification as a measure of strength of systems thinking to contrast "Certified Systems Engineering Professionals" to other control groups.

Other organizations are also engaging in internal certification programs, though the details of several of these programs are still considered proprietary information. Since the INCOSE certification was established in March 2004, this certification program is still too new for widespread certification across the industry. Many of the other internal certifications are also new. This makes it difficult to utilize SE certification as a measure of quality of systems thinking for this study.

2.3.1.2 Aptitude Test for Systems Engineers

Also mentioned previously, Yutaka Toshima developed and standardized an integrated aptitude test for systems engineers (SE) to test intellectual abilities and personality factors

(Toshima 1993). Specifically related to systems engineers in the information processing context, the aptitude test investigated intellectual abilities and personality traits of system engineers. The rationale for this study was based on interviews with five SE and five former SE. After methodical construction and standardization of the aptitude test, the validation of this instrument used 264 systems engineers working in industry. Comparing the test results to performance levels (excellent, average, or below average), the author showed that the test had a high probability for correctly discriminating performance levels. The key insight here is that a tool could be developed to predict the performance of systems engineers.

The underlying research is strong and methodical. However, the limited context of this work must be taken into consideration. The author says, "the task of the system engineer (SE) is basically to analyze transactions and business functions through Electric Data Processing operations. Thus it can be said that the function of the SE is to integrate and unify various functions so as to establish a complete information processing system." This tool predicts the performance of the information technology systems engineer, and perhaps with more research, the tool could be generalized to a broader systems thinking definition.

2.3.1.3 Systems Dynamics Assessment

John Sterman and Linda Booth Sweeney developed one form of systems thinking assessment (Sweeney and Sterman 2000). Their tool assesses particular systems thinking concepts such as feedback, time delays, and stocks and flows. The studies show that "performance deteriorates rapidly when even modest levels of complexity are introduced, and that learning is weak and slow even with repeated trials, unlimited time, and performance incentives." The key insights from this research are that: (1) certain types of systems thinking can be assessed, (2) subjects' performance is generally poor, and (3) performance does not vary with demographic variables.

The underlying research is straightforward. The subjects completed a background data sheet to indicate educational background and other demographic factors. The tests were administered to two groups of students at the MIT Sloan School of Management enrolled in the introductory system dynamics course. In the assessments, subjects were given a few paragraphs posing a problem. Subjects were asked to respond by drawing a graph of the expected behavior over time. In the article discussing the study, the tasks were given, and the performance was tabulated. These data support the key insights listed.

The limitation is that the tests measure only understanding of stock and flow dynamics, which is one particular type of systems thinking. The specificity of systems thinking is also a concern. Indeed, an important aspect of being a strong systems thinker may be the ability to assess the context in which one is embedded. Using a decontextualized systems thinking test does not assess this ability. A subject may perform poorly on a decontextualized systems thinking test, but yet be an outstanding systems manager in practice. Also, performance may vary with demographic variables if a wider definition of systems thinking is used.

2.3.1.4 Mental Model Assessment

A change in systems thinking can also be construed as a change in mental models. James Doyle, Michael Radzicki, and Scott Trees (Doyle, Radzicki et al. 1998) state that any method for measuring change in mental models must strive to achieve at least the following eight goals.

1. Attain a high degree of experimental control
2. Separate measurement and improvement
3. Collect data from individuals in isolation
4. Collect detailed data from the memory of each individual
5. Measure change rather than perceived change
6. Obtain quantitative measures of characteristics of mental models
7. Employ a naturalistic task and response format
8. Obtain sufficient statistical power

The authors discuss these eight goals in depth and then they give an example of an experiment they performed to measure changes in systems thinking. They state that, "The only prior study conducted within the system dynamics community that meets all eight of the identified criteria for rigorous research on measuring change in mental models is Vennix (1990)."

The study by Doyle, Radzicki, and Trees measures change in mental models related to a simulation game of the economic long wave, or Kondratiev Cycle, developed by Sterman and Meadows. A pre-test survey was administered to each individual participant, guiding participants through a narrative process of "telling the story" behind the pattern in the data. Participants decide how much or how little information to include about causal events, factors, variables and the relationships between them. A post-intervention survey is administered using the same instrument. Narrative models are used, since research by Pennington shows that, "story-like structures are spontaneously constructed and used to guide decision making when judgments are based on large amounts of interrelated information or experience that must be reviewed and organized." The study attempts to achieve naturalism by having participants convey mental models the way they are typically conveyed in conversation.

Results showed that the content and size of subjects' mental models increased, feedback thinking increased, but detail complexity and dynamic complexity were not changed. They show that this method can be used to capture changes in mental models. This underlying research does show that changes in mental models can be captured. However, this is once again a decontextualized assessment. In addition, it may be necessary to show that a change in mental models is the same as a change in systems thinking.

Vennix says that the most appropriate and accurate techniques for measuring change in mental models have yet to be established by the research literature. Vennix conducted a controlled experiment where subjects used a computer simulation of the Dutch social security system as an intervention. Mental models were quantified pre- and post-intervention by having the participants prepare individual two-page written policy notes addressing social security and the economy. These policy notes were coded into "cognitive maps" which were effectively utilized to assess changes in mental models.

2.3.1.5 Assessing Cognitive Correlates of Systems Thinking

A dissertation titled "An Exploration of the Cognitive Correlates of Systems Thinking" by Carol Zulauf (Zulauf 1995) attempts to determine if locus of control and conceptual stages of cognitive complexity predict success on systems thinking tasks. In the author's own words, the key insights from this work are as follows. "The results from this research show that cognitive complexity, internal locus of control, occupational level, educational level, and interest are significantly correlated with performance on system thinking tasks. The other predictor variables accounted for in the study, specifically age and gender, do not have any significant relationship with these tasks." Locus of control refers to whether a person feels like their situation is in their own control (internal locus of control) or in someone else's control (external locus of control).

These insights are rooted in data. The author used seventy-seven individuals from a large, U.S.-based corporation in the study. Zulauf's research attempted to determine if locus of control and conceptual stages of cognitive complexity would predict success on systems thinking tasks. The systems thinking tasks required the subject to identify connections among critical variables, discover dynamic feedback systems and apply systems principles to determine a solution. Zulauf states that she is studying the connection between locus of control and the ability to exercise "closed-loop thinking" as defined by Richmond.

Mentioned previously, Barry Richmond suggests seven critical systems thinking skills: dynamic thinking, closed-loop thinking, generic thinking, structural thinking, operational thinking, continuum thinking, and scientific thinking. As explained in detail in the appendix, these types of thinking may be particularly important in system dynamics. Richmond suggests that good "systems thinking" means operating on at least seven thinking tracks simultaneously. Although these types of thinking may be particularly important in system dynamics, this is not a list of the thinking skills required for a more general approach to systems. Particularly when considering a geopolitical system, "scientific thinking" as listed here may be a hindrance to systems thinking. Furthermore, "structural thinking" may not be best when considering interpersonal dynamics, since units of measure may not be the correct method to capture the interdependency.

The Zulauf thesis tests one type of systems thinking of the seven that Richmond lists. Most likely, Zulauf tested only one type of systems thinking in order to more easily operationalize this construct. Nonetheless, it is problematic to claim that strong performance on one type of systems thinking proves that one is a good systems thinker, particularly when quoting from Richmond who calls good systems thinking operating seven tasks simultaneously. Also, it is not obvious that "closed-loop thinking" is the most significant of the systems thinking skills considered.

2.3.1.6 Time Horizon as a Measure

In Elliot Jaques' book *Social Power and the CEO* (Jaques 2002), he claims that a person's time-horizon is a measure of that person's potential capability, where the time-horizon of a person is the longest time forward that a person can plan and execute an assignment or get to a goal. Perhaps a parallel could be drawn to measure a person's systems capability. Could a person's systems capability be measured by the time-horizon of the system managed? Or, is a person's systems capability measured by the impact of the organization managed? Are better systems thinkers necessarily at the top of the organization? What systems thinking skills do effective managers of engineering systems possess? What interactions do they need to understand?

2.3.1.7 Parallel to Measuring Multiple Intelligences

In Howard Gardner's book *Intelligence Reframed* (Gardner 1999), he gives tips to test developers seeking to measure multiple intelligences. Some of the same concerns could also relate to the measurement of systems thinking, since it may be true that "systems thinking" is not a single construct, but a collection of multiple constructs. It is important to distinguish between an individual's *preferences* and their *capacities*. There are risks to relying on just verbal measures of ability. It is better to draw on observations of actual skills and on testimony of people familiar with the individuals being assessed. Using a number of complementary approaches may offer a better assessment than using just one approach. Also, linguistic and logical-mathematical intelligences are often used to test other intelligences, when each type of intelligence should be studied on its own.

Gardner also stresses the dangers of jumping to assessments. The key question to remember is, "Why is the assessment needed?" Intelligence tests were originally designed to reasonably predict people's success in school. An assessment of multiple intelligences might be needed to see if a child has a cognitive impairment that inhibits a certain kind of learning. Unfortunately, assessments and measures of things such as intelligence can create new forms of labeling and stigmatization. As Gardner stresses, these intelligence measures should be used to help people learn important content, not to categorize individuals. Students should not learn to read, write, and compute just to achieve a certain score on an exam, but to gain tools to understand the important questions and topics of their time.

Likewise, the goal of developing systems thinking in engineering professionals is to prepare students and employees to understand the behavior of contemporary, complex, engineered systems. Assessments of systems thinking capabilities should be used to better understand this development process. These assessments should not be used as measures to stigmatize or categorize individuals. In summary, measurement of systems thinking is as much of a challenge as construct validation.

2.3.2 Characteristics of Systems Thinkers

There are examples in the existing literature which cite the characteristics of systems thinkers. Once again, the system definition varies, but examining these studies is useful.

2.3.2.1 Systems Engineering Roles

In order to try and decipher what it is that systems engineers do, Sarah Sheard suggested twelve systems engineering roles in 1996 (Sheard 1996). In a follow-on paper in 2000, Sheard revisits and updates these roles (Sheard 2000). Though the papers describe these roles in more depth, the general role descriptions are given here since they are helpful for deciphering the confusion. They are as follows.

(1) "Requirements Owner" - "Requirements owner / requirements manager, allocater, and maintainer / specifications writer or owner / developer of functional architecture / developer of system and subsystem requirements from customer needs"

(2) "System Designer" - "System designer / owner of 'system' product / chief engineer / system architect / developer of design architecture / specialty engineer (some, such as human-computer interface designers) / 'keepers of the holy vision'"

(3) "System Analyst" - "System analyst / performance modeler / keeper of technical budgets / system modeler and simulator / risk modeler / specialty engineer (some, such as electromagnetic compatibility analysts)"

(4) "Validation and Verification" - "Validation and verification engineer / test engineer / test planner / owner of system test program / system sell-off engineer"

(5) "Logistics and Operations" - "Logistics, operations, maintenance, and disposal engineer / developer of users' manuals and operator training materials"

(6) "Glue Among Subsystems" - "Owner of 'glue' among subsystems / system integrator / owner of internal interfaces / seeker of issues that fall 'in the cracks' / risk identifier / 'technical conscience of the program'"

(7) "Customer Interface" - "Customer interface / customer advocate / customer surrogate / customer contact"

(8) "Technical Manager" - "Technical manager / planner, scheduler, and tracker of technical tasks / owner of risk management plan / product manager / product engineer"

(9) "Information Manager" - "Information manager (including configuration management, data management, and metrics"

(10) "Process Engineer" - "Process engineer / business process reengineer / business analyst / owner of the systems engineering process"

(11) "Coordinator" - "Coordinator of the disciplines / tiger team head / head of integrated product teams (IPTs) / system issue resolver"

(12) "Classified Ads Systems Engineering" - "This role was added to the first eleven in response to frustration encountered when scanning the classified ads, looking for the INCOSE-type of systems engineering jobs. Approximately half of the advertisements for 'systems engineers' in a recent newspaper seemed to be asking for other things."

As one can see, these roles cover a very broad set of skills. The cognitive and personality characteristics of a "Requirements Owner" are most likely quite different than those of "System Designer." Being detail-oriented may be more important for a "Requirements Owner", while being creative may be more important for a "System Designer."

2.3.2.2 Types of Implementation

In order to clarify controversies about the definition of systems engineering, Sarah Sheard also defined three types of systems engineering implementation (Sheard 2000). They are: "Discovery", "Program Systems Engineering", and "Approach."

Discovery is “a discipline or specialist type that involves significant analysis, particularly of the problem space.” This type of implementation consists of unprecedented problems where there is very high complexity in the problem space. Examples include, “Postwar large projects like Atlas, SAGE, even Boston Central Artery/Tunnel, air traffic control, space missions, war fighting capability.”

Program Systems Engineering is “a coordination or generalist type that emphasizes the solution space and technical and human interfaces.” The complexity is in the solution space and the organizational space. This consists of, “Unprecedented ways of putting together largely precedented components to meet a new variation of a known need.” Examples are, “Realization of satellites, airplanes, avionics systems, control systems, large information systems, especially those including hardware.”

Approach is “a process type that can (and should) be performed by any engineer.” This is applying the systems engineering process from cradle to grave. The main goal is, “Not jumping to a solution, functions before objects, maintaining focus on what customer really wants, ensuring integration; complexity in the variation of applications, and possibly product lines.” Examples include, “Elevators, consumer goods, software, subsystems and components of larger systems, and many applications outside engineering.”

The paper describes these systems engineering implementation types in much more detail, but the key point here is the variety. The attributes that determine quality of systems thinking may vary considerably depending on the context of the systems engineering implementation. For the “Discovery” implementation, out-of-the-box thinking might be more valued, where specific technical knowledge of existing components may be more valued for "Program Systems Engineering" implementation.

2.3.2.3 Engineering Systems Thinking Laws

Moti Frank develops thirty engineering systems thinking laws, which could serve as a valuable insight for practicing systems engineers (Frank 2000), (Frank 2002). These "laws" are guidelines on what systems engineers should consider as they perform their work. Some examples are, "4. One should always look for the synergy and the relative advantages stemming from the integration of sub-systems" and "14. Pay attention to and take into account slow or gradual processes."

Frank states that the main purpose of the research is to identify the cognitive and personality characteristics of engineers with high "engineering systems thinking" skills. The research method consisted of three steps: (1) pilot interviews, (2) observation of participant work in two hi-tech companies, with 17 semi-structured interviews and content analysis of 14 lectures given in a seminar on systems engineering, and (3) a survey based on a pilot questionnaire (N=31) and a final questionnaire (N=276). Various methods were used to ensure objectivity, reliability, internal validity and external validity. A content analysis was performed to extract eighty-three categories of outstanding repeated elements.

The research is a descriptive analysis of the current state and the leap to a normative statement would be strengthened with additional substantiation of why the eighty-three categories of repeated elements are considered thirty laws. What are the qualifications of the participants, interviewees, and lecturer? Why are their opinions "laws"? How is the quality of systems thinking addressed in this study? Also, the construct validity issue as discussed previously is apparent here, since the author admits that different engineers define engineering systems thinking in different ways. Were respondents talking about the same idea?

2.3.2.4 Characteristics and Development of a Systems Engineer

George Chambers describes the functions performed by a systems engineer and identifies the knowledge, skills, and abilities that the "ideal" systems engineer should possess (Chambers 1985). The key insight relevant to practitioners is a list of the knowledge requirements for a systems engineer. For this study, the author extracted requirements for systems engineers "from classified advertisements appearing in national newspapers, technical journals, and trade magazines during the period 1982-1984." The author also reviewed pertinent information from textbooks addressing the systems engineering function, human engineering, design (both electrical and mechanical), and other related areas. Within the context of systems engineers in the military-industrial environment of the 1980s, the data substantiate the sections of the article addressing the "general duties of a systems engineer" and "knowledge, skills, and abilities required for the ideal systems engineer." Both descriptive and normative states are valid from the data. If a systems engineer wants a job, they *should* do what the classified advertisements request. These methods are similar to the ones used in this research study, since it is a descriptive collection of existing information and opinions.

However, the section addressing the "professional development of a systems engineer" seems to draw more from the author's opinion than from the underlying research. The author says that the formal educational background of a systems engineer is an important factor, but not as important as: (1) motivation, (2) a sense of eclecticism, and (3) a strong desire to see a project through to fruition. The author says that the knowledge, skills, and abilities to function as a systems engineer can be acquired in the military, in various assignments in industry, through self-study, but *not* in academia. It seems odd that one could gain the appropriate skills through self-study but not in academia. More importantly, data are not cited to support these claims.

2.3.2.5 Systems Thinking as the Fifth Discipline

Peter Senge views systems thinking as the fifth discipline in a learning organization (Senge 1990) (Senge, Kleiner et al. 1994). Senge says that the core of a learning organization is based upon five learning disciplines, which are lifelong programs of study and practice. The disciplines are personal mastery, mental models, shared vision, team learning, and systems thinking, and it is systems thinking that brings the disciplines together. The author says that both *The Fifth Discipline* and *The Fifth Discipline Fieldbook* are based on the experimentation, research, writing, and invention of hundreds of people.

2.3.3 Similarities of Systems Thinking and Leadership Literature

The evolution of systems thinking literature might be parallel to the evolution of leadership literature. As Richard Hackman says (Hackman 2003), the literature on leadership can be grouped into four general areas.

1. *What do leaders actually do? (descriptive)*
2. *Who becomes a leader? An effective leader? (trait, structural)*
3. *What is the best leadership style? (behavioral)*

4. *What should leaders actually do and when can they do it? (functional)*

Although the parallel is not exact, "system thinkers" could be substituted for "leaders" in the above list to outline the needed research in the field of "systems thinking."

1. *What do systems thinkers actually do? (descriptive)*
2. *Who becomes a systems thinker? An effective systems thinker? (trait, structural)*
3. *How can systems thinking be assessed?*
4. *What should systems thinkers actually do and when can they do it? (functional)*

The early studies on leadership were descriptive, as are some of the early studies on systems thinking. Giving a descriptive look at systems engineers, Moti Frank and George Chambers both address the question of "What do systems thinkers actually do?" Peter Senge and some of the other authors also fall in this category. They discuss what "systems thinking" is and what those who are "systems thinkers" do. Additional research is needed to address this question for systems thinkers in a broader sense.

In the discussion of leadership, the second question involves both traits and structural characteristics. Some sociologists argue that leadership is structurally determined (determined by the system) and some psychologists claim that leadership is determined by traits (height, body proportion, IQ, self-confidence, etc.) In the case of systems thinkers, the question remains open on who becomes, or is inherently, a systems thinker and who is an effective systems thinker. Do systems thinkers have certain traits or are systems thinkers structurally determined by the roles and systems in which they are embedded? Answers to these questions could help companies know who to recruit for systems training programs and how to structure their systems training programs. For systems engineers in the information processing context, the work of Yutaka Toshima answers the question of "Who becomes an effective systems thinker?" Research is needed to address this question for a broader definition of systems thinking.

A previous section already discussed the third question, "How can systems thinking be assessed?" Work by John Sterman, Linda Booth-Sweeney, James Doyle, Michael Radzicki, Scott Trees, Carol Zulauf, and others show that various components of systems thinking can be assessed. As the number of systems thinking interventions increase, assessments are needed to determine the relative effectiveness of different interventions. However, additional research must be done to show how to assess systems thinking which includes interactions, interrelationships, and interdependencies of a technical, social, socio-technical, and multi-level nature. Assessing systems thinking in a contextualized setting is another research opportunity.

Note that "What *do* systems thinkers actually do?" and "What *should* systems thinkers actually do?" are not the same question. This leap from descriptive to normative must be substantiated by research, and again, this must be expanded to the broader definition of systems thinking. Additional research is needed in this area.

2.4 Summary of Literature Review

Since there is not a well-established, central body of literature addressing the development of systems thinking in engineers, this literature review combines a wide variety of references related to this topic. The first section discusses the motivation for this research topic.

The second section discusses the challenges of using the constructs "systems thinking" and "systems engineering" in the study. While talking about construct definition, this section discusses the variety of systems thinking definitions and the variety of literature streams related to the study of systems thinking development in engineers. The discussion about the level of analysis results in the decision to focus on the individual level of analysis for this research. There are considerable validity issues when using the constructs of "systems thinking" and "systems engineering", which must be addressed by any research study on this topic.

Finally, the third section discusses additional literature that informs the study of systems thinking development in engineers. Previous systems thinking assessment methods are given. Previous work on the characteristics of systems thinkers is cited. In conclusion, a link is made between the literature on leadership and the literature on systems thinking.

Although the literature review covers a broad variety of topics, the purpose of this literature review is to collect literature that is helpful for studying systems thinking development in engineers. In relation to the research study that is the focus of this paper, the first section of the literature review discusses the motivation for this research topic. The literature in the second section of the literature review informed both the design of the research methodology and the analysis of the resulting data. Providing background on related studies, the third section also helped with the design of this research study. The literature review also identifies challenges for future researchers in studying the development of systems thinking in engineers.

3 Research Methods and Analysis

The research methods and subsequent analysis are discussed in this section. This research study was designed to be exploratory and inductive. After conducting a literature review, pilot interviews were conducted to gain understanding for designing the research method. Once the research design was completed, a field study of 10 companies and 205 subjects was conducted using semi-structured interviews and surveys. Additional interviews were conducted with proven systems experts. The data were analyzed and resulting theories were synthesized. This research is also addressed in previous papers by the author (Davidz, Nightingale et al. 2004), (Davidz, Nightingale et al. 2005), (Davidz, Nightingale et al. 2005).

3.1 Research Methods

The following section explains the research methods used in this study. The procedure for the initial pilot interviews is explained, and the design of the field study is described. The ways in which the research design addresses concerns of validity are also described.

3.1.1 Pilot Interviews

In order to gain more insight into possible enablers, barriers, and precursors to systems thinking development, twelve senior systems leaders from the International Council on Systems Engineering (INCOSE) were interviewed. Located in three countries, the subjects represented industrial, academic, and government interests. Many of the respondents are active leaders in INCOSE. These exploratory telephone interviews were each at least thirty minutes in length, and the set of questions is shown in the appendix. The questions were sent to the subjects via email prior to the interview, so each subject had an opportunity to review the questions in advance. Several of the subjects answered the questions by email prior to the telephone interview.

The objective of this series of pilot interviews was to identify potential ideas for more in-depth exploration. Due to the small sample size and the method of subject selection, key findings from these interviews are only placeholders for further exploration and confirmation in a more formal study. A content analysis was performed on the interview notes, and triangulated ideas appearing in more than three interviews are summarized in Table 3-1 as potential enablers, barriers, and precursors to systems thinking development. In each of the three categories, the items are listed in descending order of frequency, which is the number of respondents who noted the item during an interview. Interestingly, the items in this table are often contradictory, which emphasizes the need for more data to inform heuristics currently being used. An example contradiction is how one result says that "Systems thinkers are born not taught" and another result says that "Systems education paired with practical experience" enables the development of systems thinking. These results are based solely on the results of the pilot interviews, and the results are presented here since these data informed the further development of the methods used for the field study.

The participants were extremely interested and intrigued by this topic of understanding enablers, barriers and precursors to systems thinking. Currently, high potential systems thinkers are identified by existing systems leaders. Formal methods are not used to test for systems thinking potential, and there are not examples of systems thinking measures. Participants were skeptical that systems thinking *can* be measured. While there are many theories about precursors and enablers to systems thinking development, most of these theories have not yet been substantiated with data. There is considerable disagreement about what is meant by the phrase "systems thinking."

Table 3-1: Potential Enablers, Barriers, and Precursors to Systems Thinking Development

Potential Enablers, Barriers, and Precursors to Systems Thinking Development

	Potential Enabler, Barrier, or Precursor	Number of Times Cited
Enablers	Working in a role requiring systems thinking	9
	Systems education paired with practical experience	7
	Strong communication skills	5
	Undergraduate degree outside of engineering	5
	First-hand encounter with serious problems requiring systems thinking	4
	Holding jobs in multiple disciplines	4
	Technical depth and 3-5 years of work experience in a discipline before systems training	3
	Participation in professional societies like INCOSE	3
	Age - children are most open to systems thinking	3
	Broad range of interests inside and outside work	3
	Training courses	3
Barriers	Stovepiped organizations, silo activities	3
Precursors	Some people will never be systems thinkers	6
	Strong systems thinkers possess certain personality traits	5
	Systems thinkers are born not taught	3
	Natural predisposition to systems thinking is triggered or enabled	3

The most frequently cited enabler to the development of systems thinking by these individuals was working in a role that required systems thinking. One example given by a respondent was that a managerial position forces one to think more systemically since managers must take into account the social interdependencies in the system in addition to technical concerns. Another example given was that working in a test or manufacturing environment also enables systems thinking, since the daily work tasks require coordination across disciplines and departments and this integration role enables the development of systems thinking.

Subjects noted that systems education is more valuable if it is paired with practical experience. Likewise, if a person encounters problems that require systems thinking first-hand, the person is more likely to appreciate the value of systems thinking courses.

Participants agreed that working in a reductionist organizational context inhibited the development of systems thinking. Many participants stressed the importance of multiple interests both inside and outside work as an indicator of systems thinking potential.

Interestingly, multiple respondents cited an undergraduate degree outside engineering as an enabler to systems thinking. These subjects stated that traditional engineering education develops reductionist views which may be hard to overcome. One subject who has hired hundreds of systems engineers said that his best systems engineers are actually experimental physicists. They have a broader view than engineers, yet since they run experiments, they have some of the same skills as engineers.

Another interesting result was the number of subjects who consider systems thinking an innate trait that people are either born with or without. One subject stated, "I was absolutely born a systems thinker." Likewise, other subjects said that they have always had a natural tendency towards systems thinking. Multiple subjects also believe that strong systems thinkers possess common personality traits.

Although the idea was not included in Table 3-1, one subject noted that people who are simultaneously evaluated in multiple value systems perform better in systems classes. An example is a student from a bilingual home. People who have never had their core value system challenged tend to naïve realism and perform poorly in systems classes. There are no formal data to substantiate this theory, but it has been observed repeatedly by the subject who has served as an instructor of systems architecting classes both in an aerospace organization and at a university.

3.1.2 Field Study

To more formally examine some of the pilot interview assertions about the development of systems thinking in engineering professionals, a series of field studies were completed in multiple companies. Table 3-2 shows the companies who participated in the study. This enabled better understanding of how companies are currently developing senior systems engineers. In addition to understanding individual company strategies for this development, comparisons were also drawn across multiple companies. Furthermore, this research study collected the narratives of senior systems engineers across the aerospace industry to better understand how these senior systems engineers developed. The majority of companies were from the aerospace industry, since the research was sponsored by the Lean Aerospace Initiative (LAI), a consortium of key aerospace stakeholders from industry, government, and academia. The study also utilized a survey to collect more quantitative information on the development path of senior systems engineers. The strategy and logistics of the study were as follows. Examples of the research tools are included in the appendix.

3.1.2.1 Expert Panel

After working with a point-of-contact to determine the company's interest in participating, the researchers worked with a point-of-contact to identify an "expert panel." This group consisted of approximately four individuals who are very familiar with the policies and practices of how that company develops senior systems engineers. Depending on the structure of the company, this expert panel consisted of two high-level systems employees, a functional engineering representative, and a human resources representative who leads a systems engineering training program.

The members of this expert panel were interviewed individually in order to understand company procedures for developing and assessing systems thinking in engineering professionals. Individuals on the expert panel were asked questions based on the protocol listed in appendix Section 8.2. The questions are listed here since the questions themselves provoked new thinking for multiple respondents. Asking the questions influenced the system. For example, one interviewee was quite disturbed when he realized his company had a systems engineering training program in place without any method to evaluate if the training program was effective or relevant. He took action to address this, which changed the system. There was no control for this type of action, but it should not affect the study results since the time required to change the system extends beyond the amount of time it took to conduct the interviews and surveys in the company.

3.1.2.2 Additional Subjects

Next, the Expert Panelists in each company were asked to identify subjects in three groups: (1) Senior Systems Engineers, (2) Junior Systems Engineers, and (3) Senior Technical Specialists. The selection of the follow-on subjects was dependent on the opinions of the Expert Panelists. To guide the selection, the categories were described as follows. The Senior Systems Engineers were described as the stellar systems professionals, outstanding systems thinkers who are currently working in a systems role. The Junior Systems Engineers were employees working in a systems role who had been in the company a shorter period of time, like 5 to 10 years. The Senior Technical Specialists were described as senior professionals whose job is narrowly focused on a specific technical discipline.

Of course, the primary interest was in the characteristics and development histories of the senior systems professionals. The other two groups were control groups. The junior systems professionals were studied to determine if certain types of people are drawn to systems roles. The senior technical specialists were studied to determine if being a senior employee in an organization leads to systems thinking, even if that employee is outside a systems work role.

The follow-on subjects were first asked to complete a survey on demographics, educational background, and work history. The design of the study also included a personality test to determine any personality differences between the three subject groups; however, only one company chose to participate in the personality testing.

The investigator then interviewed each subject for approximately one hour, using mostly a subset of the expert panel interview questions. The expert panel interview questions, the interview questions for the follow-on subjects, and the survey tool are shown in the appendix.

If feasible in the company, the interviewer conducted the interviews blind to each subject's classification. Although the junior subjects were usually easy to identify from age, differences between the senior systems professionals and the senior technical specialists were not always obvious. According to the perception of the researcher using the understanding of systems thinking discussed earlier, some of the senior technical specialists actually displayed a broader systems understanding than some senior systems engineers. This was usually due to the definition in that organization of what tasks are included in a senior systems engineering role. This was a subjective and informal observation, and further studies may use a more formal mechanism to determine differences in quality of systems thinking between these two types of classifications. For this exploratory study, this observation indicates that there might not be solid lines and definitions delineating the classifications of Senior Systems Engineer and Senior Technical Specialist. Indeed, as later sections show, the classifications often are not statistically differentiable for many of the responses.

3.1.2.3 Design of Research Study and Research Tools

Three research tools were used in the field study: the expert panel interview questions, the interview questions for the follow-on subjects, and the survey tool. These tools are shown in the appendix in Sections 8.2, 8.3, and 8.4. Results of the literature review and results of the pilot interviews were used in the design of these tools. Before use in the field study, these research tools were pre-tested using a small set of engineers. The pilot interviews also served as a pre-test mechanism, and the evolution in question design is shown by comparing the field study interview questions to the pilot interview questions.

3.1.2.3.1 Unit and Level of Analysis

The focus of the study was on the development of systems thinking at the individual level of analysis. Nonetheless, this was an embedded study where individuals were studied in the context of a group classification (senior systems engineer, junior systems engineer, or senior technical specialist) and an organizational setting (the company). Although studying the development of systems thinking at the group level of analysis is more important, more work is needed to first understand the development of systems thinking at the individual level of analysis. In addition, by focusing on the individual, this research can be used to directly affect change in existing systems thinking interventions, such as training programs and education programs, which are designed to improve the systems thinking of the individual.

3.1.2.3.2 Survey Design

Ideas and contentions discovered in the literature review and pilot interviews were used in the design of the survey. The current state of the field showed that there were many heuristics and peculiar opinions on how systems thinking develops in engineers. The survey was designed to address the dearth of relevant data in order to inform these claims. Table 3-2 shows the topic of the survey question and the reason why that question was included.

Table 3-2: Explanation of Survey Design

Survey Question	Reason for Inclusion in Survey
Gender	Contention that women are better system thinkers
Country	Contention that certain cultures foster more communal values, so they may be more apt to think of how a local idea maps to the broader system
Level of Education	Contention that everyone is born a systems thinker, but it is trained out of us by formal education
College Attended	Contention that some schools develop systems thinking more than others
College Major	Contention that some college majors are better for developing systems thinking
Current Employer	Contention that organizational context may impact strength of systems thinking
Years at Current Employer	Contention that familiarity with system context may impact strength of systems thinking
Job Title and Description	Capture information on point-of-view
Job Position and History	Track career progression
Training History	See if training experience impacts strength of systems thinking

3.1.2.3.3 Design of Interview Questions

Similarly, findings from the literature review and the pilot interviews were used in the design of the interview questions for both the Expert Panelists and the follow-on subjects. The Expert Panelists were first asked questions about how their company develops systems thinking in employees and how these skills are evaluated. They were also asked about systems engineering training programs and the evaluation of these programs. The purpose of these questions was to understand how each company addresses these issues.

A set of questions was then common to both the Expert Panelist and follow-on subject interviews. Each interviewee was asked for his or her definition of systems thinking. As a second question, in order to baseline across interviews, a systems thinking definition was given, and interviewees were asked for a response on whether they agree or disagree with the given definition and why. Interviewees were also asked to provide a story of a successful use of systems thinking skills, in order to give an illustration of what they mean by strong systems thinking.

These questions allow the researcher to record the point-of-view of the interviewee. Responses to these questions provide a means to compare and assess the convergence across interviews. In addition, the questions on systems thinking definitions also give an indication of discriminant validity to see whether individuals are speaking of a unique construct called "systems thinking" or if they are talking about other constructs such as leadership, intelligence, creativity, openness, or eminence in the engineering field.

A key challenge in the design of the research method was identifying a practicable method to determine strength of systems thinking for this study. It was difficult finding an established scale to utilize in this research. Theoretically, if a scale to determine strength of systems thinking was discovered, responses to the questions about systems thinking definitions and stories of systems thinking use could be indicators of strength of systems thinking. In the end, it was decided to include a question in the interviews about how companies determine strength of systems thinking, to see the current state-of-practice in determining strength of systems thinking.

The interviews also included a series of questions designed to elicit opinions from each interviewee about how systems thinking develops and how the interviewee developed systems thinking. Included were questions on enablers to systems thinking, barriers to systems thinking, individual characteristics that predict systems thinking development, key steps in life that developed systems thinking, and how systems thinking strengths developed. These open-ended questions were at the heart of the exploratory study, since they provide the data on how systems thinking develops in engineers. Interviewees were also asked to compare systems thinking interventions, to show how these interventions rank in comparison to each other.

3.1.2.3.4 Determining Causality

In this research design, it is difficult to have internal validity where a study demonstrates the causal relationship between treatment and outcome. The narratives of the interviewees on how they developed systems thinking and the causal relationships they cite were the best indicators of causality. Additionally, the educational history, work experience path, and training history shown on the survey indicate possible treatments that caused the development of systems thinking.

This leads to a key problem – this study selects on the dependent variable. When studying enablers, barriers, and precursors to the development of systems thinking, "systems thinking" is the dependent variable. The follow-on subjects were selected based on their quality of systems thinking, so if systems thinking is the dependent variable, the study samples on the dependent variable. Nonetheless, this is an exploratory study which is trying to identify what interventions primarily enable the development of systems thinking. Additional research studies can then focus on each of these particular interventions to more rigorously determine causality in whether that intervention develops systems thinking or not.

This is similar to taking a set of people who are successful at something and a set of people who are not as successful at something and comparing their other characteristics. However, it is unclear whether the classifications here identify distinctly separate sets.

Nonetheless, with the current state of the field, where quality of systems thinking is determined by observation rather than formal mechanisms and where the boundaries of systems thinking are fuzzy, having the expert panelists identify the sets is a reasonable approach to determine the classifications for this exploratory study.

3.1.2.4 Anticipated Products

Designed to address the key research questions, this research methodology allowed the researcher to explore enablers, barriers, and precursors to the development of systems thinking, to understand how senior systems engineers develop, and to identify mechanisms that develop systems thinking in engineers.

> **Key Research Questions**
>
> 1. **What are enablers, barriers, and precursors to the development of systems thinking in engineers?**
> 2. **How do senior systems engineers develop?**
> 3. **What are the mechanisms that develop systems thinking in engineers?**

In addition to understanding individual company strategies for this development, comparisons were made across companies. Using the interview and survey data, comparisons were made of the characteristics and development histories of two control groups and these senior systems professionals. The surveys and follow-on subject interviews resulted in both quantitative and qualitative comparisons of the three subject groups. The interviews also produced rich narratives on how senior systems engineers developed. These individual stories were a rich and fascinating portion of the study. In aggregate, the final result is an analysis answering the key research questions. Future research ideas were also generated.

3.1.2.5 Participation and Sampling

During the field study, 205 interviews were conducted, of which 188 participants responded to the survey. Ten organizations participated, and these organizations varied from being large system integrators to subsystem suppliers to federally funded research and development centers. Most, but not all, of the organizations are in the aerospace industry in the United States. Table 3-3 shows the participating companies and sites and the system of interest for each company.

Studying predominantly aerospace companies influenced the study in the following ways. First, aerospace companies have been integrating large, complex engineered systems for decades. Though the scope of these systems has increased, systems engineering and systems integration functions are not unknown concepts in this sector. Second, the aerospace industry is particularly sensitive to changes in acquisition policies set by the Department of Defense. New policies have increased the importance of systems engineering and systems thinking. As a result, some of the companies sampled are urgently trying to revitalize and expand their systems capabilities.

In order to increase the generalizability of the findings, several steps were taken. First, a field research setting was used. Second, the sampled companies work at varying levels of system definitions, so the results are more generalizable. For some companies, the system is an aircraft engine and for other companies, the system being considered is a large system-of-systems which includes the aircraft engine along with many other products and platforms. In addition, a non-aerospace company outside the United States was sampled to give some indication of further generalizability of the findings.

Table 3-3: Organizations Participating in Field Study

Company	Site	System Context
The Aerospace Corporation	Systems Engineering in Chantilly, VA & Los Angeles, CA	FFRDC - Global Positioning System (GPS), Air Force Satellite Communications (AFSATCOM) System, etc.
Boeing	Boeing Commercial Airplanes, Engineering Liaison group in Renton and Everett, Washington	Contractor - Commercial jetliner manufacturer
Booz Allen Hamilton	Systems group, multiple locations, referred by a systems partner at headquarters in McLean, VA	Consultant - Strategic management and technology consulting firm to industry and government
BMW	Systems Architects at BMW Group in Munich, Germany	Commercial - Manufacturer of premium automobiles and motorcycles
General Dynamics Sites 1 & 2	SE at General Dynamics Advanced Information Systems in Bloomington, MN and in Pittsfield, MA	Contractor - Provider of transformational mission solutions in command, control, communications, computers, intelligence, surveillance and reconnaissance (i.e. Future Combat Systems)
MITRE	Systems Engineering in Bedford, MA & McLean, VA	FFRDC - Global Information Grid, IRS enterprise modernization program, etc.
Northrop Grumman	Airborne Ground Surveillance & Battle Management Systems, Integrated Systems, Melbourne, FL, SE	Contractor - E-8C Joint Surveillance Targeting Attack Radar System (Joint STARS), Cyber Warfare Integration Network (CWIN), etc.
Pratt & Whitney	SE in East Hartford, CT	Contractor - Design, manufacture, and support of turbine engines
Sikorsky	SE in Stratford, CT	Contractor - Design and build advanced helicopters for commercial, industrial and military use

Since the research was sponsored by the Lean Aerospace Initiative, initial sampling was conducted by asking the consortium member organizations to participate in the study. Contacts from INCOSE were also utilized to gain access to additional organizations. Sampling of individuals began when the point-of-contact in each organization identified the Expert Panelists. The Expert Panelists then identified the specific names of the subjects in the three follow-on groups of Senior Systems Engineers, Junior Systems Engineers, and Senior Technical Specialists. The selection of the follow-on subjects was dependent on the opinions of the Expert Panelists regarding each subject's classification.

3.1.3 Blue Chip and Additional Interviews

During the research process, challengers argued whether "Senior Systems Engineers" in some of the organizations studied have high quality systems thinking. "Why should I care what those people have to say?" and "What proves that the Senior Systems Engineers studied have high quality systems thinking?" were two of the comments by challengers. In order to address these concerns, a suggestion was made to interview people who are stellar, undisputed systems thinkers. In the absence of an accepted or objective measure of quality of systems thinking, even identifying stellar systems thinkers is a challenge. One person's stellar systems thinker might be labeled a reductionist thinker by someone else. In the end, a short list of six "blue chip" stellar systems thinkers was agreed to by the doctoral committee and the director of the department. Since only two of the six nominees participated in the research study, more details about their background cannot be revealed to maintain anonymity. Suffice it to say that the two "blue chip" interviewees have been recognized at the national level by multiple sources for their accomplishments on aerospace systems. The comments of the "blue chip" interviews are included in the results as additional evidence.

In addition, a few other interviews were conducted with some of the faculty members of MIT's Engineering Systems Division. It would be quite interesting to expand this into a full study to see how systems thinking has developed in engineers in an academic environment. However, it was decided that including a full exploration of faculty opinions was beyond the scope of this research project.

3.2 Analysis Method

Since this study is an exploratory and inductive study, the objective was to gather data and draw theory from the data. At this stage of our understanding of systems thinking among engineers, it would be premature to try to conduct a traditional, deductive study, where a series of pre-determined hypotheses are tested with data. As an inductive study, it is particularly important to use multiple methods of data collection and various tools for the analysis of qualitative data in order to generate testable propositions for future research. Note that this is not a purely inductive study. In particular, the multiple stages of this research mean that later stages involve deeper elaboration on propositions and concepts surfaced in earlier stages. An alternate approach would be to have a deductive study, where a series of pre-determined hypotheses are tested with data. The following sections discuss how the field study data were analyzed.

3.2.1 Survey Analysis Procedure

Participant surveys were collected by email, by post, and in person. First, the survey data were typed into the statistical processing tool SPSS Base 10.0. Descriptive statistics and charts were then produced using the data. Data were divided by company and by classification (Expert

Panel, Senior Systems Engineer, Junior Systems Engineer, and Senior Technical Specialist) to draw more insights. The full data analysis is shown in the appendix.

3.2.2 Interview Analysis Procedure

The interview transcripts were recorded real-time during the interview by laptop. For some of the early interviews, notes were taken by hand during the interview then transferred to electronic form afterwards. After all interviews were in electronic form, the interview text was then imported to the qualitative data analysis tool, the QSR NUD*IST Revision 6 (N6) software. The rather unconventional title NUD*IST stands for Non-Numerical Unstructured Data * Indexing Searching and Theorizing. This tool for qualitative data management and analysis enables the linking of documents and data from the interviews. Once all the documents were in QSR N6, a content analysis was performed on the transcripts of the interviews.

During content analysis, ideas and concepts from the interviews were "coded" into what are called "nodes." For example, if an interview respondent stated that "having a broad experience base is an enabler to systems thinking," during the content analysis that line of the interview was coded as the node "broad experience base." The software program QSR N6 keeps track of these nodes. In addition, the program allows the user to organize the nodes into hierarchies.

For this analysis, each interview document was subdivided into the text unit of a line. The author reviewed and coded each line of each interview document by hand, and the software tool was used to record the coding. The software tool can do automatic coding, but this feature was not utilized, since maximum control of the coding was desired. As the coding process progressed, a reference was recorded for each segment of text. This reference refers to the specific document, the exact line, and the corresponding coding for that line.

In this program there are two types of nodes. The first is a tree node, where nodes are grouped into a structured hierarchy of node categories. This enables clustering and "thinking aloud" about data. The second type of node is a free node, which is a node that has not yet been organized. For this analysis, the nodes were first segmented by question, and then additional node structures were organized under each question.

For the analysis, a frequency analysis was performed at what will be referred to as Level 1 and Level 2 of the hierarchy. The coding hierarchies are shown in the appendix. For example, under enablers to systems thinking in Appendix Section 8.9, "Experience" is a Level 1 node, and "Lessons Learned" is a Level 2 node underneath this. For the Level 1 analysis, only the nodes at the same level as "Experience" are considered, and all the children in the hierarchy are tabulated and rolled into the corresponding Level 1 category. For the Level 2 analysis, the nodes at the same level as "Lessons Learned" are considered.

The granularity of the node categories can alter the frequency analysis considerably. This is why the analysis is conducted at both Level 1 and Level 2. The clustering and re-clustering of the nodes can go on indefinitely. Eventually, the node clustering hierarchy had to be set in order to report the analysis. This full coding hierarchy is shown in the appendix to give readers visibility into the nodes used, and these can be used for further analysis if desired.

Note that the appendix shows the total number of occurrences for each node category, while the Level 1 tables in the text remove repeated respondents in the Level 1 grouping. For example, in Appendix Section 8.8 on key steps to systems thinking development, under the

Level 1 group "Work Experiences", one respondent may have a statement coded at the Level 2 category "Systems jobs/experiences" and a statement coded at the Level 2 category "Particular organization/company." This respondent was counted only once when tallying the number of occurrences for the Level 1 node category "Work Experiences." This is why the appendix numbers cannot be taken directly to obtain the numbers shown in the tables in the text.

At the beginning of the analysis, no "nodes" existed. The philosophy used in the coding process was to keep the node classifications as true to the respondents' words as possible. When in doubt, increased granularity was preferred compared to clustering nodes and losing visibility into the respondents' exact words.

The interview data were then exported to SPSS as well. To see if there were differences between the classifications, chi-square tests were performed in SPSS. This test determines the probability that the counts in each cell are consistent with what is expected if there were no differences between groups, or if there was some statistically significant trend distinguishing the counts in each of the cells. For example, the chi-square test determined if Expert Panelists, Senior Systems Engineers, Senior Technical Specialists, and Junior Systems Engineers were equally likely to say a "broad experience base" was an enabler to systems thinking, or if senior systems engineers were more likely to respond this way. The complete crosstabulation charts are shown in the appendix to show the expected and actual counts. In SPSS, in response to whether or not the respondent cited this node category or not, "1" indicated "yes" and "0" indicated "no." In these crosstabulation charts, "1" indicates the counts of "yes" and "0" indicates the counts of "no" for each classification.

Utilizing a factor analysis, an attempt was made to identify scales to which multiple "enablers to systems thinking" would map. However, the lack of convergence in the data made the process of identifying scales not useful. Possible implications are that a large sample size is needed, or a more convergent sample of subjects might be more useful. For example, more convergence might be seen if the sample is narrowed to only requirements owners from product-centric aerospace companies in the United States.

3.2.3 Respondents Analyzed

In the ten organizations who participated in the study, 205 interviews were conducted, of which 188 participants responded to the survey. When the interview and survey data were compared and contrasted together, only the responses of the 188 participants were considered. Of the 17 interview participants who did not complete a survey, many were very senior and experienced personnel. In order to not lose their interesting insights, the interview data were considered separately first. Since one organization withdrew from the study before completion, some interviews that were conducted in the organization had to be excluded from the analysis, and they were not included in the count of 205 interviews. The organization which withdrew was going through significant reorganization, fighting for its survival. The withdrawal should not introduce bias, since the interviewees who did participate seemed distracted anyway.

3.2.4 Reporting Procedure

During this study, significant amounts of data were collected since this was an exploratory and inductive study. In order to communicate results more clearly, the data analysis, results, and conclusions are organized in terms of key themes. Instead of reporting all the data and then reporting the resulting theory, the resulting theories are used to organize the discussion and the data to substantiate each claim are given as necessary.

For the tables that are given in the text of this document, five categories are used. "All Participants" indicates the findings for all the interview participants from all the classifications and from all the companies. The sub-groups or classifications are then "Expert Panelists", "Senior Systems Engineers", "Junior Systems Engineers", and "Senior Technical Specialists." The "N=" indicates the number of participants in each classification who responded to that question. The "Rank" is the rank of the node category in comparison to the other node categories for that question for each classification. The "Number" is the number of respondents in that classification who cited that node category. The "Percent" shows the percentage of participants in the classification who cited that node category. The cut-off is that the only nodes listed in the tables are those where 10% or more of participants cited that node category.

The "Chi-Square" value gives the result of the Pearson chi-square test for that node category across the classifications, and the other result of the chi-square test is the "Asymptotic Significance" value. The null hypothesis is that there are no differences between the classifications. When the cut-off is set at the 5% level, the null hypothesis is rejected if the value of the asymptotic significance is less than 0.05.

When examining the resulting tables shown in subsequent sections, keep in mind that when the first interview was coded, no preset nodes or node hierarchies were in place. The nodes and the node hierarchies were developed as more and more interviews were coded and patterns began to emerge. The appendix shows all the node categories that developed. This shows the "Level 1" nodes that are at the highest level of the coding hierarchy and the "Level 2" nodes at next layer below this in the hierarchy.

Though some of the percentages may seem small, keep in mind that this was a semi-structured interview which allowed for open-ended responses. It was not a structured survey tool where more convergent ideas might be identified. Thus, when convergence does appear, it is notable. For example, it is notable that 95% of Expert Panelists cite "Work Experiences" as a key step to the development of systems thinking, as shown in Table 4-3.

When company data are given, the 10 interview companies are coded from A to J (i.e. Company A, Company B, etc.). This maintains anonymity. In addition, the responses of individuals are reported in aggregate throughout the study to maintain anonymity.

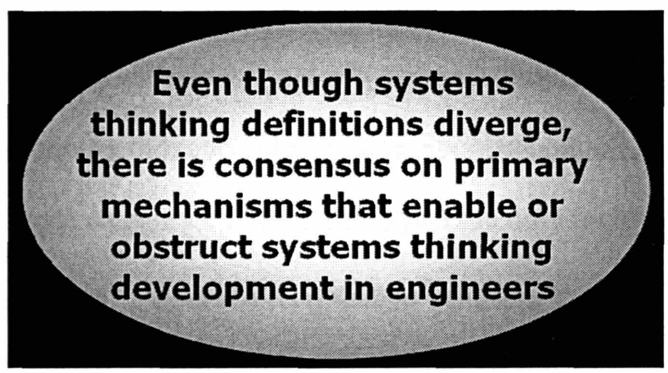
3.2.5 Summary of Analysis Method

In this exploratory study, both quantitative and qualitative data were gathered. The survey data were analyzed using the statistical processing tool called SPSS. The interview data were coded manually, and the coding references were recorded in a software program called QSR N6. The coded interview data were then imported into SPSS where statistical processing was performed on these data. This enabled inductive thought and theory building to draw conclusions from the data gathered.

4 Results with Discussion

To summarize the results of this study, even though systems thinking definitions diverge, there is convergence on mechanisms that enable and obstruct systems thinking development. Since this was an exploratory and inductive study, the data analysis was also conducted in an exploratory way. To provide clarity, the data analysis, results, and conclusions are organized in terms of the key themes. Following is a discussion of the divergence of systems thinking definitions and the resulting implications. Next, is a discussion on mechanisms that enable and obstruct systems thinking. These include experiential learning, certain individual characteristics, and a supporting environment.

4.1 Solving the Puzzle



The summarized research result presents a puzzle. How can people agree on mechanisms that enable or obstruct systems thinking when their definitions of systems thinking do not agree? The answer is that though the articulation of the systems thinking definitions diverge, there are common themes such as, (a) functions and behaviors at the contextual edge and (b) interactions of elements and how large scale things relate. The primary mechanisms cited enable and encourage: (a) translation across contextual edges, (b) consideration of interactions, and (c) higher impact learning.

Contributing to the divergence of definitions, the system of interest varies by company and even within companies. The systems thinking definitions participants provided are influenced by their unique system of interest. In addition, the articulation of a systems thinking definition is not necessarily a direct measure of the understanding of that concept in a person's mind. The articulation of a definition is limited by a person's verbal skill, the limitations of language, and the maturity of terms in the field.

4.2 Divergent Systems Thinking Definitions

Data in the study show that definitions of the phrase "systems thinking" diverge considerably. Participants were asked to define systems thinking and to give their reaction to a given definition of systems thinking, and the responses to these questions show the divergence of understandings. However, these divergent definitions can be reconciled using the systems thinking framework provided. There are both disadvantages and benefits to divergent understandings of systems thinking, and these are discussed in this section.

4.2.1 Divergent Respondent Definitions of Systems Thinking

Both the Expert Panelists and the follow-on respondents were asked, "How do you define systems thinking?" Of the 205 interviews analyzed, there were 205 unique definitions for systems thinking. The breadth and diversity of the responses were notable, and multiple respondent definitions were even contradictory. Even within the same company and within the same classification, the data show undeniably that when people refer to the phrase "systems thinking" they are often not articulating the same concept. This is particularly striking given the consensus about factors that affect systems thinking which is demonstrated in subsequent sections.

With divergent understandings of systems thinking, it is not sufficient to say that the goal is to develop a "systems thinking mindset." In the study, respondents cited process-centered systems engineering traits such as being detail oriented, structured, methodical, and analytical. Other respondents cited system-of-systems systems engineering traits such as not being detail focused, thinking out-of-the-box, being creative, and thinking abstractly. This shows that understandings of the phrase "systems thinking" can be contradictory, since "being detail oriented" and "not being detail focused" are in direct opposition. The systems thinking goal should be defined, and the intervention should match the goal. Then, this should be clearly communicated, since the data show that understandings of "systems thinking" vary.

The important point here is that many of these viewpoints on systems thinking are valid. Creativity may indeed be important when dreaming up possible complex system architectures, and attention to detail may indeed be important when tracking requirements. The point is to understand that the phrase "systems thinking" elicits many understandings, and when talking about or training for "systems thinking," it is important to be explicit about what is sought. Furthermore, when developing systems thinking, it is important to be explicit about the skills to develop. Likewise, when evaluating systems thinking, it is important to be explicit about what skills are being evaluated.

4.2.1.1 Example Definitions

Responses varied from one word or phrase, like *"interactions"* or *"big picture"* or *"worrying about everything"*, to much lengthier definitions. Here are more sample responses to the question, "How do you define systems thinking?"

- *"Thinking beyond the immediate task or element; understanding how that immediate element fits into the greater whole; understanding how the greater whole causes a requirement for each element and its attributes"*
- *"The ability to conceptualize and understand the inner workings of subsystems and components and the INTERWORKING between them and the environment in which they function"*
- *"Connecting lots of dissimilar disciplines and weighing trade offs between them... "*
- *"ABSTRACT thinking that must be applied and focused on one task... LOTS OF ABSTRACT CONCEPTS to pull together constantly"*
- *"System thinking is the ability to think about a system or system architecture holistically, considering the design elements, complexities, the "ilities", the context that product or system will be used in, etc."*
- *"You have to think extremely broadly. You can't focus on a specific aspect. Think from the application of what a product is. Think from what the customer wants explicitly. Be able to think in all the areas that are related to that device. It's broad and deep thinking. If you can't do both, then you shouldn't do systems stuff. You must be organized. Think without boundaries at the start. If you think that your job is the requirements, then you are a clerk, not a systems engineer."*

Though differences between some of these definitions are subtle, other differences are more apparent. Focusing on the inner workings of subsystems is different than focusing on the big picture alone. Thinking about what the customer wants explicitly is different than abstract thinking.

4.2.1.2 Diverse Definitions within the Same Company

Even within the same classification in the same company, systems thinking definitions diverge. For example, in a very well-regarded systems organization, one Senior Systems Engineer focused on the decomposition process when defining systems thinking as a, "*Deliberate decomposition process where you have requirements defined into functions and then those functions are broken down into design; feedback loops between requirements and functions; process of decomposing a complex problem*" Another Senior Systems Engineer in the same organization focused on the domain when responding, "*You MUST UNDERSTAND THE DOMAIN. You have to understand how the system could be used...*" Another Senior Systems Engineer in the same organization focused on the types of system elements when responding, "*I used to think about it as technical. NOW, as I get into monetary items, it's DOTMILPF... people, technology, money, etc.*" (Note that DOTMILPF is the acronym for Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities.) Another Senior Systems Engineer in the same organization focused on interactions when defining systems thinking as, "*Similar to how Ackoff does, look at the system function in the larger system, that sets the context, the larger system. Then, disaggregate that bigger system, which is* *not the same as decomposition. Look at it in the INTERACTIONS, not the internal functions, look at it in the context of the higher level system."*

Why is this divergence of understandings noteworthy? This divergence is noteworthy for multiple reasons. As will be discussed in detail in later sections, quality of systems thinking is often solely evaluated using the opinions of managers and senior systems engineers. If the opinions of what constitutes systems thinking differ among managers and senior systems engineers, there may be inconsistencies in the types of behaviors and characteristics that are rewarded and nurtured in the organization. This certainly is inefficient when trying to accelerate the development of systems skills. For example, using the example from the previous paragraph, one Senior Systems Engineer might determine quality of systems thinking as skill in executing the decomposition process, another Senior Systems Engineer might determine quality of systems thinking as expertise in a specific domain, another Senior Systems Engineer might determine quality of systems thinking as the ability to identify various types of system elements, and another Senior Systems Engineer might determine quality of systems thinking as the ability to identify interactions. These are not equivalent measures. It is then not a surprise when Junior Systems Engineers voice confusion on what skills they are trying to develop or what skills are rewarded in the organization.

This was not the only company where participants within the same company and within the same classification differ in their interpretation of the phrase "systems thinking". In another company, when asked "How do you define systems thinking?" one Senior Systems Engineer said *"BRING IDEAS INTO REALITY. Come up with a concept [at a] level of abstraction to the functional, operational view of what it should do. Make it happen."* Another Senior Systems

Engineer said *"understanding the action of a function and the interaction of that function with its surroundings. To cover it all, it is the components and how they interact."* Another Senior Systems Engineer at this company said it is, *"Broad and not deep. Look at the total set of requirements from stakeholders. Do the trades for the total benefit of the system. Make dreams into reality. Balance the down and deep guys."* For one person, it is bringing ideas into reality, for another it is understanding the interaction of components, and for another it is balancing between the component design engineers. Again, though the distinction between these might seem subtle, the requisite skill set varies. Bringing ideas into reality might involve leadership and determination. Understanding the interaction of components might involve skills like analysis and organization. Balancing between the component design engineers might involve traits like communication and strong interpersonal skills. These are not equivalent skills.

The diverse definitions are also visible in other classifications. For the Expert Panelists in the company from the previous paragraph, one Expert Panelist said that systems thinking is *"always keeping in mind the top level requirement for the product, how it will be used, what void it is filling. Engineers push to maximums. Systems engineers think if [we are] meeting requirements."* Another Expert Panelist said that *"Systems thinking is organizational learning. System dynamics might be getting to those five major questions (variety, feedback, etc.), 5th discipline stuff."* Another Expert Panelist said it is *"the ability to think of the larger system as opposed to individual components, the context in which the system operates, the big picture."* A fourth Expert Panelist said systems thinking is, *"broad understanding of what are all the elements, from concept to integration, test, and support. It is how to meet with the customer, how to put requirement in a document, how to figure out the architecture, who are the people*

[one] needs to talk with, what are the processes, people, and customer needs. Work with the project manager, know the political things, know the customer requirements and needs. For systems thinking, there are a hundred different ways to do something. Different people bring different ideas. The key is empowering people. As the lead, I encourage them, give them constructive criticism. Systems thinking is tied to leadership. The systems guy must know little pieces and go to people throughout the lifecycle. Learn from everyone. Know what to do next time. [Our company's] systems development life cycle is a process on the web. Click on it to see what happens at each stage. It is a set of guides so people don't have to start from scratch."
One person is talking about requirements, one is talking about organizational learning, one is talking about the big picture, and one gives a sprawling account of a multitude of ideas. Even within the same company and the same classification, there are diverse understandings of the definition of "systems thinking". This was shown for multiple companies and multiple classifications.

4.2.2 Divergent Respondent Reaction to a Given Definition of Systems Thinking

A sample definition of systems thinking was given to interviewees to baseline across the interviews. Interviewees were asked, "Considering the definition of systems thinking as, 'analysis, synthesis, and understanding of interconnections, interactions, and interdependencies that are technical, social, temporal, and multi-level,' what aspects of this definition do you agree or disagree with? Why?" The reactions to this given definition were as diverse as the systems thinking definitions that were generated by the participants.

However, it is interesting to note that many respondents displayed surprise in seeing the word "social" in the definition. Many of these respondents initially displayed surprise in seeing the word "social" in the definition, but then agreed that it was important. Some respondents initially displayed surprise in seeing the word "social" in the definition but then decided that the social component had nothing to do with their systems. This could be problematic for organizations trying to expand their engineers' system definitions beyond the technical components of classical, product-focused systems.

Here is an example reaction to the given definition. "The struggle that the community is struggling with today is the idea of enterprise systems thinking and complex systems engineering. We're in this dilemma in the systems engineering environment where we are very comfortable if [we are] given a requirement and can decompose that into functions and can do 'analysis, synthesis, and understanding of interconnections, interactions, and interdependencies'. [We] do the design and deliver the system. Today [the] problem is capturing the requirements in a flexible system, [since we are] not sure what the future threat is. [This] plays into the social view. [We] want it to be interchangeable, and we don't know what will change socially. [We are] not sure if it will be a bio attack, or police or military or whomever can take care of that. For this definition of systems thinking, I don't see the term requirements in there and that's the differentiator. If [one] knows the requirements, then systems engineering. If [one] doesn't know the requirements, then normal systems engineering does not apply. I am not even sure if the people educated in systems engineering are the same people to do complex systems engineering. Systems engineering is always required, but the enterprise systems thinking and complex systems engineering [are different]. I am not sure if the Senior Systems Engineers in the traditional sense are the same people that would be able to address complex systems engineering problems."

4.2.3 A Systems Thinking Framework to Reconcile the Divergence

From the data shown, it is clear that definitions of "systems thinking" diverge. However, interview respondents did cite some common themes and definition components that might be expected, including components such as: holism, the "big picture", system elements, context, complexity, "ilities", contingencies/risk analysis, feedback, temporal concerns, life cycle issues, interrelations, interactions, strategy, synthesizing, optimizing, application knowledge, customer perspective, management, inputs, outputs, multi-disciplinary knowledge, abstract thinking, broad AND deep thinking, thinking without boundaries, looking across boundaries, being out of one's comfort zone, thinking broader than the box one is working on, knowing the right level to work at, etc. This is a much abbreviated list, provided to give the reader a sample of the diversity in responses.

In many cases, it appears that people are just describing different parts of the same system. Synthesizing all the definitions considered, five foundational elements describe a systems thinking framework: (1) componential, (2) relational, (3) contextual, (4) dynamic, and (5) modal. A proposed definition is then, "*Systems thinking* is utilizing modal elements to consider the componential, relational, contextual, and dynamic elements of the system of interest."

COMPONENTIAL - The componential element addresses what types of things are considered in systems thinking. This answers the question of "what." This includes behavior, form, purpose/objectives, performance, data, and management, as discussed by Rechtin and Maier (Maier and Rechtin 2002). In addition, this includes balance and social and technical components. This also tells what types of disciplines are considered. For example, the componential element includes economics, politics, electrical engineering, structural engineering, abstract ideas, design elements, ethics, etc. All the elements of the common SE acronym POET (Political, Organizational, Economic, and Technical) are included in this componential element.

RELATIONAL - The relational element addresses the interconnections, interactions, and interdependencies both within the system of interest and between the system of interest and other systems. Complexity would also fit here. From some of the definitions given earlier, examples that are of the relational element include: "Being able to think in all the areas that are related to that device" and "the ability to conceptualize and understand the inner workings of subsystems and components."

CONTEXTUAL - The contextual addresses the nested and embedded nature of systems. Whenever a system of interest is considered, boundaries are drawn. However, the system considered is part of many layers of systems. The context of a system must be considered. Examples could include the economic sector in which the system is embedded, the system-of-systems in which the system of interest is embedded, or even the organizational context in which a system is embedded. Though the word "embedded" has a specific meaning in certain communities of traditional systems engineering, it seems the most appropriate term to describe this phenomenon.

DYNAMIC - The dynamic element considers important aspects such as feedback, uncertainty, risk, and the "ilities". Any system is linked in time to uncertain futures and past decisions. Any system design for today is impacted by history and past events, and any system design for today should anticipate future perturbations. Often included in the "ilities", robustness is an important characteristic to keep in mind at each time step.

MODAL – The modal element aids with understanding and comprehension of the system. This is the "how" in how the individual performs systems thinking. In order to comprehend or compose all the complexity of the system, various aids can be used. These aids include tools and methods, different types of thinking, models and simulations, and processes and frameworks. Types of thinking include holistic thinking, analytical thinking, deductive thinking, logical thinking, visual thinking, critical thinking, creativity, synthesis, etc. Common in systems engineering, the decomposition process is another mode with which a system may be examined. The tracking of system requirements and the validation and verification of requirements are other aids to understanding a system's behavior. The modal element also includes recursion control and stopping rules so an individual knows what level of granularity and detail is sufficient. The modal element produces a subjective view of a system, since any mode chosen to examine the system is incomplete.

Figure 4-1 is a conceptual illustration of systems thinking. The componential element is shown by reference to behavior, form, purpose/objectives, performance, data, management, and social and technical components. The relational element is shown by the reference to interconnections, interactions, and interdependencies. References to environment, context, and embedded systems show the contextual element. The dynamic element is shown by the repeating, underlying path which emphasizes feedback, uncertainty, risk, and the “ilities”. The modal element is shown by the magnifying glasses. These are ways to view and comprehend the system, and they include different types of thinking, tools and methods, models and simulations, and processes and frameworks. In addition, whenever a system is considered, it is important to balance all these elements, which is why the word “balance” is also shown in the illustration.

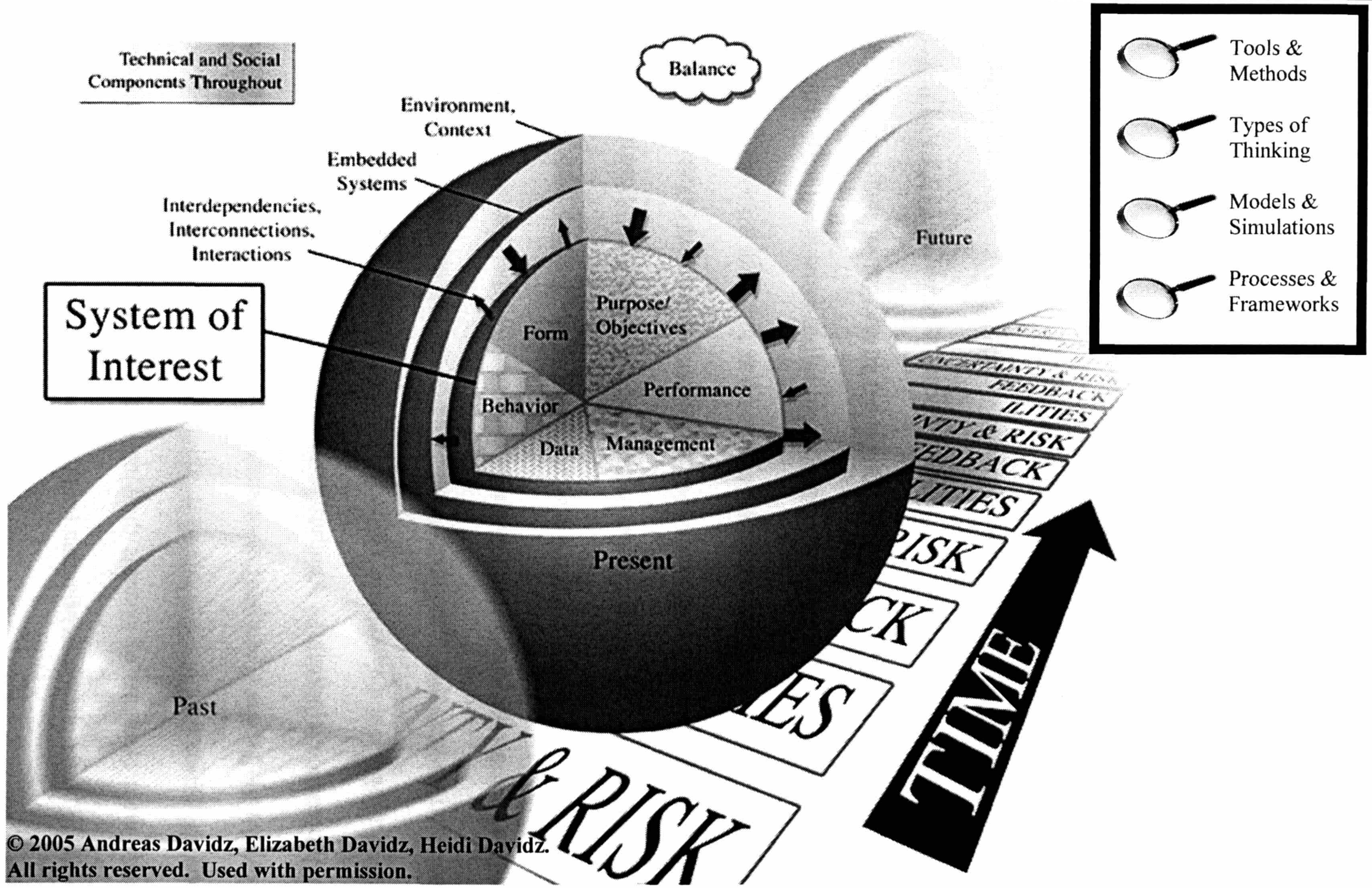


Figure 4-1: Conceptual Illustration of Systems Thinking

4.2.4 Disadvantages of Multiple Systems Thinking Perspectives

When definitions of "systems thinking" diverge, there are two key disadvantages. First, this divergence may lead to imprecise goal definitions. Second, this divergence may lead to inconsistent measures of strength of systems thinking in an organization.

4.2.4.1 Imprecise Goal Definition

At a recent conference of a respected professional society, a keynote speaker stated, "We need people with a systems thinking mindset." This is not an uncommon statement as systems issues gain attention. However, that type of platitude and call-to-arms is not sufficient, since the data show undeniably this is a nebulous and hazy goal. More powerful is a specific and explicit annunciation of the "systems thinking mindset" one desires. Developing "systems thinking" is ineffectual if people in the same organization are working towards different goals, goals consistent with their own, perhaps unarticulated, version of what "systems thinking" means.

Likewise, if a senior leader in an organization says, "We need more systems thinking," that may translate into very different actions depending on the person in charge of setting up the intervention. One person may translate this into the need for a training course in systems engineering process development. Another person may translate this into the need for an organizational learning class. Another person may interpret this as a call for a class on creative problem solving. Since the phrase "systems thinking" has multiple meanings, it is important to explicitly state what elements of systems thinking one is trying to foster. Leaving the phrase "systems thinking" to implicit interpretation leads to divergence and confusion.

4.2.4.2 Inconsistent Determination of Strength of Systems Thinking

When respondents know how an organization determines strength of systems thinking, the data show that strength of systems thinking is determined by observation not objective measure. When interpretations of "systems thinking" diverge, observations on strength of systems thinking also diverge, leading to inconsistent measures of strength of systems thinking.

During the interviews, the follow-on participants were asked, "How does your company determine if an employee displays strong systems thinking?" Note that the Expert Panelists were not asked this specific question. Primarily, strength of systems thinking is determined by observation. This includes observation from interactions, from past performance, from artifacts, from reputation, from performance in a systems role, etc.

Table 4-1 is a typical chart that will be used throughout this document. To explain the table format, the title shows the level of node category considered. The first column listed the node categories. The next column lists the rank of the node category for "All Participants" who responded to the study. The corresponding number and percentage of respondents is shown next. The following columns show this information for each of the classifications. The only node categories listed are those where 10% of more of the respondents in the classification cited that node category. The "Chi-Square" column shows the result of running a Pearson chi-square statistical test to see if there are differences between comparison groups. The "Asymptotic Significance" shows if the result is significant, and the cut-off for significance is 0.05.

Table 4-1: Top Level 1 Coding for Determination of Strong Systems Thinking

Top Level 1 Coding for Determination of Strong Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=165)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=51)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Difficulty with this	1	100	61%	2	30	48%	1	33	65%	1	37	71%	6.659	0.036
Experience and observation	2	95	58%	1	41	66%	2	29	57%	2	25	48%	3.788	0.150
Look for certain characteristics	3	28	17%	3	9	15%	3	12	24%	3	7	13%	2.277	0.320
Formal methods	4	23	14%	4	7	11%	4	11	22%	4	5	10%	3.648	0.161

As Table 4-1 shows, the highest ranked Level 1 category was "Difficulty with this." This refers to people who replied with answers such as, "I don't know." This table shows that 71% of Junior Systems Engineers responded with an answer coded as "Difficulty with this", while only 48% of Senior Systems Engineers responded in this way. The next highest Level 1 category is "Experience and observation." For the Senior Systems Engineers, 66% said this is how their company determines strong systems thinking in their organization. For both of these node categories in all the classifications, the percentages are 48% or higher, which is relatively high convergence for this study.

As Table 4-2 shows, the top-ranked Level 2 categories are "Do not know", "Experience/demonstrate ability", "Not formal method in company", "Observation", "Look for certain characteristics", and "Management identifies/evaluates." Again, this emphasizes that employees either do not know how their companies are determining strong systems thinking and the primary measures of quality are experience and observation.

Note in the table that there are very subtle differences between some of the categories. For example, "observation" refers to people evaluating systems thinking by watching others as in the response, "Not sure, mostly from observations in design reviews." In contrast, the category "interaction" refers to direct interaction with the person, as in the response, "Through the interaction of working with them." These categories are combined when the numbers are tallied for the Level 1 category "Experience and observation."

Table 4-2: Top Level 2 Coding for Determination of Strong Systems Thinking

Top Level 2 Coding for Determination of Strong Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=165)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=51)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Do not know	1	58	35%	1	17	27%	1	16	31%	1	25	48%	5.757	0.056
Experience/demonstrate ability	2	39	24%	1	17	27%	3	11	22%	3	11	21%	0.790	0.674
Not formal method in company	3	37	22%	4	14	23%	3	11	22%	2	12	23%	0.035	0.983
Observation	4	31	19%	3	15	24%	5	10	20%	5	6	12%	3.001	0.223
Look for certain characteristics	5	28	17%	5	9	15%	2	12	24%	4	7	13%	2.277	0.320
Management identifies/evaluates	6	21	13%	5	9	15%	6	9	18%	8	3	6%	3.557	0.169
Performance appraisals	7	15	9%	7	3	5%	7	7	14%	6	5	10%	2.699	0.259
Artifacts/quality of work	8	9	5%	7	3	5%	12	1	2%	6	5	10%	2.998	0.223

Considering the chi-square test results, for the Level 1 node category "Difficulty with this," the low asymptotic significance value of 0.036 shows that the null hypothesis can be rejected, and there is a difference between the classifications for this node category. Appendix Sections 8.7.5 and 8.7.6 show the complete crosstabulation tables with expected counts versus actual counts. At Level 1, 37.6 Senior Systems Engineers were expected to say they had "Difficulty with this", while only 30 Senior Systems Engineers actually responded in this way. However, 31.5 Junior Systems Engineers were expected to say they had "Difficulty with this," while 37 actually responded in this way. Similarly at Level 2, 18.3 Junior Systems Engineers were expected to say "Do not know", but actually 25 Junior Systems Engineers responded that they "Do not know." These results show that while Senior Systems Engineers are less likely to have difficulty knowing how the company determines if an employee exhibits strong systems thinking, the Junior Systems Engineers are more likely to have difficulty with this than is expected. If systems thinking is a trait the organization hopes to foster, it is important for the Junior Systems Engineers to also know how they are being evaluated against this goal. It is discouraging that 71% of the Junior Systems Engineers have difficulty answering this question and 48% do not know how this is determined, and it is also discouraging that they are more likely than expected to respond in this way.

Here are some sample responses showing that respondents do not know how strength of systems thinking is determined in their company. The phrase "I don't know" was a very common response. One participant said, "I am not sure. The best I can say is based on my experience at [Company X] is that they throw you in the fire and see if you burn. This was my experience with three different managers."

Other responses continue with the theme of observation. One participant said, "We use the trial by fire method. We allow young engineers to be exposed to problems with multiple facets and see if they are successful in fostering a solution." Another participant responded first with a laugh, which was not an uncommon reaction, and then said "Whenever there is a fire, that person gets the fire duty. [When a person is] good at systems thinking, architecture, etc., they travel more between sites and see the sponsor more. They get the role as emissary to collect data, needs, etc. from various programs and see how to use it in the company. [They have the] task of understanding the mission of the system, where the system is moving."

Other responses highlight the subjective nature of existing methods to determine strength of systems thinking. One participant said it is "very subjective, in the eye of the beholder. [There is] no organized way of doing it. [It is] given that it's an art. Two people could rank the same person very differently." Another participant said that "[I] talk to them and know if [the person is a] systems person or a technical specialist. See if they hunger for the bigger picture." Another typical response was, "Beats me. I don't know how I do it. I do have people pegged as good systems thinkers – sort of a feeling I get…" A participant said that it is "hard to say. In certain jobs in the company, you put certain people in certain jobs because you know they have systems thinking. The job I'm doing now was given to me because people see I have this systems thinking. But, I think it's the experience the bosses have, or they know the employees. There is not a certain procedure to determine if someone has systems thinking. It's just the experience with that person."

The blue chip interviewees also cite the importance of observation in determining systems thinking quality. As one blue chip respondent stated, "The training was all on-the-job-training. We would have young guys work on a section of the program, then they would move up to be in charge of a particular element, then they would work there for 4-5 years, then they would move to a subsystem level, then they would move up to be responsible for a segment of the program. Each time, we could pick from 5-8 engineers to move up to the position at that higher level. We measured performance by observation." Another blue chip interviewee stated, "I can walk into a room and pick out the good systems engineers. I watch how the engineer works, operates, and lays out the fundamentals of a problem. These people see WHY something is happening. In addition to intellect and education, the good ones have this and the bad ones don't."

There were some respondents who cited formal processes. "We tend to use a five-point scale. First is testing and integration of someone else's thing, then [working] requirements, then designing something, then integrating, then top level as integrating a big piece. [We] place people in these categories. Level 1: V&V problem (0-2 yrs experience); Level 2: write a spec; Level 3: lead effort with various components, performance of them; Level 4: conceptual and create system; Level 5: chief systems engineer, conceptual at large level. [This is] not in the HR construct, but [we] use this when we talk to each other. Most people in systems engineering will have: Associate Systems Engineer, Systems Engineer, then Senior Systems Engineer, Principal Systems Engineer, then Staff Systems Engineer. Various companies have various names for these things, but they tend to have 4-5 levels."

Various respondents pointed to a performance evaluation as a formal measure of systems thinking. "There is not a formal black and white system for this. They have an annual review and some of the items on this hint at systems thinking. Example items are analytical thinking, business judgment, and customer focus, though there are probably ten more. Putting these together could result in systems thinking. Mostly, systems thinking is measured through this annual performance tool."

Even if a company has a method to identify high potential systems thinkers, when the determination of strength of systems thinking is left to individual managers, there is a process breakdown if the manager who is supposed to be recognizing systems thinking cannot do this. The following quote shows the downfall of determining quality of systems thinking by observation, "Very difficult question. It depends heavily on the managers and executors. There is a formal way - we talk at one time every year about the potentials. This is one way we can identify the systems thinkers and give them a plan to develop them. [We] identify systems thinkers by observation by management. But there are some managers who cannot recognize systems thinking, and then a systems thinker would have problems in the organization."

Herein is the fundamental problem. The data show that strength of systems thinking is determined by observation. However, if the observers and evaluators have varying opinions on the definition of systems thinking, the measure of strength of systems thinking is inconsistent both within companies and across companies. It is no wonder that some of the Junior Systems Engineers sampled simply throw up their hands in frustration and respond to this question with a laugh or with "I have no idea." Also, the lack of an objective measure of strength of systems thinking is a challenge when conducting research in this area.

4.2.5 Advantages of Multiple Systems Thinking Perspectives

On the other hand, there are advantages to having multiple systems thinking perspectives in an organization. Viewing the same system with multiple lenses may provide more insight into system behavior. For example, a more complete understanding of the system may result if one team member uses a system decomposition to represent the system, while another team member focuses on the system interdependencies, and another team member focuses on the system performance. Assuming the team members coordinate and communicate their perspectives, the conglomeration of diverse system understandings produces a more complete representation of the system. In addition, if the system context dramatically changes instantaneously, diverse system understandings may assist the organization in being more robust to change.

4.3 Mechanisms That Enable or Obstruct Systems Thinking Development

Although systems thinking definitions diverge, there is convergence on mechanisms that enable and obstruct systems thinking development. These include experiential learning, individual characteristics, and a supporting environment, and the following sections describe these mechanisms.

4.3.1 Importance of Experiential Learning

The data show that systems thinking is thought to be developed among engineers primarily by experiential learning. This includes both work experience and life experience. Comparing this conclusion to current systems thinking development policies shows that policy changes are needed in industry, in academia, and in the government. To develop systems thinking, systems engineering education and training programs should include experiential opportunities. The following sections present the supporting evidence for this conclusion and discuss the resulting implications.

4.3.1.1 Experiential Learning as a Key Step to the Development of Systems Thinking

The analysis of the question, "What were key steps in your life that developed your systems thinking abilities?" also shows that experiential learning is significant. At Level 1, "Work Experiences" were cited by 139 of all participants, which is 69% of the participants. In each category, more respondents cited "Work Experiences" than any other Level 1 category. As Table 4-3 shows, the percentages for this are quite high, compared to the percentages seen in other tables. As the highest sign of convergence in the study, an astounding 95% of Expert

Panelists cited “Work Experiences” as a key step to the development of systems thinking. Another experiential learning category, “Life experiences outside work”, was also a top node category for all classifications. The full list of node categories for this question is shown in the appendix.

At Level 2, the top node categories for all participants also emphasize experiential learning. Table 4-4 shows that for all participants, the top five key steps to the development of systems thinking are all experiential learning, either work experience or life experience. These include, “Work on diverse thing”, “Systems jobs/experiences”, “Family”, “Early life experiences”, and “Hobbies.” “Work on diverse things” was a top category for each of the classifications, and all but one classification had “Systems jobs/experiences” and “Family” as a top category.

An example of a response that was coded at Level 1 as “Work Experiences” and at Level 2 as “Military” is as follows. One respondent who worked on a nuclear submarine said that a key step in his life that developed his systems thinking is, “Ship qualifications in the military. You see the impact of how other people’s stuff impacts your own. In the ship qualifications, you look at stuff you aren’t responsible for. This submarine training shows how everyone else works and how it all ties together (cooks, hydraulics, pneumatics, oxygen production, waste disposal, ventilation, ship handling, emergency response, etc., etc.) You spend at least an hour on each of these systems, learning about them, sometimes you spend weeks. You are either qualified or not qualified. This is distinct from your job rating, where there are tiers/levels of expertise.” It is clear that when your life and existence directly relies on the proper functioning of a complex system like a submarine, the proper functioning of that full system might be of immediate interest. In addition, one might be more apt to care about parts of the system outside one's own responsibility.

Interestingly, "Family" and "Early life experiences" were next highest, with "Family" being the highest ranked category for the Senior Technical Specialists. Using a broad definition of experiential learning that includes both work and life experiences, these categories are also considered experiential learning. Here is an example of what one respondent said which was coded on Level 1 as "Life experiences outside work" and coded at Level 2 as "Family." He learned "to report about speeches, if someone asks about a speech of a politician, teacher, priest, etc. My father was the organist at another church, and he wanted to know what our priest said." Each week when he returned from services, his father would ask for a report of what the priest had said. "At first when he asked me, I had many details in my head and no one line. Later, I learned what he wanted to say as the key message. Then the details are easier to remember. That was very early, when I was like 10-12 years old. Later, it was easier for me to remember what the key messages were in speeches, etc. It is the same matter with technical things. If [one] understands the key point for a part or [specific system deleted], it is easier to remember the details."

Table 4-3: Top Level 1 Key Steps to the Development of Systems Thinking

Top Level 1 Key Steps to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=202)			Expert Panelists (N=37)			Senior Systems Engineers (N=61)			Senior Technical Specialists (N=52)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Work Experiences	1	139	69%	1	35	95%	1	36	59%	1	38	73%	1	30	58%	17.625	0.001
Education	2	80	40%	3	13	35%	3	22	36%	3	17	33%	2	28	54%	6.076	0.108
Individual characteristics	4	64	32%	2	16	43%	4	16	26%	4	11	21%	3	21	40%	7.605	0.055
Life experiences outside work	3	72	36%	4	5	14%	2	27	44%	2	19	37%	3	21	40%	10.402	0.015
Interpersonal	5	37	18%	4	5	14%	5	13	21%	4	11	21%	5	8	15%	1.515	0.679
Training	6	16	8%	6	4	11%	6	7	11%	6	2	4%	6	3	6%	2.994	0.393

Table 4-4: Top Level 2 Key Steps to the Development of Systems Thinking

Top Level 2 Key Steps to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=202)			Expert Panelists (N=37)			Senior Systems Engineers (N=61)			Senior Technical Specialists (N=52)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Work on diverse things	1	41	20%	1	11	30%	2	11	18%	3	8	15%	1	11	21%	3.028	0.387
Systems jobs/experiences	2	29	14%	2	9	24%	6	6	10%	3	8	15%	6	6	12%	4.384	0.223
Family	3	25	12%	24	1	3%	3	9	15%	1	10	19%	7	5	10%	6.129	0.105
Early life experiences	4	23	11%	8	3	8%	9	4	7%	3	8	15%	2	8	15%	3.452	0.327
Hobbies	5	21	10%	24	1	3%	1	13	21%	13	2	4%	7	5	10%	12.582	0.006
Curiosity/wants more understanding	10	15	7%	3	5	14%	17	3	5%	7	5	10%	19	2	4%	3.885	0.274
Specific project	14	12	6%	3	5	14%	9	4	7%	24	1	2%	19	2	4%	5.749	0.124
Training	7	16	8%	5	4	11%	5	7	11%	13	2	4%	13	3	6%	2.994	0.393
Project work/open-ended problems	24	5	2%	5	4	11%	75	0	0%	69	0	0%	33	1	2%	13.583	0.004
Leadership/responsibility	15	11	5%	5	4	11%	9	4	7%	24	1	2%	19	2	4%	3.726	0.293
Particular organization/company	6	18	9%	8	3	8%	3	9	15%	7	5	10%	33	1	2%	5.755	0.124
General experience	7	16	8%	24	1	3%	20	2	3%	2	9	17%	10	4	8%	9.470	0.024
Mentoring	7	16	8%	8	3	8%	8	5	8%	6	7	13%	33	1	2%	4.762	0.190
Natural/innate	11	14	7%	13	2	5%	17	3	5%	24	1	2%	2	8	15%	8.300	0.040
Thinking	15	11	5%	64	0	0%	29	1	2%	9	3	6%	4	7	13%	10.347	0.016
Systems courses/degree	12	13	6%	24	1	3%	9	4	7%	24	1	2%	4	7	13%	6.879	0.076
Teams	18	10	5%	24	1	3%	9	4	7%	69	0	0%	7	5	10%	5.845	0.119

This example also shows the approximate nature of the coding process. This excerpt could have been coded as "Life experiences outside work/Family" or "Life experiences outside work/Early life experiences." In the case of these two categories, if a respondent mentioned anything about the influence of family members, the item was coded as "Family." If the respondent mentioned an early life experience and did not directly mention a family member, the item was coded as "Early life experiences."

Considering the chi-square test results for the Level 1 node category "Work experiences," the low asymptotic significance value of 0.001 shows that the null hypothesis can be confidently rejected, and there is a statistically significant difference between the classifications. This is due to 95% of the Expert Panelists responding that "Work experiences" were key steps to systems thinking development, which is a high percentage compared to the responses of the other classifications. For the Level 1 node category "Life experiences outside work," the asymptotic significance value is 0.015. Again, this shows that there is a statistically significant difference between classifications for this node category. Here, only 14% of Expert Panelists cite "Life experiences outside work" as a key step, while 44% of Senior Systems Engineers cite this. The Expert Panelists differ significantly from the other classifications in both of these node categories. A possible explanation is that the Expert Panelists have focused their efforts in work experiences, which is why they have achieved the level of "Expert Panelist" and why they cite work experiences so highly. Others may have systems thinking development experiences balanced more between life inside and outside work. The full crosstabulation tables with expected versus actual values are shown in the Appendix Section 8.8.5.

For the Level 2 node category "Hobbies," the asymptotic significance is 0.006, which shows that there is a statistically significant difference in the responses from the different classifications. Looking at the expected versus actual values shown in the appendix, many more Senior Systems Engineers cited this node category than expected. The actual count was 13, and the expected count was only 6.3. For the Junior Systems Engineers, the actual count was also a bit higher than the expected count, with 5.4 expected and 5 as the actual count. This means that hobbies were key steps to systems thinking development for Senior Systems Engineers more than for the Expert Panelists or Senior Technical Specialists.

4.3.1.2 Experiential Learning as an Enabler to Systems Thinking Development

During the interviews, participants were asked the question, "In your experience, what enablers or barriers have you seen to the development of systems thinking in engineers?" Considering the responses that address enablers, the responses to this question highlight the importance of experiential learning.

As an illustration of the importance of experiential learning, for all participants, "Experience" is the top ranked node category for the Level 1 enablers to systems thinking, as Table 4-5 shows. The classifications of Expert Panelists, Senior Systems Engineers, and Senior Technical Specialists also cite "Experience" as the top-ranked Level 1 node category, with forty percent or more of the participants in each of these categories identifying this category. For the Junior Systems Engineers, this was still a top concern, though the rank is third instead of first. Junior Systems Engineers that do not see experience as the number one factor may be less patient with policies that emphasize experience.

Table 4-5: Top Level 1 Enablers to the Development of Systems Thinking

Top Level 1 Enablers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=177)			Expert Panelists (N=35)			Senior Systems Engineers (N=52)			Senior Technical Specialists (N=43)			Junior Systems Engineers (N=47)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Experience	1	81	46%	1	16	46%	1	28	54%	1	21	49%	3	16	34%	4.134	0.247
Individual Skills & Traits	2	76	43%	2	13	37%	2	25	48%	2	20	47%	2	18	38%	1.677	0.642
Interpersonal	3	49	28%	4	6	17%	5	10	19%	3	13	30%	1	20	43%	**9.129**	**0.028**
Organization	4	45	25%	2	13	37%	4	13	25%	4	9	21%	4	10	21%	3.424	0.331
Interventions	5	39	22%	5	5	14%	3	16	31%	4	9	21%	5	9	19%	3.791	0.285
Tools & Methodology	6	18	10%	7	3	9%	6	9	17%	6	2	5%	6	4	9%	4.573	0.206
Current trends	7	12	7%	6	4	11%	7	4	8%	7	1	2%	7	3	6%	2.627	0.453

Table 4-6: Top Level 2 Enablers to the Development of Systems Thinking

Top Level 2 Enablers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=177)			Expert Panelists (N=35)			Senior Systems Engineers (N=52)			Senior Technical Specialists (N=43)			Junior Systems Engineers (N=47)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Broad experience base	1	37	21%	2	7	20%	1	18	35%	2	8	19%	7	4	9%	10.434	0.015
Job/opportunity to see systems view	2	35	20%	1	8	23%	3	8	15%	1	10	23%	1	9	19%	1.181	0.757
Training	3	23	13%	4	3	9%	2	11	21%	8	4	9%	3	5	11%	4.417	0.220
Experience in general	4	17	10%	16	1	3%	6	6	12%	3	7	16%	9	3	6%	4.828	0.185
Education	4	17	10%	10	2	6%	8	4	8%	4	6	14%	3	5	11%	1.824	0.610
Innate	4	17	10%	10	2	6%	4	7	13%	4	6	14%	13	2	4%	3.987	0.263
Broad perspective	4	17	10%	4	3	9%	4	7	13%	6	5	12%	13	2	4%	2.686	0.443
Current trends	10	12	7%	3	4	11%	8	4	8%	16	1	2%	9	3	6%	2.627	0.453
Step outside own box/comfort zone	12	10	6%	35	0	0%	7	5	10%	11	2	5%	9	3	6%	3.758	0.289
Mentors	8	13	7%	16	1	3%	14	3	6%	6	5	12%	7	4	9%	2.479	0.479
Teams	8	13	7%	16	1	3%	14	3	6%	9	3	7%	2	6	13%	3.264	0.353
Communication	10	12	7%	10	2	6%	8	4	8%	16	1	2%	3	5	11%	2.588	0.460
Cross disciplines	16	7	4%	35	0	0%	27	1	2%	16	1	2%	3	5	11%	7.834	0.050

The top enablers of systems thinking at Level 2 are "Broad experience base" and "Job/opportunity to see systems view", as shown in Table 4-6. This also highlights the importance of experiential learning. The node category "Job/opportunity to see systems view" was identified as a top enabler for systems thinking development by all classifications. The node category "Broad experience base" was identified as a top enabler for all classifications except the Junior Systems Engineers, who most likely have not yet had a chance to develop a broad experience base.

"Broad experience base" can refer to a variety of experiences within the company or a variety of experiences in general. According to one participant, "The biggest enabler is for people to move between different jobs that enable them to work in different jobs related to the system. [They] must work in some areas in depth. Not just technical, but project management and customer function perspectives also. [A] key enabler is moving people to technical, project, business, customer side of the business." When asked how long employees should spend in each position, the participant said it is "best if you spend significant time in the first assignment, like 3-5 years to get a firm grounding. Then, 2-3 years in the following assignments." This was a common response. Another respondent referred to how a broad experience base across fields and companies can be an enabler to systems thinking development. An enabler to systems thinking is, "people who have worked in different fields, [who] work in one company and move to another, [who have a] large spectrum of knowledge." Another respondent said that, "I think there are a lot of systems engineers that don't think of the broader context. Most strong systems engineers have a technical tap root that they have come from, [and they] rely on that tap root when they work in the systems role. When people develop different technical tap roots, [they] get broader domain knowledge, [and have an] easier time in the systems thinking environment. An enabler is multiple technical tap roots to understand the broader application of the technology." This highlights a key tension. In some companies, the churning among assignments every 2-3 years is great for developing management generalists, but this is not good for developing technical depth. There is a tension between developing a broad experience base while still having strong technical tap roots on which to draw.

As an example of "Job/opportunity to see systems view", one participant said that an enabler is the being able to "really explore how [something] fits in with other things. I'm an advocate of bringing designers into the customer meetings to see the bigger picture and see what the big issues are. They may not get this opportunity, [since they may be] isolated from this by several layers of management." Another person stated that an enabler is, "Providing opportunities for engineers to actively participate in system level activities. Often, they pigeon-hole people in one role, and it can be hard for that person to look out and see the big picture. One key is to create positions that allow people to look out of their zone of control. An "aero integrator" position is an example, since this position gives engineers exposure to the program office and allows them to think at that level. To take this to the next level, some positions drive customer decisions, though there are limited opportunities there."

One of the companies who participated in the study has a training program where participants rotate through a series of work assignments while also participating in advanced engineering courses. This program was viewed quite favorably by participants. One participant noted that "In the training program we have here, the advanced courses, [we worked] solutions of real engineering problems. [This] required resources from a number of tasks and disciplines to solve a problem. For the first time, I tied different aspects of my education together for more integrated problem solving."

For the Level 1 node category "Interpersonal," the asymptotic significance value is 0.028, which is statistically significant. This is due to the high percentage of Junior Systems Engineers citing this node category. Comparing the expected and actual counts shown in the full crosstabulation tables in Appendix Section 8.9.5, 20 Junior Systems Engineers cite this node category, when the expectation is that only 13 would cite this. Looking at the node hierarchy, one can see that items such as "Communication," "Teams," and "Mentors" fall under "Interpersonal." It is no wonder that these types of enablers are most important to Junior Systems Engineers, since they have the most to learn and they rely on others to help develop their knowledge more than the other classifications.

With a high chi-square value and an asymptotic significance value of 0.015, the Level 2 node category "Broad experience base" also showed a significant statistical difference between the responses of the different classifications. Here, the Junior Systems Engineers once again contribute to the difference between the categories. Only 4 Junior Systems Engineers cited this, though 9.8 were expected to cite this. In addition, 18 Senior Systems Engineers cited "Broad experience base" as an enabler, when only 10.9 were expected to cite this. Most likely, the Junior Systems Engineers do not have a broad experience base yet, so they cannot speak to the value of having this. Instead, they value things like "Teams," "Communication," "Training," and "Education" more than the other classifications.

As explained earlier, "blue chip" interviews were also conducted as part of this study. These were interviews with people whose achievements are so outstanding that there is little question that they are strong systems thinkers. Responses of the blue chip interviewees also supported the importance of experiential learning for developing systems engineers and systems thinking in engineers. One of the blue chip interviewees had the following comment,

> "When I was involved in the mid-60s, programs went from concept to operation in 3-5 years. In a period of 15 years of experience, an engineer would work on 3-5 programs. They would work up progressively to larger and larger responsibilities. There was a whittling down process so that we could pick the systems engineer. There would be 3-5 programs with 4-5 segments each, so we could pick the systems engineers for the new programs from this pool. We would have 3 to 5 to 8 people to pick from, and we could pick the best.
>
> We never had a problem with training, since this was provided by on-the-job training and experience. We never thought about setting up training until the 2001 timeframe when we thought about how to fix the problems in space acquisition...
>
> The training was all on-the-job. We would have young guys work on a section of the program, then they would move up to be in charge of a particular element, then they would work there for 4-5 years, then they would move to a subsystem level, then they would move up to be responsible for a segment of the program. Each time, we could pick from 5-8 engineers to move up to the position at that higher level."

This same respondent later emphasized how being able to utilize systems engineering skills is an enabler to development and it is hard to go directly from training in these roles, "An enabler and barrier to the development of senior systems engineers is having the opportunity to use those systems engineering skills. This is one of the things we are lacking right now. It is hard to take someone from training to these types of roles."

In response to the question, "Have you utilized formal systems engineering training programs? If yes, how do you evaluate if the systems engineering training program was successful?" another blue chip interviewee stated the following, which also emphasizes the importance of experiential learning.

> "Systems engineering training programs are important for understanding fundamental concepts. However, one cannot become a senior systems engineer by training alone. Training is less important than having multiple experiences with senior systems engineers. One can never get to the stage we are talking about without experience. Most of the strongest systems engineers I know never went to systems engineering training programs. I am an advocate of training programs for intermediate level systems engineers. The role of the systems engineer ranges from controlling documents to making the system work, and a part of systems engineering will benefit very much from a training program. If this study is conducted twenty years from now, many more senior systems engineers will have had systems engineering training, since this is more a contemporary capability."

These responses are additional evidence illustrating the importance of experiential learning for developing systems engineers and systems thinking in engineers.

In addition, the initial pilot interviews that were conducted very early in this research study also emphasize the importance of experiential learning. Looking again at the top potential enablers identified by the pilot interviews in Section 3.1, there are multiple top enablers that relate to experiential learning. These include: "Working in a role requiring systems thinking", "Systems education paired with practical experience", "First-hand encounter with serious problems requiring systems thinking", "Holding jobs in multiple disciplines", and "Technical depth and 3-5 years of work experience in a discipline before systems training."

From the data on key steps that developed systems thinking, the data of enablers to systems thinking, the blue chip interview data, and the pilot interview data, a conclusion can be drawn that systems thinking is thought to be developed in engineers primarily by experiential learning. Though opinions do not prove causality, with the number of respondents noting the importance of experiential learning, with the breadth of respondents noting this, and with the strong convergence of opinions (95% of the Expert Panelists noting "work experience" as a key step), the data substantiate the conclusion that experiential learning enables systems thinking development in engineers.

4.3.1.3 Comparison with Existing Systems Thinking Development Processes

The Expert Panel interviews and Section 2.1.2 indicate that government and corporate systems engineering policies emphasize training courses as a primary mechanism to develop systems thinking in engineers. Figure 2-1 showed that one of the key "Elements of SE Revitalization" was "Training/Education." The data presented show that respondents ranked interventions such as training and education below experiential learning categories. Since the data from the participants show that experiential learning has had more of an impact than training, policies should be changed to emphasize experiential learning and work experiences when developing systems thinking in engineers. This is not to say that training and education programs do not enable systems thinking development. They have just not had the same level of impact that experiential learning has had. Systems engineering education and training programs should include experiential opportunities, and these interventions may be more valuable when students have an opportunity to apply the knowledge they are learning in the classroom.

Time scale may be a factor in the effectiveness of an intervention. Most training or educational interventions are usually a short duration, while work experiences and experiential learning usually extend for a much longer duration. This may also contribute to the high ranking of experiential learning over training and education by the research participants. Also, the data speak to the training experienced by the research participants. It may be possible to have systems training and educational interventions in the future which are transformational to the extent that they surpass experiential learning. Another research study would have to be performed to measure the effectiveness of current and future training and educational methods.

Some participants said that the systems training they received was negated when they went back to a job task or work environment that did not support systems thinking. After systems training or systems education classes, some participants went back to a task that does not utilize the new learning. As Table 4-6 showed, an enabler to systems thinking is having a job or opportunity to see the systems view. Often, there are not enough jobs where a systems view is required. This is an issue of job design, and organizations can restructure tasks to foster or require systems thinking. It is more effective if systems thinking and systems engineering training coordinate with an employee's work task.

At the aerospace sector level, these data call for changes in acquisition policy to give engineers more opportunities to develop systems skills. Figure 4-2 shows new United States military aircraft programs by decade, along with a typical engineer career length of forty years. This chart is from (Murman, Walton et al. 2003) citing (Hernandez). As the figure shows, the number of programs is far fewer, so the opportunity for aeronautical engineers to work on multiple programs is far more limited than in the past. The blue chip interviews point out that a key method for developing senior systems engineers in the past was to have engineers work on multiple systems over their career. In the current environment, an aerospace engineer might spend an entire career working on a single program such as the Joint Strike Fighter. If this is the case, not only will this engineer not see an entire product life cycle, but this engineer will not have multiple program experiences to draw from when encountering system challenges. If systems thinking is attained by experience, the systems thinking of engineers will benefit from more programs and more systems opportunities. This is something to consider when designing acquisition strategies, since more programs provide more opportunities to develop systems thinking skills in the engineering workforce.

James Martin shows how the knowledge, skills and abilities (KSA) of people evolve over time (Martin 1997). He contends that ability is approximately constant in life, while knowledge generally increases. Skills, such as using certain tools, peak then decrease, unless care is taken to keep the skills current. Martin states that, "Some corporate cultures assume that knowledge and skills are not necessarily relevant as long as they hire the smartest engineers around. Unfortunately, high grade point average does not necessarily correspond to excellent SE skills and knowledge." Linking this to the current research topic, work experiences increase knowledge and skills, while the individual characteristics speak to the ability of a person.

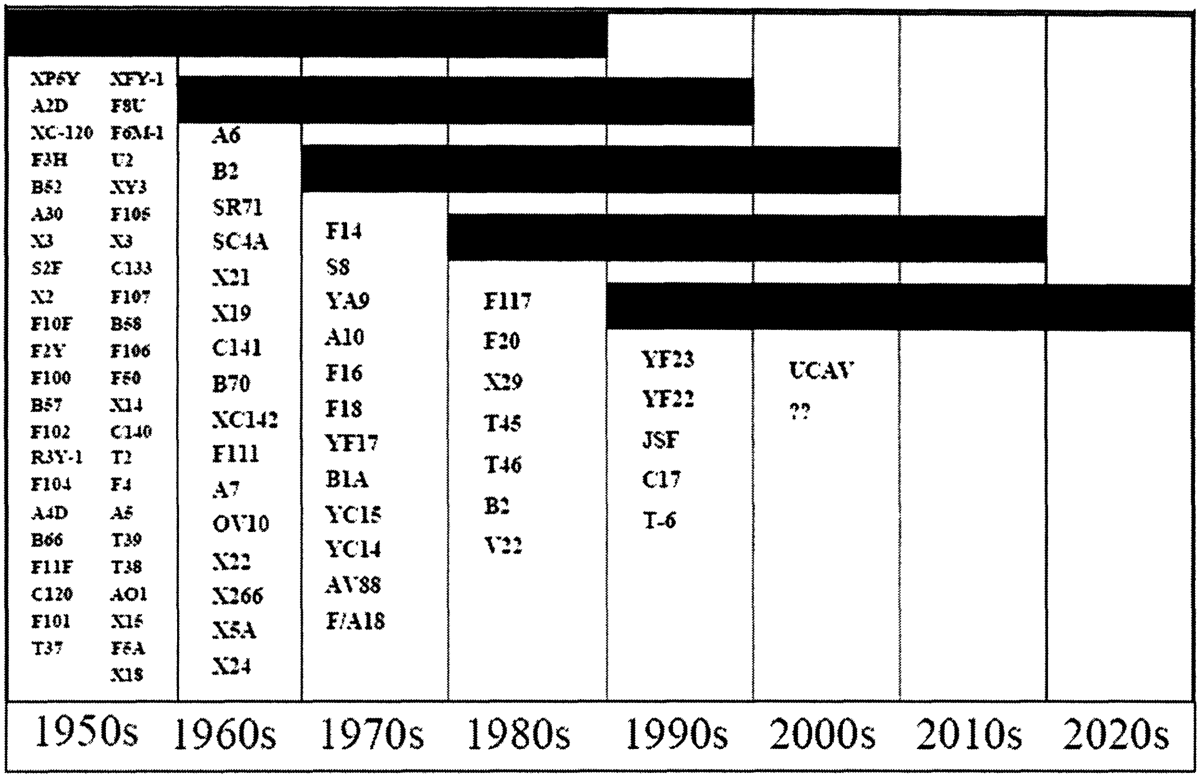


Figure 4-2: New United States Military Aircraft Programs by Decade and Career Lengths of a Typical Engineer from (Murman, Walton et al. 2003) citing (Hernandez)

4.3.2 Individual Characteristics that Enable Systems Thinking Development

Certain individual characteristics also enable systems thinking development in engineers. Here, the supporting data are shown, and the resulting implications are discussed. Not only can these results be used to identify filters to use when selecting individuals for systems roles, but these results can also be used identify characteristics to foster in an organization in order to enable systems thinking development.

4.3.2.1 Enabling Individual Characteristics and Traits

Table 4-7 shows the top ranked Level 1 responses for the interview question "Are there certain individual characteristics or innate traits that seem to predict the development of systems thinking? If so, what are they?" As the data show, a majority of respondents do believe that there are certain individual characteristics or innate traits that predict the development of systems thinking. "Personality" and "Thinking" characteristics were at the top of the Level 1 lists. The complete coding hierarchy and the tables with the sequential rankings for each of the classifications are shown in the appendix.

For more visibility into the responses, the top Level 2 node categories are shown in Table 4-8. Here, "thinking broadly", "curiosity", "questioning", and "strong interpersonal skills" are top-ranked characteristics cited by all the classifications. As an example, one respondent said that these people are "always looking for the bigger picture. They are curious people. Good systems thinkers are curious." "Open-mindedness" was a top-ranked characteristic for all participants, Junior Systems Engineers, and Senior Systems Engineers. "Communication" was a top-ranked category for all classifications except the Senior Technical Specialists. "Tolerance for uncertainty" was a top node category for all participants, Expert Panelists, and Senior Systems Engineers. The last top node category for all participants was thinking outside-the-box.

Individual Characteristics That Enable Systems Thinking Development

- **Thinking Broadly**
- **CURIOSITY**
- **QUESTIONING**
- **OPEN-MINDEDNESS**
- **Strong Communication Skills**
- **Tolerance for Uncertainty**
- **Strong interpersonal Skills**
- **Thinking Out-of-the-Box**

The example shown in the appendix as an example of the coding procedure happens to be the excerpts that were coded as "curiosity" from the interview transcripts for this question. Many respondents just used the word "curiosity" directly, while others expanded on this thought, as in "naturally curious, ask lots of questions, wonder what's on the other side, ask what's in the box, what makes the output come out as it does, interested in interdependencies." One respondent used the unique phrase "technical wanderlust" to represent this type of thinking. Though the complete excerpt was coded as both curiosity and a type of thinking, the full context of the respondent's comment was that people "have to want to seek out these things. [They] have to pursue this on their own initiative, even if it is not directly relevant to the task at hand. It's curiosity, a tendency to overcome the inertia of a particular task, a technical wanderlust."

Interestingly, "Disciplined" was only cited by the systems engineers, the Junior Systems Engineers and Senior Systems Engineers. Perhaps this is because they are the ones most familiar with formal, rigorous systems engineering processes. Many companies have very disciplined processes for performing systems engineering and tracking requirements, and it is the systems engineers in the organization who would be most familiar and experienced with these processes.

Table 4-7: Top Level 1 Individual Characteristics to the Development of Systems Thinking in Engineers

Top Level 1 Systems Thinking Individual Characteristics and Traits for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=202)			Expert Panelists (N=37)			Senior Systems Engineers (N=61)			Senior Technical Specialists (N=52)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Personality	1	126	62%	1	29	78%	1	39	64%	1	32	62%	2	26	50%	7.510	0.057
Thinking	2	125	62%	2	25	68%	2	34	56%	2	29	56%	1	37	71%	4.202	0.240
Problem Solving/Style	3	82	41%	3	15	41%	3	24	39%	3	25	48%	3	18	35%	2.018	0.569
Interpersonal	4	46	23%	4	12	32%	5	10	16%	4	10	19%	4	14	27%	4.255	0.235
Experience	5	32	16%	6	4	11%	6	8	13%	4	10	19%	5	10	19%	1.939	0.585
Communication	6	27	13%	5	5	14%	4	11	18%	9	4	8%	6	7	13%	2.594	0.459
Interventions	7	19	9%	10	2	5%	6	8	13%	7	5	10%	7	4	8%	1.861	0.602
Activities	9	12	6%	7	3	8%	8	7	11%	12	0	0%	11	2	4%	7.348	0.062
Wide range of interests	8	15	7%	10	2	5%	9	3	5%	6	6	12%	7	4	8%	2.063	0.560
No/not sure	10	11	5%	7	3	8%	10	2	3%	7	5	10%	12	1	2%	4.075	0.254

Table 4-8: Top Level 2 Individual Characteristics to the Development of Systems Thinking in Engineers

Top Level 2 Systems Thinking Individual Characteristics and Traits for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=202)			Expert Panelists (N=37)			Senior Systems Engineers (N=61)			Senior Technical Specialists (N=52)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Cluster for thinking broadly	1	65	32%	1	13	35%	1	15	25%	1	18	35%	1	19	37%	2.352	0.503
Cluster for curiosity	2	43	21%	1	13	35%	3	12	20%	2	12	23%	5	6	12%	7.378	0.061
Cluster for questioning	3	34	17%	3	8	22%	7	8	13%	3	11	21%	3	7	13%	2.324	0.508
Open-minded	4	28	14%	9	3	8%	2	13	21%	9	4	8%	2	8	15%	5.620	0.132
Communication	5	27	13%	5	5	14%	4	11	18%	9	4	8%	3	7	13%	2.594	0.459
Cluster for tolerance for uncertainty	6	23	11%	4	7	19%	5	9	15%	15	3	6%	8	4	8%	5.096	0.165
Strong interpersonal skills	7	22	11%	5	5	14%	11	6	10%	5	6	12%	7	5	10%	0.442	0.931
Cluster for think out-of-box	8	20	10%	9	3	8%	15	4	7%	4	9	17%	8	4	8%	4.380	0.223
Analytical	11	15	7%	7	4	11%	11	6	10%	29	1	2%	8	4	8%	3.428	0.330
Teams	22	9	4%	7	4	11%	20	3	5%	29	1	2%	38	1	2%	5.108	0.164
Cluster for disciplined	9	19	9%	14	2	5%	8	7	11%	9	4	8%	5	6	12%	1.458	0.692
Abstract thinking	11	15	7%	25	1	3%	5	9	15%	29	1	2%	8	4	8%	8.262	0.041
Education	10	17	8%	14	2	5%	8	7	11%	9	4	8%	8	4	8%	1.247	0.742
Myers-Briggs/other	15	12	6%	14	2	5%	8	7	11%	29	1	2%	21	2	4%	5.274	0.153
Wide range of interests	11	15	7%	14	2	5%	20	3	5%	5	6	12%	8	4	8%	2.063	0.560
Cluster for initiative/motivation	14	13	6%	9	3	8%	15	4	7%	7	5	10%	38	1	2%	2.805	0.423
No/not sure	17	11	5%	9	3	8%	24	2	3%	7	5	10%	38	1	2%	4.075	0.254

Another interesting note is that 10% of the Senior Technical Specialists commented that they do not think there are certain individual characteristics or innate traits that seem to predict the development of systems thinking, as indicated by the node category "No/not sure." They were the only classification where this response was ranked as a top node category.

The resulting data from the responses to other questions also highlight the importance of individual characteristics in developing systems thinking. As seen previously in Table 4-5, "Individual Skills & Traits" is the second most frequent Level 1 enabler to the development of systems thinking for all participants and for each of the classifications. For Level 2, all the participants and the Senior Systems Engineers and the Senior Technical Specialists cite "Innate" and "Broad perspective" as top enablers of systems thinking. Speaking about the innateness of systems thinking, one respondent said, "Systems thinking is to systems engineering as leadership is to a manager. It's not necessarily true that leaders are born not made, but extraordinary leaders were born. It's the same with systems thinking. Extraordinary systems thinkers are born, but one can still develop the systems thinking of a systems engineer. A good systems engineer must be a good systems thinker."

Likewise, the data on the key steps to developing systems thinking also illustrate the importance of individual characteristics in developing systems thinking. As previously shown in Table 4-3, "Individual Characteristics" is one of the top-ranked Level 1 key steps for each of the classifications, and it is the third-ranked key step for all participants combined. The frequency of the specific Level 2 individual characteristics can be seen in the appendix.

As the subsequent section on barriers will show, "Individual characteristics" is the number one, top-ranked Level 1 barrier to the development of systems thinking for all participants. It is also a top-ranked barrier to systems thinking development for each of the classifications. At Level 2, "Local thinking/myopia" ranks second for all research participants and is one of the top-ranked barriers to systems thinking for each of the classifications. "Comfortable" is ranked fifth for all research participants, and it is one of the top-ranked barriers for Senior Systems Engineers, Senior Technical Specialists, and Junior Systems Engineers. "Comfortable" refers to how some people get comfortable where they are, and they do not desire a systems perspective.

The blue chip interviews also identified individual characteristics and traits that predict the development of systems thinking. In responding to the question, "Are there certain individual characteristics or innate traits that seem to predict the development of systems thinking? If so, what are they?" one blue chip interviewee responded with the following.

> "I have often wondered if it is genetic. There are definitely characteristics. One is thinking about the problem while cutting grass or getting ready in the morning. It's an attitude of constantly thinking about what could go wrong, an attitude that's constantly looking for problems, for issues. The person will look at the test data. Even if a system is within the acceptable limits, if all the points but one are at a certain level, a good SE looks for why this one point was an anomaly, even if it passed the test This is probably a function of environment, when one gets to work with other good systems engineers. Good systems engineers are really people who are constantly looking for problems, trends, and issues. At a meeting, they are never satisfied with the MS PowerPoint presentation. They go to the hardware. They always go the extra mile. One probably can't teach this at MIT. This is probably something young engineers learn from their environment. If young engineers learn that if something passes the test, then it's fine, they won't investigate the anomaly as described above. I believe that there are people with this inquisitive, psychological nature. At 6 pm at night, they are still willing to work on it."

Another blue chip interviewee said, "Strong systems engineers are good communicators. The most notable characteristic is to focus on the output of the system one is involved in. What is the end objective of that thing? Don't worry about all the details. They need good technical background, but the ability to focus at that higher level is essential."

As discussed earlier, the initial pilot interviews also indicate opinions on how individual characteristics impact the development of systems thinking in engineers. Comments about precursors to the develop of systems thinking include the following: "Some people will never be systems thinkers", "Strong systems thinkers possess certain personality traits", "Systems thinkers are born not taught", and "Natural predisposition to systems thinking is triggered or enabled".

4.3.2.2 Link to Subjectivity of Systems Thinking Definitions

The divergence of systems thinking definitions affects the types of individual characteristics cited, which accounts for the lower convergence seen for the individual characteristics. For example, the diversity of the types of thinking respondents viewed as important to systems thinking is reflected in the table in the appendix. "Even thinking", "logical thinking", "long-term thinking", "independent thinking", "analytical thinking", "abstract thinking", "critical thinking", "rigorous thinking" and "lateral thinking" are some examples. Some of these are quite different concepts, such as "logical thinking" compared to "lateral thinking." Considering logisticians as systems thinkers, one respondent quoted an article saying, "Logisticians…see the entire forest BECAUSE of the trees…AND the shrubs AND the grassy areas AND the rocks AND the streams AND the wildlife, not in spite of them. We are able to understand the big picture because we understand that many other smaller things influence its existence." The respondent said this quote came from, "A Brief History in Time: One Loggy's 'Education', Logistics Spectrum, Vol 37, Iss 3, July-Sept 2003." For another respondent, strategy and longer-term thinking is important. This respondent starts with the very common response, "I know it when I see it. It is difficult to articulate..." and goes on to say that, "A person needs to be able to look and see several moves ahead, like a chess game. A world view of where this next step is going to take the project is analogous to the chess game. Unless one is thinking 3 to 5 to 6 moves later, one may lose the game."

4.3.2.3 Personality

Part of the original design of the research study included a personality test to determine any personality differences between the three subject groups. However, only one company chose to participate in the personality testing, and in that company, only 13 respondents chose to complete the personality test. Nonetheless, the data from that small sample support the results from the interviews. Of the 14 respondents, there were 2 Expert Panelists, 3 Senior Systems Engineers, 2 Senior Technical Specialists, and 7 Junior Systems Engineers.

The personality test used was the Revised NEO Personality Inventory (NEO PI-R™) designed by Paul Costa, Jr. and Robert McCrae. Widely used and validated in the

Domains
N: Neuroticism
E: Extraversion
O: Openness
A: Agreeableness
C: Conscientiousness

Neuroticism Facets
N1: Anxiety
N2: Angry Hostility
N3: Depression
N4: Self-Consciousness
N5: Impulsiveness
N6: Vulnerability

Extraversion facets
E1: Warmth
E2: Gregariousness
E3: Assertiveness
E4: Activity
E5: Excitement-Seeking
E6: Positive Emotions

Openness facets
O1: Fantasy
O2: Aesthetics
O3: Feelings
O4: Actions
O5: Ideas
O6: Values

Agreeableness facets
A1: Trust
A2: Straightforwardness
A3: Altruism
A4: Compliance
A5: Modesty
A6: Tender-Mindedness

Conscientiousness facets
C1: Competence
C2: Order
C3: Dutifulness
C4: Achievement Striving
C5: Self Discipline
C6: Deliberation

Figure 4-3: Domains and Facets Measured by the Revised NEO Personality Inventory

personality psychology literature (Larsen and Buss 2002), this inventory is based on the five-factor model of personality, where the five factors are Neuroticism, Extraversion, Openness, Conscientiousness, and Agreeableness. The test measures the five major dimensions, or domains, of personality, along with six important traits or facets of each. These are shown in Figure 4-3. As Costa and McCrae state, "Together, the 5 domain scales and 30 facet scales of the NEO PI-R allow a comprehensive assessment of adult personality" (Costa and McCrae 1992). They also describe the validation of the test:

> "The NEO PI-R embodies a conceptual model that distills decades of factor analytic research on the structure of personality. The scales themselves were developed and refined by a combination of rational and factor analytic methods and have been the subject of intensive research conducted for 15 years on both clinical and normal adult samples. Evidence on scale reliability, stability, and construct validity is presented in detail in a series of publications and is summarized in this manual."

Interestingly, the responses to the personality test support the results from the interviews. Table 4-9 shows the personality test responses considered "Very High" or "High" compared to established norms. In comparison to the normal population, 100% of Senior Systems Engineers, 80% of Senior Systems Engineers and Expert Panelists, 70% of systems engineers, and 77% of all respondents scored "Very High" or "High" on the facet of Openness to Ideas. This supports the interview data which say that "curiosity" and "openness" are important characteristics to systems thinking development. As the personality test authors state, "a high scorer on the Ideas facet enjoys rich, varied, and novel experiences in his or her intellectual life." They go on to say that:

> "Intellectual curiosity is an aspect of Openness that has long been recognized (Fiske, 1949). This trait is seen not only in an active pursuit of intellectual interests for their own sake, but also in open-mindedness and a willingness to consider new, perhaps unconventional ideas. High scorers enjoy both philosophical arguments and brain-

> teasers. Openness to ideas does not necessarily imply high intelligence, although it can contribute to the development of intellectual potential. Low scorers on the scale have limited curiosity and, if highly intelligent, narrowly focus their resources on limited topics."

It is unfortunate that there were not more Senior Technical Specialists completing the personality test to contrast with this. Nonetheless, this emphasizes the importance of curiosity and openness to the development of systems thinking. This personality characteristic gives a person intrinsic motivation to learn about new parts of the system, to learn about related disciplines. This is also related to questioning, since curiosity drives questioning.

Also, 100% of Senior Systems Engineers, 80% of Senior Systems Engineers and Expert Panelists, 60% of systems engineers, and 54% of all respondents scored "Very High" or "High" on the facet of Conscientiousness, Competence. As the personality test authors state, "Competence refers to the sense that one is capable, sensible, prudent, and effective. High scorers on this scale feel well-prepared to deal with life." This seems to fit since systems engineers must, of course, be competent.

Table 4-10 shows the personality test responses considered "Very Low" or "Low" compared to the population norms by classification. There are interesting data here as well. 100% of Senior Systems Engineers, 80% of Senior Systems Engineers and Expert Panelists, 60% of systems engineers, and 62% of all respondents scored "Very Low" or "Low" on the facet of Self-Consciousness. In addition, 100% of Senior Systems Engineers, 80% of Senior Systems Engineers and Expert Panelists, 60% of systems engineers, and 54% of all respondents scored "Very Low" or "Low" on the facet of Tender-Mindedness. As the test authors explain for Tender-Mindedness, "High scorers are moved by others' needs and emphasize the human side of social policies. Low scorers are more hardheaded and less moved by appeals to pity. They would consider themselves realists who make rational decisions based on cold logic."

Table 4-9: Personality Test Responses Considered "Very High" or "High" Compared to Norms by Classification

Responses Considered "Very High" or "High" Compared to Norms

	All Respondents * (N=14)	Only Senior Systems Engineers ** (N=3)	Only Senior Systems Engineers and Expert Panelists * (N=5)	Only Systems Engineers ** (N=10)
Openness, Ideas (O5)	77%	100%	80%	70%
Openness, Values (O6)	62%			
Conscientiousness, Competence (C1)	54%	100%	80%	60%
Extroversion, Assertiveness (E3)	54%	100%	100%	
Openness, Actions (O4)	54%			
Conscientiousness, Achievement Striving (C4)		100%	80%	
Neuroticism, Anxiety (N1)				60%

* Note: This includes all categories where greater than 50% or responses ranked "Very High" or "High"

** Note: This includes all categories where at least 80% of responses ranked "Very High" or "High"

Table 4-10: Personality Test Responses Considered "Very Low" or "Low" Compared to Norms by Classification

Responses Considered "Very Low" or "Low" Compared to Norms

	All Respondents * (N=14)	Only Senior Systems Engineers ** (N=3)	Only Senior Systems Engineers and Expert Panelists * (N=5)	Only Systems Engineers ** (N=10)
Neuroticism, Self-Consciousness (N4)	62%	100%	80%	60%
Agreeableness, Tender-Mindedness (A6)	54%	100%	80%	60%
Neuroticism, Vulnerability (N6)	54%	100%	80%	
Openness, Fantasy (O1)	54%			
Extroversion, Excitement-Seeking (E5)		100%		
Extroversion, Warmth (E1)			80%	
Agreeableness, Altruism (A3)			80%	
Agreeableness, Modesty (A5)			80%	

* Note: This includes all categories where greater than 50% or responses ranked "Very Low" or "Low"

** Note: This includes all categories where at least 80% of responses ranked "Very Low" or "Low"

Again, these data support observations in the interviews. Systems engineers need to be self-confident and a bit tough to weigh all the competing interests they must balance in a system. Being too tender-minded might make them susceptible to being swayed back and forth by the competing component designers. In addition, they cannot be self-conscious, and they must be competent. Openness to ideas gives them an intrinsic motivation to explore and gain knowledge in multiple aspects of the system.

As a side note, note in Table 4-9 that "Anxiety" is not an issue for the Senior Systems Engineers, but when the Junior Systems Engineers are added to the sample in the cell for all systems engineers, "Anxiety" suddenly appears. This tendency was also observed in the interviews. It can be very stressful to be junior level and be a systems engineer, since systems engineers are often expected to have extensive and broad knowledge of the system, and it is tough for Junior Systems Engineers to immediately attain that. In addition, as the data show, work experience is highly valued, and Junior Systems Engineers who have not yet "served their time" may have a hard time being taken seriously as a systems engineer, whether justified or not.

4.3.2.4 Link to Interdisciplinary Studies Project

These personality results correlate to findings by the Interdisciplinary Studies Project at Project Zero at the Harvard Graduate School of Education. Led by Howard Gardner and Veronica Boix-Mansilla as the Principal Investigators, this project is "exploring the cognitive, organizational, and pedagogical qualities of interdisciplinary work as it takes place in exemplary expert institutions, collegiate, and pre-collegiate educational programs." The description of the project goes on to say that, “We have produced preliminary characterizations of ‘end state performances’ of the interdisciplinary mind at work.”

Though interdisciplinary work is not directly mapped to the systems thinking of systems engineers, one key aspect of the systems role is crossing disciplinary boundaries. In a publication by this group (Mansilla, Dillon et al. 2000)s, the authors report the results of a study of five exemplary interdisciplinary institutions. The authors state that, “At the individual intellectual level, the paper characterizes exemplary interdisciplinary workers as embodying a disposition toward curiosity, risk-taking, open mindedness and humility.” They go on to say that, “Curiosity in multiple areas of knowledge was a mobilizing force for the interdisciplinary workers in our study. Curiosity emerged implicitly in their accounts of professional growth as well as explicitly as a driving force of interdisciplinary work.”

Speaking of open-mindedness, the authors state that, “Open-mindedness is the second trait repeatedly attributed to interdisciplinary workers and collaborators.” Interestingly, one of the participants they studied linked open-mindedness to feeling secure in one’s own discipline when he says that, “open-mindedness is most often the result of feeling secure in one’s own discipline; it is the counterbalance to knowing the discipline well. The confidence one gains from accomplishment in a discipline helps to feed intellectual exploration rather than to hinder it.”

These findings of the Interdisciplinary Studies Project validate the findings in this study. Curiosity and open-mindedness are important traits when crossing disciplinary boundaries and performing interdisciplinary work, such as the work of Senior Systems Engineers. In addition to the respondent data and the personality test results, this is a third source citing the importance of curiosity and open-mindedness. It also begins to link the results of this research study back to the literature on psychology, education, and cognition.

4.3.2.5 Utilizing the Results on Individual Characteristics

The data show that individual characteristics impact systems thinking development. Using the opinions of participants, at the top level of Level 1, personality, type of thinking, problem solving style, interpersonal skill, experience, and communication predict the development of systems thinking development. At the second level, key individual characteristics that predict the development of systems thinking include: thinking broadly, curiosity, questioning, open-mindedness, communication, tolerance for uncertainty, and strong interpersonal skills. There are indications in the data that strong systems thinking have an innate skill, though additional research is needed before this opinion can become substantiated fact.

There are two implications here. First, an organization might use the research results to identify filters to use when selecting individuals for systems roles. In addition, organizations might want to foster these individual behaviors in their organization. However, before the descriptive research results are turned into prescriptive suggestions of actions to take, it is important to understand that the data gathered are the opinions of those sampled and leaps from opinions to actions should be justified. An example of this justification could be that an organization understands that these results are aggregates of opinions, not objectively-verified facts, but nonetheless they agree that they want people in their systems organization who are curious, questioning, open-minded, and tolerant to uncertainty. The justification of the leap from descriptive to prescriptive is the organization's agreement that these are characteristics that they choose to foster in their systems group.

4.3.3 Importance of a Supportive Environment

Another mechanism that enables the development of systems thinking in engineers is having a supportive environment. In this section, data are presented to substantiate this conclusion, and this is followed by a discussion of the resulting implications. Systems training should coordinate with organizational incentives and investments in systems training may be invalidated by a misaligned work environment.

4.3.3.1 Barriers to Systems Thinking Development

The importance of a supportive environment is emphasized in the participants' responses to the interview question, "In your experience, what enablers or barriers have you seen to the development of systems thinking in engineers?" The enablers were discussed earlier, and the barriers are discussed here. Table 4-11 shows the top Level 1 barriers to the development of systems thinking for all classifications, and Table 4-12 shows the top Level 2 barriers to the development of systems thinking for all classifications. The appendix shows the node categories that were developed for barriers to systems thinking.

At Level 1 in Table 4-11, three of the top node categories for all research participants are "Organizations", "Schedule and cost constraints" and "Work design", which also appear as a top node category for each of the classifications. These support the theory that a supportive environment is a key contributor for the development of systems thinking.

One respondent summarized the importance of the interaction between individual characteristics and a supporting environment by saying, "I think systems thinking engineers are born, not made, to a certain extent. Given that, our environment encourages or discourages these tendencies in people. The rewards are for the engineer who has the deep technical knowledge and comes up with a technical solution. The rewards are not as overt for a systems thinker.... This can keep people from developing their systems thinking."

Looking at the top Level 2 barriers to the development of systems thinking shown in Table 4-12, there is considerable agreement on which node categories are ranked the highest. "Schedule and cost constraints" is a top ranked node category for each of the classifications. "Organizational boundaries/structure" is a top category for all but the Senior Technical Specialists. Perhaps the work tasks of Senior Technical Specialists are more isolated within specific functions in the organization, and the other classifications work across functions and find organizational boundaries and structure a hindrance. "Narrow job" is a top category for all but the Expert Panelists, which is interesting because the Expert Panelists are least likely to have a narrow, limited work task. These categories emphasize the importance of having a supportive environment in which to develop systems thinking. Speaking about a narrow job as a barrier to the development of systems thinking, one respondent said that in "most job assignments, if [one is] assigned a remote control, [the person will] focus on the remote control without having the same emotional investment in the rest of the system. Giving someone an area of responsibility gives someone borders where people don't have to care about anything outside of those boundaries."

Table 4-11: Top Level 1 Barriers to the Development of Systems Thinking in Engineers

Top Level 1 Barriers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=192)			Expert Panelists (N=36)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=46)			Junior Systems Engineers (N=48)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Individual characteristics	1	82	43%	3	9	25%	1	24	39%	1	25	54%	1	24	50%	**8.609**	**0.035**
Organizations	2	63	33%	1	13	36%	1	24	39%	5	6	13%	2	20	42%	**11.017**	**0.012**
Schedule and cost constraints	3	42	22%	2	12	33%	5	10	16%	2	8	17%	3	12	25%	4.779	0.189
Training/Education	4	32	17%	4	5	14%	3	13	21%	7	5	11%	4	9	19%	2.289	0.515
Work design	5	30	16%	5	4	11%	5	10	16%	2	8	17%	5	8	17%	0.717	0.869
SE	6	29	15%	6	3	8%	3	13	21%	4	7	15%	6	6	13%	3.204	0.361
Experience	7	16	8%	7	2	6%	7	4	6%	5	6	13%	7	4	8%	1.987	0.575
Interpersonal	8	13	7%	8	1	3%	7	4	6%	7	5	11%	8	3	6%	2.164	0.539

Table 4-12: Top Level 2 Barriers to the Development of Systems Thinking in Engineers

Top Level 2 Barriers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=192)			Expert Panelists (N=36)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=46)			Junior Systems Engineers (N=48)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Schedule and cost constraints	1	42	22%	1	12	33%	3	10	16%	2	8	17%	1	12	25%	4.779	0.189
Local thinking/myopia	2	41	21%	2	6	17%	4	9	15%	1	15	33%	3	11	23%	5.736	0.125
Organizational boundaries/structure	3	37	19%	2	6	17%	1	14	23%	5	5	11%	1	12	25%	3.693	0.297
Narrow job	4	26	14%	7	2	6%	4	9	15%	2	8	17%	5	7	15%	2.638	0.451
Comfortable	5	24	13%	28	0	0%	4	9	15%	4	7	15%	4	8	17%	6.446	0.092
Education issues	5	24	13%	4	3	8%	2	12	19%	7	3	7%	6	6	13%	4.738	0.192
Interpersonal	7	13	7%	9	1	3%	7	4	6%	5	5	11%	9	3	6%	2.164	0.539

Aspects of an Environment That Obstruct Systems Thinking Development

- **Schedule and cost constraints**
- **Organizational boundaries/structure**
- **Narrow job**

As the full node hierarchy in the appendix shows, note that "Schedule and cost constraints" is both a Level 1 and Level 2 category. Since it was a category of its own, there were no sub-categories to roll into it when the Level 1 tally was completed. Here is an example of what one respondent said regarding schedule and cost constraints. "One barrier to systems thinking is what we call the 'tyranny of the urgent'. The biggest barrier is that something may not be the most important thing to do, but the boss and the urgency dictate priority. In systems thinking, [one must] go beyond this to address the most important thing." As another participant stated, "A barrier to systems thinking is schedule pressure. There is no time to think of all the scenarios." One is hassled if one is just trying to think. "They want paper, deliverables, not thinking."

Barriers related to systems engineering and the support of systems engineering were also voiced. Not surprisingly, Senior Systems Engineers had the highest percentage of respondents citing this category. As the table in the appendix shows, these items included confusion in the field, marginalization of systems engineering, and the need to develop skills. One respondent expressed frustration at the call to use systems engineering without adequate organizational support, "We often find ourselves in a position where the company promised all these things without anyone knowing if it can be done. They sign up because there is a contract to be had. Once you do all those trades, if what you end up with is lousy, if promises are off-the-wall and won't comply in 2-3 areas, even if [you do] good systems engineering, [you] can't do it. [It's like having] one gallon of paint to paint a big house. [They] tell them to "use SE" to paint the house, but the paint is just not there. [These are] over-constrained problems."

For the Level 1node category "Individual characteristics," the asymptotic significance value of 0.035 shows that there is a statistically significant difference between the classifications for this node category. This is due to the difference between the Expert Panelist responses and the responses of the other classifications. Comparing the expected counts and the actual counts shown in the full crosstabulation tables in the appendix, the expected count for the Expert Panelists was 15.4, but the actual count was only 9. On the contrary, for the Senior Technical Specialists, the actual count was 25, where the expected count is only 19.6. In addition, for the Junior Systems Engineers, the actual count was 24 where the expected count was 20.5. This indicates that the Senior Technical Specialists and the Junior Systems Engineers believe that individual characteristics are a barrier to the development of systems thinking, where the Expert Panelists cite other barriers instead.

In addition, the asymptotic significance value of 0.012 for the Level 1 node category "Organizations" shows that there is also a statistically significant difference between the classifications here. For this node category, the responses of the Senior Technical Specialists differed from the other classifications. For the other classifications, the actual count was higher than the expected count, but for the Senior Technical Specialists, the expected count was 15.1, but the actual count was only 6. Once again, perhaps the work tasks of Senior Technical Specialists are more isolated within specific functions in the organization, which is why organizational issues may not be as much of a barrier to them.

More evidence of the importance of a supportive environment for the development of systems thinking is shown by the data on enablers to systems thinking development, where "Organization" is a top Level 1 enabler to systems thinking development for all the classifications. As the full node hierarchy in the appendix shows, the Level 1 category of "Organization" is an aggregate of Level 2 categories such as "Working environment/culture", "Organizational structure", "Organizational support", etc. As one respondent stated, an enabler to the development of systems thinking is "the environment that someone is working in -- if there are the tools, processes, and the right people around them to do that... Some organizations are better set up for systems thinking and systems problems."

Data from the blue chip interviewees also substantiate the need for a supportive environment to develop systems thinking. One blue chip interviewee had the following response to the question, "In your experience, what enablers or barriers have you seen to the development of systems thinking in engineers?"

> "One barrier is if someone in a senior position says that the most important criterion is cost. This is an enormous barrier to systems thinking. When the primary criterion becomes cost, senior management comes along to put criteria in place to track this.
>
> The number of design engineers is straightforward, but the number of systems engineers is not straightforward. In my past experience, [Company X] saluted when the [Government Organization Y] wanted cost to be the most important criteria. They had 3-4 systems engineers at the launch site who were eliminated. These systems engineers were part of the safety net. They didn't really have a definable job, but what they did was to constantly look for problems. In one instance, someone made a factor-of-ten mistake. If these systems engineering folks had been there, this would have averted the loss of a $2 billion vehicle.
>
> Good systems engineering is one of the first things to suffer, though the focus should be on mission success and good systems engineering."

The name of the company and the government organization are removed to maintain anonymity. Coinciding with the node "Schedule and cost constraints" from the barriers to systems thinking discussed earlier, this illustration shows the impact of cost constraints and a lack of a supportive environment.

The initial pilot interviews also emphasize the need for an environment supportive of systems thinking. In the pilot interviews, "stovepipe organizations" and "silo activities" were listed as barriers to systems thinking development. These instances address how the organizational structure impacts systems thinking development.

4.3.3.2 Coordinating Organizational Environment with Systems Thinking Development

The data of barriers to systems thinking, the data of enablers to systems thinking, the blue chip interview data, and the pilot interview data show that a supporting environment enables systems thinking development. It seems straightforward and logical that efforts to develop systems thinking in engineers should be coordinated with the surrounding organizational environment, but the data in this study show that this is not the reality many participants experience.

The implications are straightforward. First, systems training should coordinate with the organizational environment. Organizational incentives should promote the development of systems thinking. Resources should be in place to enable systems thinking development. Second, leaders need to understand that investments in systems engineering training can be invalidated by the work environment if they are not aligned. Even if an employee receives extensive systems engineering training, if the surrounding work environment discourages the use of those skills, the systems training may be wasted.

4.3.3.3 A Supportive Acquisition Environment for Systems Thinking Development

In addition, the acquisition environment set by the Department of Defense (DoD) also impacts the development of systems thinking. When the DoD incentives systems engineering and systems thinking by requirements at key decision points, this promotes industrial commitments to promote systems engineering and systems thinking. The node of "Schedule and cost constraints" is directly affected by the contracting procedures set by acquisition policy.

4.4 Survey Results

One aspect of the field study that has not been discussed is the survey. The surveys were given to each of the four classifications of Expert Panelists, Senior Systems Engineers, Senior Technical Specialists, and Junior Systems Engineers. The significance of the survey is that throughout the execution of this study, various people expressed heuristics and opinions on the demographics of Senior Systems Engineers. Here, data show the actual demographics of the engineers sampled to better inform these arguments and opinions. The usefulness to practitioners is that these data begin to collect the hiring patterns and development strategies for various companies. Appendix Section 8.14 discusses the full analysis and results of the survey questions which address interview company, interview classification, highest level of education, Bachelor's degree major, number of years at current employer, number of years listed in the job history, job rotations, systems engineering training, and process improvement training.

Unfortunately, the survey data did not produce a rich field for theory development. There were not significant differences between the classifications for participation in job rotation programs, systems engineering training, or process improvement training. Considering the number of years listed in the job history, the mean number of years of experience for the Senior Systems Engineers was 20.27 years, which is not surprising. For Company G, the mean number of years at the company is 7.00 years, while the mean number of years at the company is 17.67 years for Company F. Company J had the most Senior Systems Engineers participating, with 12.

Highest level of education and Bachelor's degree major varied by company, which is expected since the technical skills needed by each company vary. The Master's degree was the most common highest level of education, with over 50% of survey participants indicating this level. There were more Junior Systems Engineers with Master's degrees than there were participants with Master's degrees from the other classifications. This is most likely due to current trends in education where more students are seeking Master's degrees, and the Junior Systems Engineers are closer to leaving the current educational system. Company F had the highest number of participants with Bachelor's degrees as the highest level of education, with 17 participants indicating this. This is 73.9% of the participants from this company. In Company A, 82.4% of the participants have a Master's degree as their highest level of education. Company J has the most participants with a Doctoral degree as the highest level of education, with 8 participants or 30.8% of the company's participants indicating this. More detailed analysis can be found in the appendix.

4.5 Statistical Differences

Since the qualitative data were transformed to quantitative form, this allowed for statistical exploration of the data. Statistical tests were run to compare: (a) differences between all the classifications, (b) paired differences between Senior Systems Engineers and the other groups, (c) differences between all the companies, and (d) differences between two opposing companies. Pearson chi-square tests were performed on each of the top node categories reported in the tables to see if the distributions were different from what is expected if there were no differences between groups. Summary tables are shown here. In general, statistical differences between classifications and between companies are quite low.

The full crosstabulation results for the tests of the differences between all the classifications and the differences between all the companies are shown in the appendix. The additional tables which show differences between the two opposing companies and the paired differences between the Senior Systems Engineers and the other classifications are not included due to space restrictions. However, the summaries are shown. In addition, since these calculations are a subset of the comparisons between all classifications, the actual counts and the percentage of respondents in the company citing each node category can be found in the crosstabulation charts that are shown in the appendix.

It is expected that the chi-square asymptotic significance value would be less than 0.050 only 5% of the time if there are no differences between the comparison groups. For the tests contrasting the classifications, when there are no differences between the comparison groups, an Expert Panelist, a Senior Systems Engineer, a Senior Technical Specialist, and a Junior Systems

Engineer are just as likely to respond with a particular node category. For the tests contrasting the companies, when there are no differences between the comparison groups, a participant from any company is just as likely to respond with a particular node category.

4.5.1 Differences Between All Classifications

Considering all the classifications in comparison to each other, Table 4-13 shows the number of node categories where the chi-square asymptotic significance value is less than 0.050. As the table shows, this happens 22% of the time for Level 1 and 6% of the time for Level 2. It is expected that this would happen only 5% of the time, so particularly for Level 1 there is a larger number of significant results than would be expected by chance. For Level 2, since 6% is quite close to the expected 5%, this is consistent with statistical variability or noise.

However, for the key steps to the development of systems thinking at Level 1, 40% of the time the chi-square asymptotic significance value is less than 0.050. Again, this result is expected only 5% of the time. The key steps at Level 1 are where 95% of Expert Panelists cite "Work Experiences" as a key step to the development of systems thinking, and only 14% of Expert Panelists cite "Life experiences outside work" as a key step. It is in the key steps that the Expert Panelists differ significantly from the other classifications.

Table 4-13: Statistical Comparison of All Classifications

Statistical Comparison of All Classifications

Number of Node Categories Where the Chi-Square Asymptotic Significance < 0.05

Analysis Group	Level 1 Top-Ranked Node Categories for All Participants			Level 2 Top-Ranked Node Categories for All Participants		
	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05
Strength	1	4	25%	0	6	0%
Key Steps	2	5	40%	1	5	20%
Enablers	1	6	17%	1	7	14%
Individual Traits	0	6	0%	0	8	0%
Barriers	2	6	33%	0	6	0%
Overall	6	27	22%	2	32	6%

4.5.2 Paired Differences Between Senior Systems Engineers and Other Classifications

One of the key aspects of the research design was to have two control groups to compare with the Senior Systems Engineers. Tables 4-14, 4-15, and 4-16 show the results of the statistical tests comparing the Senior Systems Engineers to the Expert Panelists, the Senior Technical Specialists, and the Junior Systems Engineers, respectively. The biggest difference is between the Senior Systems Engineers and the Expert Panelists, where 13% of the time the chi-square asymptotic significance value is less than 0.050 at Level 1. Since this result is only expected 5% of the time, there is a larger number of significant results than would be expected by chance. Most of the time, the results were not different from what is expected if there were no differences between Senior Systems Engineers and the other classifications.

Table 4-14: Statistical Comparison of Senior Systems Engineers and Expert Panelists

Statistical Comparison of Senior Systems Engineers and Expert Panelists

Number of Node Categories Where the Chi-Square Asymptotic Significance Is Less Than 0.05

Analysis Group	Level 1 Top-Ranked Node Categories for All Participants			Level 2 Top-Ranked Node Categories for All Participants		
	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05
Key Steps	2	5	40%	1	5	20%
Enablers	0	6	0%	0	7	0%
Individual Traits	0	6	0%	0	8	0%
Barriers	1	6	17%	2	6	33%
Overall	3	23	13%	3	26	12%

Table 4-15: Statistical Comparison of Senior Systems Engineers and Senior Technical Specialists

Statistical Comparison of Senior Systems Engineers and Senior Technical Specialists
Number of Node Categories Where the Chi-Square Asymptotic Significance Is Less Than 0.05

Analysis Group	Level 1 Top-Ranked Node Categories for All Participants			Level 2 Top-Ranked Node Categories for All Participants		
	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05
Quality	0	4	0%	0	6	0%
Key Steps	0	5	0%	1	5	20%
Enablers	0	6	0%	0	7	0%
Individual Traits	0	6	0%	1	8	13%
Barriers	1	6	17%	1	6	17%
Overall	1	27	4%	3	32	9%

Table 4-16: Statistical Comparison of Senior Systems Engineers and Junior Systems Engineers

Statistical Comparison of Senior Systems Engineers and Junior Systems Engineers
Number of Node Categories Where the Chi-Square Asymptotic Significance Is Less Than 0.05

Analysis Group	Level 1 Top-Ranked Node Categories for All Participants			Level 2 Top-Ranked Node Categories for All Participants		
	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05
Quality	1	4	25%	1	6	17%
Key Steps	0	5	0%	0	5	0%
Enablers	2	6	33%	1	7	14%
Individual Traits	0	6	0%	0	8	0%
Barriers	0	6	0%	0	6	0%
Overall	3	27	11%	2	32	6%

4.5.3 Differences Between All Companies

Table 4-17 shows the results of the statistical tests comparing all companies. As the table shows, the chi-square asymptotic significance value is less than 0.050 only 15% of the time at Level 1. This means that 15% of the time the results are unusual enough to warrant rejection of the null hypothesis that there are no differences between the companies. When there are no differences between companies, a respondent in any company is just as likely to respond with that particular node category. The differences by company in the expected counts, the actual counts, and the percentage of respondents in each company citing the node category can be seen in the appendix.

Table 4-17: Statistical Comparison of All Companies

Statistical Comparison of All Companies

Number of Node Categories Where the Chi-Square Asymptotic Significance < 0.05

Analysis Group	Level 1 Top-Ranked Node Categories for All Participants			Level 2 Top-Ranked Node Categories for All Participants		
	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05
Strength	0	4	0%	0	6	0%
Key Steps	0	5	0%	0	5	0%
Enablers	1	6	17%	1	7	14%
Individual Traits	1	6	17%	2	8	25%
Barriers	2	6	33%	1	6	17%
Overall	4	27	15%	4	32	13%

4.5.4 Differences Between Two Companies

To see whether the product context differentiated the responses from the companies, two companies were directly compared. A direct comparison was evaluated between Company B and Company J. One company has a product-centric systems focus, while the other deals more with systems-of-systems issues. The summary is shown in Table 4-18. As the table shows, at Level 2, the chi-square asymptotic significance value is less than 0.050 only 9% of the time. Since the chi-square asymptotic significance value is expected to be less than 0.050 only 5% of the time, there is a slightly larger number of significant results than would be expected by chance, though this difference is quite small. Interestingly, one of the node categories where there was a difference was "tolerance for uncertainty." Participants from the company dealing with systems-of-systems issues more often cited this as an individual characteristic important to the development of systems thinking. This could be expected, since systems-of-systems involve much uncertainty, and thus a tolerance for uncertainty is important for those working on these types of systems.

Table 4-18: Statistical Comparison of Companies B and J

Statistical Comparison of Companies B and J

Number of Node Categories Where the Chi-Square Asymptotic Significance < 0.05

Analysis Group	Level 1 Top-Ranked Node Categories for All Participants			Level 2 Top-Ranked Node Categories for All Participants		
	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05	Number of Node Categories Where Significance <0.05	Total Number of Node Categories	Percent of Node Categories Where Significance <0.05
Strength	0	4	0%	1	6	17%
Key Steps	1	5	20%	0	5	0%
Enablers	0	6	0%	1	7	14%
Individual Traits	0	6	0%	1	8	13%
Barriers	0	6	0%	0	6	0%
Overall	1	27	4%	3	32	9%

4.6 Application of Results

Next, applications of these results are discussed. First, levels of intervention maturity are discussed. Following are possible applications of this research study for the government, industry, and academia.

4.6.1 Intervention Maturity

In the study, ascending levels of intervention maturity were found. First, organizations may know they want "systems-like professionals", but the intervention and the final goal are undefined. For example, "The DoD wants us to have strong SE capabilities, but we don't know what that means and we don't know how to develop that capability." This is depicted in Figure 4-4.

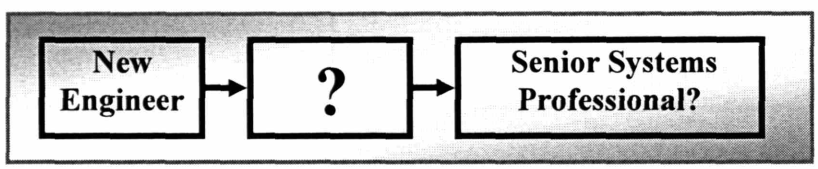


Figure 4-4: First Level of Intervention Maturity

Next, an organization may have a final goal in mind and they may have a couple interventions in place, but the design of those interventions is just a guess. This is depicted in Figure 4-5.

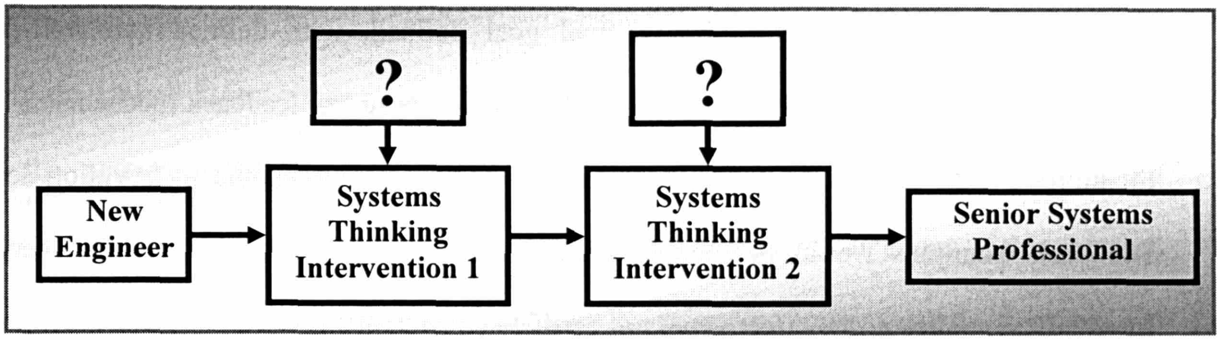


Figure 4-5: Second Level of Intervention Maturity

An organization may have a final goal defined, with defined and intentionally-designed interventions, but the design of those interventions is based on heuristics and there are weak (if any) feedback mechanisms. For example, in the study Expert Panelists were asked how they know if their systems thinking interventions were effective and they replied that they have participant course evaluations at the end of their training classes. This is not a strong measure of the effectiveness of the training program. This is depicted in Figure 4-6.

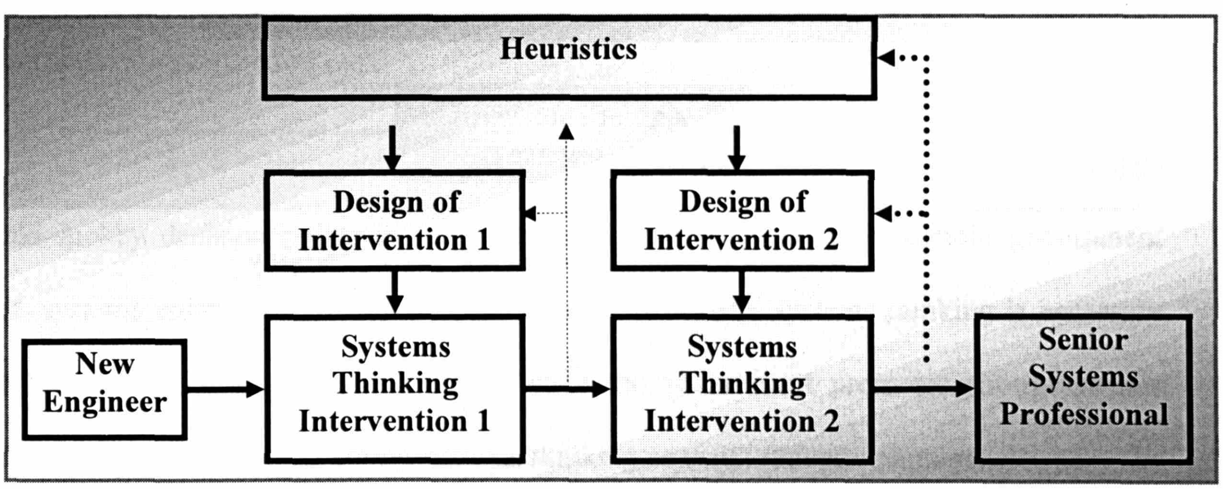


Figure 4-6: Third Level of Intervention Maturity

Ideally, an organization has a final goal defined, with defined and well-designed interventions that are based on knowledge. And, there are strong feedback mechanisms in place to improve both the design of the interventions and the design of the intervention sequence. Feedback examples would be mental model assessments before and after an intervention, longitudinal studies of the effectiveness of certificate programs, in-depth interviews with systems engineers about their development, etc. This is shown in Figure 4-7. In summary, systems thinking interventions should be based on knowledge and include feedback mechanisms.

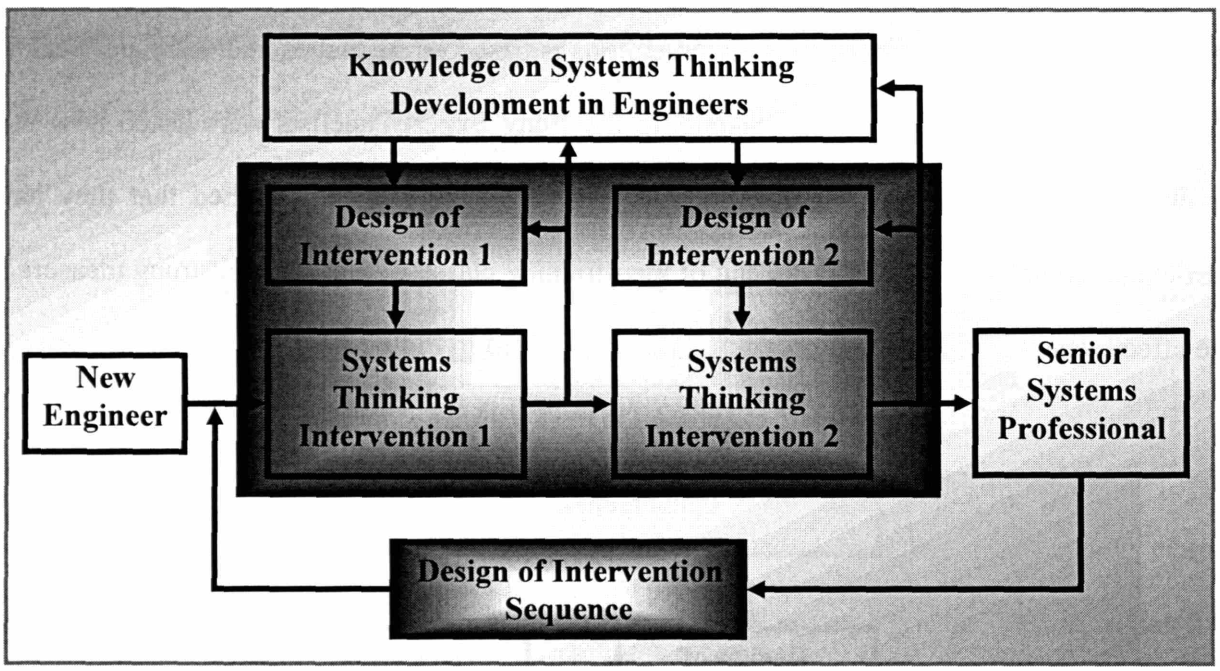


Figure 4-7: Fourth Level of Intervention Maturity

4.6.2 Government

In the United States, since government agencies like the Department of Defense heavily impact the aerospace industry, applications of this research by the government would substantially elevate the systems thinking capabilities in this sector. Applications of this research for the government include: (1) Provide incentives to promote strong systems thinking, (2) Adjust policies to emphasize experiential learning for systems thinking development, (3) Change acquisition strategy to provide more programs and opportunities for engineers to develop systems thinking, (4) Promote research on the mechanisms for effective systems thinking development, (5) Encourage systems programs that teach systems skills and systems thinking.

<u>Applications of Research for Government</u>

(1) Provide incentives to promote strong systems thinking

(2) Adjust policies to emphasize experiential learning for systems thinking development

(3) Change acquisition strategy to provide more programs and opportunities for engineers to develop systems thinking

(4) Promote research on the mechanisms for effective systems thinking development

(5) Encourage systems programs that teach systems skills and systems thinking

Government agencies should provide incentives to promote strong systems thinking. Although some incentives currently exist, the promotion of systems thinking should be expanded. Since systems engineering is embedded in key decision points in the product acquisition process for certain government agencies, systems engineering is priority. As argued previously, systems thinking is necessary but not sufficient for systems engineering. When the government promotes strong systems engineering, they are promoting strong systems thinking as well. Government agencies have the power to incentivize systems thinking by embedding it in the acquisition process.

Government agencies should also adjust policies to emphasize experiential learning for systems thinking development. As discussed earlier, current policies emphasize training and education. While advances in systems training and education may make these interventions more effectual, the data show that for the research participants, experiential learning has had more of an impact than training and education courses. This is not to say that training and education courses are not helpful, the data just show that experiential learning has had more of an impact. Thus, policies should be changed to emphasize experiential learning and work experiences when developing systems thinking in engineers. Systems engineering education and training programs should include experiential opportunities, and these interventions may be more valuable when students have an opportunity to apply the knowledge they are learning in the classroom.

Government agencies should also change acquisition strategy to provide more programs and opportunities for engineers to develop systems thinking. As discussed earlier, the number of military aircraft programs is declining, which gives engineers fewer opportunities to both develop and practice systems skills. Providing engineers with more systems opportunities will improve the systems thinking capabilities of the aerospace workforce.

The field of studying enablers to systems thinking development in engineers is immature. Government agencies should promote research on the mechanisms for effective systems thinking development in engineers. Additional research should be funded and encouraged. When new systems education and development programs are started, a question should be asked about how the design of the program maps to existing literature on systems thinking development. How do you know that your program will develop systems thinking? Addition research and literature on the mechanisms that effectively develop systems thinking would alleviate the waste of sponsoring programs that have a questionable link to the actual development of systems thinking.

Government agencies should encourage systems programs that teach systems skills and systems thinking. These programs should help engineers to understand the componential, relational, contextual, and dynamic elements of systems. In addition, these programs should prepare engineers to use thinking aids such as models, simulations, processes, frameworks, tools, methods, and types of thinking.

4.6.3 Industry

There are five key applications of this research for industry. These are: (1) structure systems thinking interventions to emphasize experiential learning, (2) offer systems programs to teach systems skills and systems thinking, (3) filter and foster identified individual characteristics in systems organizations, (4) provide an environment supportive to the development of systems thinking, and (5) clearly communicate how strength of systems thinking is assessed.

Applications of Research for Industry

(1) Structure systems thinking interventions to emphasize experiential learning,
(2) Offer systems programs to teach systems skills and systems thinking
(3) Filter and foster identified individual characteristics in systems organizations
(4) Provide an environment supportive to the development of systems thinking
(5) Clearly communicate how strength of systems thinking is assessed.

One of the key findings of the study is the importance of experiential learning for developing systems thinking. Companies should structure systems thinking interventions to emphasize experiential learning. Training courses should be coordinated with work task.

Though experiential learning is primary, it is also important to offer systems programs to teach systems skills and systems thinking. Engineers should understand the componential, relational, contextual, and dynamic elements of systems. In addition, these engineers should be prepared to use thinking aids such as models, simulations, processes, frameworks, tools, methods, and types of thinking. Any systems program should also be designed with feedback mechanisms, so there is a way to capture current performance of the program and make adjustments to continually improve.

Organizations should also filter for the individual characteristics desired in their systems organizations and foster the development of those characteristics. For all participants in the study, the top ranked characteristics were thinking broadly, curiosity, questioning, open-mindedness, communication, tolerance for uncertainty, strong interpersonal skills, and thinking out-of-the-box. The particular characteristics desired for an organization may differ depending on their system context, but deciding which individual characteristics to filter for and foster should be an explicit and carefully planned decision.

Organizations should provide a supportive environment in which to develop systems thinking. This includes multiple aspects. First, systems training should be coordinated with job task and work environment. After systems training or systems education classes, an employee should be able to utilize the new learning. Second, the organization should manage schedule and cost constraints to allow time to utilize and to develop systems thinking. In addition, the organization should provide jobs and opportunities to see the systems view. Often, there are not enough jobs where a systems view is required. This is an issue of job design, and organizations can restructure tasks to foster or require systems thinking.

Finally, organizations should clearly communicate how strength of systems thinking is assessed. If systems thinking is a capability that the organization wants to foster, the measure of this capability should be considered and then communicated clearly. Particularly since systems thinking has ambiguous interpretations, it is important to explicitly communicate how systems thinking is evaluated and which aspects of systems thinking are being evaluated.

4.6.4 Academia

Academia affects systems thinking development in engineers in multiple ways. Academics should: (1) offer systems programs to teach systems skills, (2) use feedback mechanisms to continually improve systems programs and systems courses, (3) structure programs and courses to emphasize experiential learning, (4) structure courses to promote systems thinking by emphasizing context and knowledge integration, and (5) continue research on the mechanisms for effective systems thinking development.

Applications of Research for Academia

(1) Offer systems programs to teach systems skills and systems thinking
(2) Use feedback mechanisms to continually improve systems programs and systems courses
(3) Structure programs and courses to emphasize experiential learning
(4) Structure courses and programs to promote systems thinking by emphasizing context and knowledge integration
(5) Continue research on the mechanisms for effective systems thinking development

First, the growing number of systems educational degree programs offered in the United States and internationally is hopefully an indicator of the increase in the systems thinking. These programs help engineers to understand the componential, relational, contextual, and dynamic elements of systems. In addition, these programs prepare engineers to use thinking aids such as models, simulations, processes, frameworks, tools, methods, and types of thinking.

However, it is inadequate to assume that a systems department will necessarily yield systems thinkers. Instilling feedback mechanisms would help systems departments better understand how effective they are in developing systems thinking. Multiple measures could be utilized. One example is that students could be assessed at the entrance and exit of the systems program using interviews and mental model assessments to see how their systems thinking has developed and matured. Another measure could be tracking an experimental group of students in a systems department against a control group of students in other departments to see the differences in systems thinking as alumni. This would require agreed-upon indicators or validated measures of strength of systems thinking. These feedback measures could be utilized at the course level in addition to the program level to measure the effectiveness of a systems course.

One of the key points of this research is that experiential learning is an important mechanism to develop systems thinking in engineers. Educational programs and courses should be structured to incorporate this. Examples could be requiring an internship or requiring a period of work on a real system during the course of an educational program. Another application could be designing courses that are not based solely on the traditional classroom format and include experiential components that engage more of the five senses and more of the various methods of learning. Another application could affect admissions, admitting students who already have some systems experience.

The structure of a course should be designed to first provide an overview and context, and then present the applicable detailed material. Commenting on how aspects of education are barriers to the development of systems thinking, one respondent said that there was "one thing I didn't like about my undergrad education. The first engineering class I had was hardness of materials. Instead of a high-level overview of the field and what the field deals with, they just right away throw you into the smallest level details. [They] don't tell you about the field or the discipline first. This turned me off to engineering. They never brought it together until the end... Establish context before you go into detail."

In addition, the criteria for success in a class should promote knowledge integration. One respondent said that both an enabler and a barrier can be "how exams are structured in school. I had teachers in both directions. For me, it starts in school in the conception of exams. Even in history, [you] learn dates and the event, but if you are asked what the important thing is in the Renaissance, [you] need to see what is important in the entirety, not only details. [It is the] same thing in engineering. [You] need to know the total thing, not just the detail parts. You have criteria for success in details, but systems thinking is looking for the entirety of things. If exams are structured like this, it is important for pupils to look at the whole thing."

This knowledge integration should be taken to the educational program level as well. Programs should be designed to help students integrate knowledge attained from discrete courses. Integrative project courses and research projects are a mechanism for this. Another participant said, "A barrier is the way we as engineers are educated in the first place, as a product of the university system. [Students] take discrete courses and courses are treated separately, so

[we] don't gain an appreciation on how to combine resources from different courses. [Students are] absorbed in individual details and problems and don't see how these fit together."

Another key application of this research is to continue the research on the mechanisms that most effectively develop systems thinking. There are a growing number of systems educational programs; however, to design these programs most effectively, a considerable amount of research still needs performed to understand how systems thinking actually develops in engineers. Better understanding of the mechanisms that effectively produce systems thinking will increase the impact of these educational programs. The following section describes how this research might be continued.

5 Future Research

This exploratory research study has identified countless areas for follow-on research. For example, more research could lead to validated indicators of quality of systems thinking. This could then lead to research on how to measure success for systems thinking development programs. Using the results of this study, each of the top items identified in the tables could be explored in more depth. Each one of these top enablers, barriers, individual traits, and key steps could be the basis for another research study. The study could be expanded to understand how systems thinking develops at the group and organizational levels of analysis. Personality tests could be further utilized to see if there are differences between Senior Systems Engineers, Senior Technical Specialists, and Junior Systems Engineers. A study could also be conducted in an academic environment to contrast with the industry results of this study. Furthermore, the study could be expanded to include more international and non-aerospace companies to see how systems thinking develops in engineers in those settings. In short, this research maps the plan for numerous areas where additional research could considerably enhance understanding of systems thinking development in engineers.

5.1 Quality of Systems Thinking

As this study shows, there is a dearth of understanding on how to determine the quality of systems thinking. At this point, validating subjective measures of the quality of systems thinking is a challenge. Ideally, there could eventually be validated, objective measures of the quality of systems thinking. In addition to aiding organizations in assessing an individual's systems thinking abilities, a validated and objective measure could enable additional research investigations.

One idea might be to utilize the INCOSE Systems Engineering Certification process. Researchers could interview people who have their INCOSE SE certification to see how these people developed their systems thinking skills. In addition, comparisons could be made between those who have their INCOSE SE certification and a group of technical experts, to determine if there are differences in their personality, development history, or problem solving processes.

Likewise, if a company is using an internal certification process, similar comparisons could be made within the company. Researchers could interview people who have their internal, company SE certification to see how these people developed their systems thinking skills. In addition, comparisons could be made between those who have their SE certification and a group of technical experts, to determine if there are differences in their personality, development history, or problem solving processes.

5.2 Measures of Success for Systems Thinking Development Programs

A key problem is how to measure if a systems thinking development program was successful. With some type of feedback mechanism in place to measure the impact of a systems development intervention, adjustments can be made to make the intervention more effective and efficient. As an example, if a company has a systems training class, a recognized measure of the impact of the class could help organizers adjust class material, assist the instructor's delivery of the material, adjust the class timing and staging, change the class material with changes in the business climate, etc. For an academic department, having some type of feedback or measure of success for an educational program could help organizers adjust curriculum, adjust degree requirements, alter admission requirements, change any internship or work experience requirements, etc. Having a measure of success for a program instills a feedback mechanism in the process, which helps control results so there is greater impact and fewer wasted resources.

Current measures of success for a systems thinking development program include having a course evaluation form at the end of a class or asking managers if they think their workers have benefited from a class, which both seem like weak measures. Future research could identify more useful measures. In the meantime, here are a couple possibilities, which could be validated with future research.

In industry, government, or academia, a longitudinal study could be performed on a specific systems thinking development program to see how graduates fare in their careers in indicators of systems thinking. For example, if a company has job rotation program designed to develop systems thinking, graduates could be tracked throughout their career to see if they fare better or worse than a control group.

For an academic department, students admitted to a systems department could participate in entry interviews and exit interviews, to get feedback on the systems program and to see what mechanisms in the program were most effective. Comparisons could be made of the content in the entry interview and the content in the exit interview to determine the level to which systems thinking developed over the course of the program. This approach could also be used in industry for longer systems training or education programs there.

5.3 Exploration of Top Items

The tables shown in presenting the results of this research identify multiple items which might be fruitful for further investigations. For example, "work experience" was a top result for the question about key steps to develop systems thinking. A follow-on study could focus specifically on how "work experiences" affect systems thinking development. More details could be gathered on the types of work experiences, the duration of the experiences, the circumstances of the experiences, the staging in one's career, etc. Another interesting study could be further exploring how "hobbies" and "family" impact systems thinking development, since these are two of the top Level 2 key steps and since these categories might not be expected.

5.4 Additional Levels of Analysis

Additionally, further work could be done on the enablers and barriers to the development of systems thinking for the group and for the organization. Particularly since large, complex engineered systems are procured, designed, and managed by groups and organizations, research on the systems thinking development of these additional levels may be particularly useful. This could tie into the organizational learning work of Peter Senge and others. Also, it could be of interest to specifically understand how systems engineering capability develops in a group or an organization, along with understanding enablers and barriers to the development of this capability.

5.5 Personality Tests

Personality tests could be further utilized to see if there are differences between participants in the classifications of Senior Systems Engineer, Junior Systems Engineer, Senior Technical Specialist, and Expert Panelist. In addition, tests could be performed to determine if there are differences in the problem solving and thinking processes between these classifications. In particular, future studies could explore the personality trait of openness to ideas.

5.6 Study of the Academic Environment

A few interviews were conducted with some of the faculty members of MIT's Engineering Systems Division to see how they developed systems thinking. It would be quite interesting to expand this into a full study to see how systems thinking has developed in engineers in an academic environment. Comparisons could be made between faculty in a systems department and a technically narrow department to see if there are differences in systems thinking quality and other areas that may possibly be related, such as cognitive patterns, problem solving approaches, experience, demographics, personality, or interpersonal skills. Students could also be studied, and longitudinal studies could be performed to track systems students compared to a control group of students from other departments.

Considering even a relatively short-term intervention such as a course in the Engineering Systems Division (ESD), students could be randomly assigned at the beginning of the course to treatment groups and control groups. Perhaps their systems thinking could be assessed before and after the course intervention by using a mental model assessment or interviews.

5.7 International and Non-Aerospace Studies

Similarly, the study could be expanded to include more international and non-aerospace companies to see how systems thinking develops in engineers in those settings. This could help decipher how surrounding culture affects systems thinking, how different educational traditions affect systems thinking, and how different traditions of work style and schedule affect systems thinking development in engineers. In non-aerospace companies, perhaps having exposure to numerous full product-development life cycles may assist systems thinking development as well.

6 Conclusion

To conclude, the intellectual contributions of this work are discussed. In addition, a summary of the work is given.

6.1 Intellectual Contributions

A key question at the end of a doctoral dissertation is, "What do we know now that we did not know before?" This document provides multiple intellectual contributions. First, this document provides an organized analysis of existing literature on enablers to systems thinking development at multiple levels of analysis. The systems thinking literature is found in disparate fields and journals, from systems dynamics to systems engineering to general philosophy. Literature on enablers to systems thinking development is sparse. This document collects insights from multiple fields that provide information about how systems thinking develops in engineers.

During the study, an extensive data set was assembled on systems thinking development. The primary findings discussed in this document only scratch the surface of this database, since this database can seed numerous additional studies on systems thinking development. This work provides actual data to disprove or substantiate existing heuristics about systems thinking development. Though lack of data is a non-issue to some, having actual data enables theory development which leads to true understanding of how systems thinking develops in engineers. With enlightened, data-based understanding, more effective and efficient systems thinking interventions can be designed.

An original framework for reconciling divergent systems thinking definitions was developed. In addition, a conceptual illustration of systems thinking was given to aid visualization and comprehension of the complex facets of systems thinking.

The study also revealed the dearth of measures for strength of systems thinking. The data allowed quantification of the high percentage of respondents who do not know how their company is measuring strong systems thinking. In addition, the data show the extent to which systems thinking is measured by observation, which is particularly problematic when systems thinking definitions diverge.

A key intellectual contribution is that this study uncovered primary mechanisms that enable systems thinking development in engineers. Data were provided to highlight the significance of experiential learning. In addition, the study revealed specific individual traits that enable systems thinking development. Further substantiating the importance of curiosity and openness, evidence was shown from the field study data, the personality test data, and an outside research study. The importance of a supportive environment was also found.

The research study highlighted inconsistencies between existing policies and effective systems thinking development mechanisms. Diagrams depicting the evolution of systems thinking interventions were provided. In addition, implications for government, industry, and academia were given.

6.2 Summary

In the midst of the flurry of activity surrounding the currently urgent topic of systems, the results of this exploratory study demand that systems professionals step back to think. The mechanisms which develop systems thinking are not yet well-understood, though this research is a step towards enhanced understanding. The development mechanisms that are currently being utilized are not necessarily the most effective. Before valuable resources are poured into systems thinking development interventions, it is important to look at what the data in this study say about how systems thinking develops in engineers.

First of all, this study provides the data to explicitly expose the divergence of understandings of "systems thinking." When this phrase is used, it should be accompanied by an explanation, since the data show that people are not thinking of the same thing, even in the same classification in the same organization. In addition, strength of systems thinking is determined by subjective measures such as observation. When observers do not agree on a definition of systems thinking, their appraisals of strength of systems thinking can differ as well, leading to confusion and inefficiencies in developing systems thinking capability in the organization. In order to reconcile the divergent definitions observed, an original systems thinking framework, definition and accompanying conceptual illustration are given.

Despite the divergence on the construct definition and despite use of a research method which adds to the divergence, there is nonetheless considerable convergence on mechanisms which develop systems thinking. It is astounding that 95% of the Expert Panelists agree that "work experiences" were a key step to their systems thinking development. In addition, "work experiences" were identified as a key step for 69% of all participants, which is again a high percentage given the divergence of definitions and the expected divergence due to the research method. It is not surprising that a systems approach is needed to develop systems thinking in engineers. Multiple levels of analysis must be aligned to enable systems thinking development in engineers. While certain individual characteristics enable systems thinking development in engineers, a supporting environment is also important. To enhance the material taught in a training class, organizational incentives should be aligned with the class content.

In addition to defining the research space on this topic, this document also suggests applications for this research. First, levels of intervention maturity are shown. Applications of research for government are: (1) Provide incentives to promote strong systems thinking, (2) adjust policies to emphasize experiential learning for systems thinking development, (3) change acquisition strategy to provide more programs and opportunities for engineers to develop systems thinking, (4) promote research on the mechanisms for effective systems thinking development, and (5) encourage systems programs that teach systems skills and systems thinking. Here are the applications of the research for industry: (1) Structure systems thinking interventions to emphasize experiential learning, (2) offer systems programs to teach systems skills and systems thinking, (3) filter and foster identified individual characteristics in systems organizations, (4) provide an environment supportive to the development of systems thinking, and (5) clearly communicate how strength of systems thinking is assessed. The applications of the research for academia are: (1) offer systems programs to teach systems skills and systems thinking, (2) use feedback mechanisms to continually improve systems programs and systems courses, (3) structure programs and courses to emphasize experiential learning, (4) structure courses and programs to promote systems thinking by emphasizing context and knowledge integration, and (5) continue research on the mechanisms for effective systems thinking development. Better understanding of systems thinking development provides a foundation for educational interventions and employee development in systems thinking for engineering professionals across industry, government, and academia.

This dissertation defines the research space on this topic while also providing information about current understanding and practice. In addition to informing curriculum design for education and training programs, enhanced understanding of systems thinking development in engineers provides a foundation for more effective employee development programs. The results of this research can help organizations streamline their interventions to accelerate the development of senior systems engineers across industry, government, and academia.

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8 Appendix

8.1 Pilot Interview Questions

In addition, here is the list of the questions asked in the pilot interviews.

1) I define systems thinking as the ability to understand technical interdependencies in a system, the ability to understand social interdependencies in a system, the ability to think about feedback dynamics in a system, and the ability to understand multi-level/enterprise dynamics. Do you agree with this definition? Do you have any comments, additions or corrections to this definition?
2) What were key steps in your career path that developed your systems thinking abilities?
3) In your experience, have you seen any enablers, barriers and/or precursors to the development of systems thinking in engineers?
4) Are there certain characteristics that seem to predict the development of systems thinking?
5) Are there certain types of environments that seem to enable the development of enterprise and systems thinking?
6) How do you know if you have a high potential systems thinker?
7) What do you do to develop systems thinking in that person?
8) Considering interventions to promote systems thinking, do you find that some interventions are better than other interventions? If so, please specify.
9) In your opinion, how much systems training should each member in your organization receive?
10) How would you plot the growth in systems thinking versus time in a career?

11) Do you have any recommendations for papers or studies related to this topic?

12) May I contact you later if I have questions related to our conversation?

8.2 Expert Panel Interview Questions on Systems Thinking Development

In your company

1. In your company, how do employees move into a systems engineering position?
2. How many systems engineers are in your company?
3. How do you know if you have a high potential systems thinker in your company?
4. How many high potential systems thinkers do you know in your company? Who are they and what kinds of positions do they hold (not necessarily systems engineers)?
5. In your company, what is a typical career path for a systems engineer?
6. In your company, how are the abilities of systems engineers developed?
7. Does your company use formal systems engineering training programs?
8. If yes, how do you evaluate if the systems engineering training program was successful?
9. In your company, how do you measure strong systems performance for systems engineers?
10. How have systems engineers contributed to your company's success?

In your opinion

11. How do you define systems thinking?
12. Considering the definition of systems thinking as, "analysis, synthesis, and understanding of interconnections, interactions, and interdependencies that are technical, social, temporal, and multi-level," what aspects of this definition do you agree or disagree with? Why?
13. In your experience, what enablers or barriers have you seen to the development of systems thinking in engineers?
14. Are there certain individual characteristics or innate traits that seem to predict the development of systems thinking? If so, what are they?
15. Considering interventions (such as training programs, mentoring, job rotations, etc.) to promote systems thinking, do you find that some interventions are better than other interventions? If so, please specify.
16. What were key steps in your life that developed your systems thinking abilities?
17. What are your strengths as a systems thinker? How did they develop?
18. Please give a story of a successful use of your systems thinking skills.

8.3 Subject Interview

Thank you for participating in this interview! During this interview, I hope to learn more about you, your experience with systems thinking, and your views on complex systems.

Definitions

1. How do you define systems thinking?

2. Considering the definition of systems thinking as, "analysis, synthesis, and understanding of interconnections, interactions, and interdependencies that are technical, social, temporal, and multi-level," what aspects of this definition do you agree or disagree with? Why?

Questions about your experience with systems thinking

3. In your experience, what enablers or barriers have you seen to the development of systems thinking in engineers?

4. Are there certain individual characteristics or innate traits that seem to predict the development of systems thinking? If so, what are they?

5. Considering interventions (such as training programs, mentoring, job rotations, etc.) to promote systems thinking, do you find that some interventions are better than other interventions? If so, please specify.

6. How does your company determine if an employee displays strong systems thinking?

Questions about you

7. What key enablers or barriers did you encounter in reaching your current position?

8. What were key steps in your life that developed your systems thinking abilities?

9. What are your strengths as a systems thinker? How did they develop?

10. Please give a story of a successful use of your systems thinking skills.

Questions about complex systems

In the Engineering Systems Division at MIT, we are interested in studying very large, complex, engineered systems such as the International Space Station or Boston's Big Dig.

11. Please name a large, complex, engineered system that is familiar to you.

12. Why do you consider this system "complex"?

8.4 Survey of Your Background

Thank you for agreeing to take this survey. Please complete the following survey by entering the correct information in the blank space provided or by checking the appropriate box.

1. Name ____

2. Phone number (for research purposes ONLY) ______________________

3. Email (for research purposes ONLY) ___________________________

4. What is your gender? ☐ Female ☐ Male

5. What is your current country and state/province of residence? ______________

6. What is your level of education? Please check the highest level attained.
   a. _____ High school graduation or GED equivalent
   b. _____ Two-year post-secondary or technical certificate
   c. _____ Bachelor's degree or equivalent
   d. _____ Master's degree
   e. _____ Doctoral degree

7. If applicable, please list the educational institutions you attended and your major(s) at each.

Degree	College Attended	Major(s) and thesis title, if appropriate
Bachelor's degree		
Master's degree		
Doctoral degree		

8. Who is your current employer? ______________________________

9. How many years have you worked for your current employer? ____________

10. Please provide a BRIEF title and job description for your current position.

11. Please list the job positions you have held during your career.

Job Position (most recent first, including current position)	**Company**	**Length of Time**

12-14. Have you participated in the following types of training programs?

Training Program	**Yes or No?**	**Comments**	**Total Time in Training**
12. Training program with job rotations	☐ Yes ☐ No		
13. Systems engineering training program	☐ Yes ☐ No	☐ Internal, company training program ☐ University certificate program ☐ University degree program ☐ Other	
14. Process improvement training, such as Lean or Six Sigma training	☐ Yes ☐ No		

8.5 Survey of Your Background (German Education Version)

Thank you for agreeing to take this survey. Please complete the following survey by entering the correct information in the blank space provided or by checking the appropriate box.

1. Name ____

2. Phone number (for research purposes ONLY) ______________________

3. Email (for research purposes ONLY) __________________________

4. What is your gender? ☐ Female ☐ Male

5. What is your current country and state/province of residence? _____________

6. What is your level of education? Please check the highest level attained.
   a. _____ High school graduation or GED equivalent (Hochschulreife)
   b. _____ Two-year post-secondary or technical certificate (Techniker)
   c. _____ Bachelor's degree or equivalent (FH-Studium, mit 3-4 Jahren Regelstudienzeit)
   d. _____ Master's degree (Universitat)
   e. _____ Doctoral degree

7. If applicable, please list the educational institutions you attended and your major(s) at each.

Degree	College Attended	Major(s) and thesis title, if appropriate
Bachelor's degree		
Master's degree		
Doctoral degree		

8. Who is your current employer? ______________________________

9. How many years have you worked for your current employer? ____________

10. Please provide a BRIEF title and job description for your current position.

11. Please list the job positions you have held during your career.

Job Position (most recent first, including current position)	Company	Length of Time

12-14. Have you participated in the following types of training programs?

Training Program	Yes or No?	Comments	Total Time in Training
12. Training program with job rotations	☐ Yes ☐ No		
13. Systems engineering training program	☐ Yes ☐ No	☐ Internal, company training program ☐ University certificate program ☐ University degree program ☐ Other	
14. Process improvement training, such as Lean or Six Sigma training	☐ Yes ☐ No		

8.6 Consent to Participate in Non-Biomedical Research

Enablers, Barriers, and Precursors to the Development of Systems Thinking

You are asked to participate in a research study conducted by the Lean Aerospace Initiative at the Massachusetts Institute of Technology (M.I.T). This work will contribute directly to a doctoral dissertation. You were selected as a possible participant in this study because of your current position in an engineering organization. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

- **PARTICIPATION AND WITHDRAWAL**

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

- **PURPOSE OF THE STUDY**

The purpose of this study is to better understand the development of systems thinking in engineers. As systems become more complex and as industry roles change, companies are more responsible for systems solutions. Global conditions demand that engineers consider the broader social context in which technology is entwined. However, there is a shortage in systems talent. Currently, there is increasing interest in educating and training engineers to think systemically. Since it may take more than twenty years to develop a senior systems engineer, accelerating this development process is of immediate concern.

By identifying enablers, barriers, and precursors to the development of systems thinking, this research will provide an empirical foundation for more effective and efficient interventions in the systems thinking development process. Currently, many systems training programs are structured using heuristics and isolated experiences. By studying the systems thinking development process, this research will positively impact educational interventions and employee development in systems thinking for engineering professionals across industry, government, and academia.

This work is part of ongoing research in the Lean Aerospace Initiative (LAI), a consortium of academia, industry, unions, and government. The primary goal of the LAI is to provide practical knowledge to the aerospace industry to facilitate transformation.

- **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things.

Please complete the survey and personality test. If you volunteer to participate in this study, we would ask you to answer the survey questions to the best of your knowledge. The survey will be administered to a sample of employees from three groupings: (1) senior systems architects or senior systems engineers, (2) senior technical specialists, and (3) junior systems architects or engineers. The survey and personality test together will take about one hour to complete.

Subjects will then be asked to participate in semi-structured interviews. If you volunteer to participate in this study, we would ask you to answer the interview questions to the best of your knowledge.

- **POTENTIAL RISKS AND DISCOMFORTS**

There are no foreseeable risks or discomforts due to participation in this study. All research will be confidential, non-attributable, and reported as aggregate data.

- **POTENTIAL BENEFITS**

Companies who participate in this research could better understand how their development process for systems engineers compares with other companies' practices. This could lead to more efficient processes, indirectly benefitting employees through improved company performance. In addition, subjects could access research results to see what they can do to further develop their systems thinking abilities.

This study could further existing knowledge on the systems thinking development process in engineers. This could positively impact educational interventions and employee development in systems thinking for engineering professionals across industry, government, and academia.

- **PAYMENT FOR PARTICIPATION**

There is no payment for participation.

- **CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Data will be stored securely until research is complete, at which time any attributable data will be destroyed. Reported data will be non-attributable.

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about the research, please feel free to contact:

Ms. Heidi L. Davidz
Doctoral Researcher
77 Massachusetts Avenue, Room 41-205
Cambridge, MA 02139
1-617-258-7984
hdavidz@mit.edu

Dr. Deborah J. Nightingale
Professor of the Practice
Department of Aeronautics and Astronautics and the Engineering Systems Division
77 Massachusetts Avenue, Room 33-312
Cambridge, MA 02139
1-617-253-7339
dnight@mit.edu

- **EMERGENCY CARE AND COMPENSATION FOR INJURY**

Note: The following is a required element of informed consent.
In certain cases COUHES may decide that it may be omitted:

"In the unlikely event of physical injury resulting from participation in this research you may receive medical treatment from the M.I.T. Medical Department, including emergency treatment and follow-up care as needed. Your insurance carrier may be billed for the cost of such treatment. M.I.T. does not provide any other form of compensation for injury. Moreover, in either providing or making such medical care available it does not imply the injury is the fault of the investigator. Further information may be obtained by calling the MIT Insurance and Legal Affairs Office at 1-617-253 2822."

- **RIGHTS OF RESEARCH SUBJECTS**

You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of

Humans as Experimental Subjects, M.I.T., Room E32-335, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253 6787.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Subject

____
Name of Legal Representative (if applicable)

____ ______________
Signature of Subject or Legal Representative Date

SIGNATURE OF INVESTIGATOR

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____ ______________
Signature of Investigator Date

8.7 Determination of Strong Systems Thinking

8.7.1 Coding for Determination of Strong Systems Thinking

Determination of Strong Systems Thinking	Total
Ideas	
- Should add to yearly review	1
- Idea - peer review	1
- Should have instruments for this	1
Difficulty with this	
- Do not know	58
- Don't have privilege to sort people out	1
- Promote them out of a job	1
- Not formal method in company	37
- Management question	2
- No single way	1
- Can't speak for company	1
- Hard to know in interviews	1
- Management has hard time ID this	2
- Struggle with this	5
Employee initiative	5
Look for certain characteristics	28
Education/college training	2
Experience and observation	
- Get more work	2
- Reputation	2
- Observation	31
- Interaction	8
- Experience/demonstrate ability	39
- Artifacts/quality of work	9
- Volume	1
- Management identifies/evaluates	21
- Movement to and from systems areas	4
- Peer review	2
Formal Methods	
- Check marks/steps	2
- Performance appraisals	15
- Annual talk about potentials	1
- Criteria to enter development program	1

- Surveys	1
- Competency model/standard skills	2
- Formal categories	1

8.7.2 Level 1 Coding for Determination of Strong Systems Thinking

Level 1 Coding for Determination of Strong Systems Thinking	Total
Ideas	3
Difficulty with this	109
Employee initiative	5
Look for certain characteristics	28
Education/college training	2
Experience and observation	119
Formal Methods	23

8.7.3 Top Level 1 Categories for Determination of Strong Systems Thinking

Top Level 1 Categories for Determination of Strong Systems Thinking for All Participants (N=165)

Rank	Node Category	Number of Participants	Percent of Participants
1	Difficulty with this	100	61%
2	Experience and observation	95	58%
3	Look for certain characteristics	28	17%
4	Formal Methods	23	14%

Top Level 1 Categories for Determination of Strong Systems Thinking for Senior Systems Engineers (N=62)

Rank	Node Category	Number of Participants	Percent of Participants
1	Experience and observation	41	66%
2	Difficulty with this	30	48%
3	Look for certain characteristics	9	15%
4	Formal Methods	7	11%

Top Level 1 Categories for Determination of Strong Systems Thinking for Senior Technical Specialists (N=51)

Rank	Node Category	Number of Participants	Percent of Participants
1	Difficulty with this	33	65%
2	Experience and observation	29	57%
3	Look for certain characteristics	12	24%
4	Formal Methods	11	22%

Top Level 1 Categories for Determination of Strong Systems Thinking for Junior Systems Engineers (N=52)

Rank	Node Category	Number of Participants	Percent of Participants
1	Difficulty with this	37	71%
2	Experience and observation	25	48%
3	Look for certain characteristics	7	13%
4	Formal Methods	5	10%

8.7.4 Summary of Top Level 1 Coding for Determination of Strong Systems Thinking for All Classifications

Top Level 1 Coding for Determination of Strong Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=165)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=51)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Difficulty with this	1	100	61%	2	30	48%	1	33	65%	1	37	71%	6.659	0.036
Experience and observation	2	95	58%	1	41	66%	2	29	57%	2	25	48%	3.788	0.150
Look for certain characteristics	3	28	17%	3	9	15%	3	12	24%	3	7	13%	2.277	0.320
Formal methods	4	23	14%	4	7	11%	4	11	22%	4	5	10%	3.648	0.161

8.7.5 Crosstabulation Tables by Classification for Top Level 1 Coding for Strong Systems Thinking

8.7.5.1 Crosstabulation Table by Classification for Top Level 1 Measure "Difficulty with this"

Translated Classification * Difficulty with this Crosstabulation

			Difficulty with this		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	32	30	62
		Expected Count	24.4	37.6	62.0
		% within Translated Classification	51.6%	48.4%	100.0%
		% within Difficulty with this	49.2%	30.0%	37.6%
		% of Total	19.4%	18.2%	37.6%
	3_Senior Tech Specialist	Count	18	33	51
		Expected Count	20.1	30.9	51.0
		% within Translated Classification	35.3%	64.7%	100.0%
		% within Difficulty with this	27.7%	33.0%	30.9%
		% of Total	10.9%	20.0%	30.9%
	4_Junior Systems Engineer	Count	15	37	52
		Expected Count	20.5	31.5	52.0
		% within Translated Classification	28.8%	71.2%	100.0%
		% within Difficulty with this	23.1%	37.0%	31.5%
		% of Total	9.1%	22.4%	31.5%
Total		Count	65	100	165
		Expected Count	65.0	100.0	165.0
		% within Translated Classification	39.4%	60.6%	100.0%
		% within Difficulty with this	100.0%	100.0%	100.0%
		% of Total	39.4%	60.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.659[a]	2	.036
Likelihood Ratio	6.669	2	.036
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 20.09.

8.7.5.2 Crosstabulation Table by Classification for Top Level 1 Measure "Experience and observation"

Translated Classification * Experience and observation Crosstabulation

			Experience and observation		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	21	41	62
		Expected Count	26.3	35.7	62.0
		% within Translated Classification	33.9%	66.1%	100.0%
		% within Experience and observation	30.0%	43.2%	37.6%
		% of Total	12.7%	24.8%	37.6%
	3_Senior Tech Specialist	Count	22	29	51
		Expected Count	21.6	29.4	51.0
		% within Translated Classification	43.1%	56.9%	100.0%
		% within Experience and observation	31.4%	30.5%	30.9%
		% of Total	13.3%	17.6%	30.9%
	4_Junior Systems Engineer	Count	27	25	52
		Expected Count	22.1	29.9	52.0
		% within Translated Classification	51.9%	48.1%	100.0%
		% within Experience and observation	38.6%	26.3%	31.5%
		% of Total	16.4%	15.2%	31.5%
Total		Count	70	95	165
		Expected Count	70.0	95.0	165.0
		% within Translated Classification	42.4%	57.6%	100.0%
		% within Experience and observation	100.0%	100.0%	100.0%
		% of Total	42.4%	57.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.788[a]	2	.150
Likelihood Ratio	3.807	2	.149
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 21.64.

8.7.5.3 Crosstabulation Table by Classification for Top Level 1 Measure "Look for certain characteristics"

Translated Classification * Look for certain characteristics Crosstabulation

			Look for certain characteristics		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	53	9	62
		Expected Count	51.5	10.5	62.0
		% within Translated Classification	85.5%	14.5%	100.0%
		% within Look for certain characteristics	38.7%	32.1%	37.6%
		% of Total	32.1%	5.5%	37.6%
	3_Senior Tech Specialist	Count	39	12	51
		Expected Count	42.3	8.7	51.0
		% within Translated Classification	76.5%	23.5%	100.0%
		% within Look for certain characteristics	28.5%	42.9%	30.9%
		% of Total	23.6%	7.3%	30.9%
	4_Junior Systems Engineer	Count	45	7	52
		Expected Count	43.2	8.8	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Look for certain characteristics	32.8%	25.0%	31.5%
		% of Total	27.3%	4.2%	31.5%
Total		Count	137	28	165
		Expected Count	137.0	28.0	165.0
		% within Translated Classification	83.0%	17.0%	100.0%
		% within Look for certain characteristics	100.0%	100.0%	100.0%
		% of Total	83.0%	17.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.277[a]	2	.320
Likelihood Ratio	2.182	2	.336
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.65.

8.7.5.4 Crosstabulation Table by Classification for Top Level 1 Measure "Formal methods"

Translated Classification * Formal Methods Crosstabulation

			Formal Methods		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	55	7	62
		Expected Count	53.4	8.6	62.0
		% within Translated Classification	88.7%	11.3%	100.0%
		% within Formal Methods	38.7%	30.4%	37.6%
		% of Total	33.3%	4.2%	37.6%
	3_Senior Tech Specialist	Count	40	11	51
		Expected Count	43.9	7.1	51.0
		% within Translated Classification	78.4%	21.6%	100.0%
		% within Formal Methods	28.2%	47.8%	30.9%
		% of Total	24.2%	6.7%	30.9%
	4_Junior Systems Engineer	Count	47	5	52
		Expected Count	44.8	7.2	52.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Formal Methods	33.1%	21.7%	31.5%
		% of Total	28.5%	3.0%	31.5%
Total		Count	142	23	165
		Expected Count	142.0	23.0	165.0
		% within Translated Classification	86.1%	13.9%	100.0%
		% within Formal Methods	100.0%	100.0%	100.0%
		% of Total	86.1%	13.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.648[a]	2	.161
Likelihood Ratio	3.456	2	.178
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.11.

8.7.6 Crosstabulation Tables by Company for Top Level 1 Coding for Strong Systems Thinking for All Classifications

8.7.6.1 Crosstabulation Table by Company for Top Level 1 Measure "Difficulty with this"

Crosstab

			Difficulty with this		
			0	1	Total
Company	A	Count	9	5	14
		Expected Count	5.5	8.5	14.0
		% within Company	64.3%	35.7%	100.0%
		% within Difficulty with this	13.8%	5.0%	8.5%
		% of Total	5.5%	3.0%	8.5%
	B	Count	6	7	13
		Expected Count	5.1	7.9	13.0
		% within Company	46.2%	53.8%	100.0%
		% within Difficulty with this	9.2%	7.0%	7.9%
		% of Total	3.6%	4.2%	7.9%
	C	Count	7	14	21
		Expected Count	8.3	12.7	21.0
		% within Company	33.3%	66.7%	100.0%
		% within Difficulty with this	10.8%	14.0%	12.7%
		% of Total	4.2%	8.5%	12.7%
	D	Count	2	13	15
		Expected Count	5.9	9.1	15.0
		% within Company	13.3%	86.7%	100.0%
		% within Difficulty with this	3.1%	13.0%	9.1%
		% of Total	1.2%	7.9%	9.1%
	E	Count	6	10	16
		Expected Count	6.3	9.7	16.0
		% within Company	37.5%	62.5%	100.0%
		% within Difficulty with this	9.2%	10.0%	9.7%
		% of Total	3.6%	6.1%	9.7%
	F	Count	11	8	19
		Expected Count	7.5	11.5	19.0
		% within Company	57.9%	42.1%	100.0%
		% within Difficulty with this	16.9%	8.0%	11.5%
		% of Total	6.7%	4.8%	11.5%
	G	Count	5	6	11
		Expected Count	4.3	6.7	11.0
		% within Company	45.5%	54.5%	100.0%
		% within Difficulty with this	7.7%	6.0%	6.7%
		% of Total	3.0%	3.6%	6.7%
	H	Count	8	10	18
		Expected Count	7.1	10.9	18.0
		% within Company	44.4%	55.6%	100.0%
		% within Difficulty with this	12.3%	10.0%	10.9%
		% of Total	4.8%	6.1%	10.9%
	I	Count	6	8	14
		Expected Count	5.5	8.5	14.0
		% within Company	42.9%	57.1%	100.0%
		% within Difficulty with this	9.2%	8.0%	8.5%
		% of Total	3.6%	4.8%	8.5%
	J	Count	5	19	24
		Expected Count	9.5	14.5	24.0
		% within Company	20.8%	79.2%	100.0%
		% within Difficulty with this	7.7%	19.0%	14.5%
		% of Total	3.0%	11.5%	14.5%
Total		Count	65	100	165
		Expected Count	65.0	100.0	165.0
		% within Company	39.4%	60.6%	100.0%
		% within Difficulty with this	100.0%	100.0%	100.0%
		% of Total	39.4%	60.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.115[a]	9	.088
Likelihood Ratio	15.942	9	.068
N of Valid Cases	165		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.33.

8.7.6.2 Crosstabulation Table by Company for Top Level 1 Measure "Experience and observation"

Crosstab

			Experience and observation 0	Experience and observation 1	Total
Company	A	Count	5	9	14
		Expected Count	5.9	8.1	14.0
		% within Company	35.7%	64.3%	100.0%
		% within Experience and observation	7.1%	9.5%	8.5%
		% of Total	3.0%	5.5%	8.5%
	B	Count	5	8	13
		Expected Count	5.5	7.5	13.0
		% within Company	38.5%	61.5%	100.0%
		% within Experience and observation	7.1%	8.4%	7.9%
		% of Total	3.0%	4.8%	7.9%
	C	Count	11	10	21
		Expected Count	8.9	12.1	21.0
		% within Company	52.4%	47.6%	100.0%
		% within Experience and observation	15.7%	10.5%	12.7%
		% of Total	6.7%	6.1%	12.7%
	D	Count	6	9	15
		Expected Count	6.4	8.6	15.0
		% within Company	40.0%	60.0%	100.0%
		% within Experience and observation	8.6%	9.5%	9.1%
		% of Total	3.6%	5.5%	9.1%
	E	Count	8	8	16
		Expected Count	6.8	9.2	16.0
		% within Company	50.0%	50.0%	100.0%
		% within Experience and observation	11.4%	8.4%	9.7%
		% of Total	4.8%	4.8%	9.7%
	F	Count	6	13	19
		Expected Count	8.1	10.9	19.0
		% within Company	31.6%	68.4%	100.0%
		% within Experience and observation	8.6%	13.7%	11.5%
		% of Total	3.6%	7.9%	11.5%
	G	Count	6	5	11
		Expected Count	4.7	6.3	11.0
		% within Company	54.5%	45.5%	100.0%
		% within Experience and observation	8.6%	5.3%	6.7%
		% of Total	3.6%	3.0%	6.7%
	H	Count	5	13	18
		Expected Count	7.6	10.4	18.0
		% within Company	27.8%	72.2%	100.0%
		% within Experience and observation	7.1%	13.7%	10.9%
		% of Total	3.0%	7.9%	10.9%
	I	Count	5	9	14
		Expected Count	5.9	8.1	14.0
		% within Company	35.7%	64.3%	100.0%
		% within Experience and observation	7.1%	9.5%	8.5%
		% of Total	3.0%	5.5%	8.5%
	J	Count	13	11	24
		Expected Count	10.2	13.8	24.0
		% within Company	54.2%	45.8%	100.0%
		% within Experience and observation	18.6%	11.6%	14.5%
		% of Total	7.9%	6.7%	14.5%
Total		Count	70	95	165
		Expected Count	70.0	95.0	165.0
		% within Company	42.4%	57.6%	100.0%
		% within Experience and observation	100.0%	100.0%	100.0%
		% of Total	42.4%	57.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.376[a]	9	.702
Likelihood Ratio	6.447	9	.694
N of Valid Cases	165		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.67.

8.7.6.3 *Crosstabulation Table by Company for Top Level 1 Measure "Look for certain characteristics"*

Crosstab

			Look for certain characteristics 0	1	Total
Company	A	Count	11	3	14
		Expected Count	11.6	2.4	14.0
		% within Company	78.6%	21.4%	100.0%
		% within Look for certain characteristics	8.0%	10.7%	8.5%
		% of Total	6.7%	1.8%	8.5%
	B	Count	12	1	13
		Expected Count	10.8	2.2	13.0
		% within Company	92.3%	7.7%	100.0%
		% within Look for certain characteristics	8.8%	3.6%	7.9%
		% of Total	7.3%	.6%	7.9%
	C	Count	18	3	21
		Expected Count	17.4	3.6	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Look for certain characteristics	13.1%	10.7%	12.7%
		% of Total	10.9%	1.8%	12.7%
	D	Count	12	3	15
		Expected Count	12.5	2.5	15.0
		% within Company	80.0%	20.0%	100.0%
		% within Look for certain characteristics	8.8%	10.7%	9.1%
		% of Total	7.3%	1.8%	9.1%
	E	Count	13	3	16
		Expected Count	13.3	2.7	16.0
		% within Company	81.3%	18.8%	100.0%
		% within Look for certain characteristics	9.5%	10.7%	9.7%
		% of Total	7.9%	1.8%	9.7%
	F	Count	16	3	19
		Expected Count	15.8	3.2	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Look for certain characteristics	11.7%	10.7%	11.5%
		% of Total	9.7%	1.8%	11.5%
	G	Count	9	2	11
		Expected Count	9.1	1.9	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Look for certain characteristics	6.6%	7.1%	6.7%
		% of Total	5.5%	1.2%	6.7%
	H	Count	14	4	18
		Expected Count	14.9	3.1	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Look for certain characteristics	10.2%	14.3%	10.9%
		% of Total	8.5%	2.4%	10.9%
	I	Count	11	3	14
		Expected Count	11.6	2.4	14.0
		% within Company	78.6%	21.4%	100.0%
		% within Look for certain characteristics	8.0%	10.7%	8.5%
		% of Total	6.7%	1.8%	8.5%
	J	Count	21	3	24
		Expected Count	19.9	4.1	24.0
		% within Company	87.5%	12.5%	100.0%
		% within Look for certain characteristics	15.3%	10.7%	14.5%
		% of Total	12.7%	1.8%	14.5%
Total		Count	137	28	165
		Expected Count	137.0	28.0	165.0
		% within Company	83.0%	17.0%	100.0%
		% within Look for certain characteristics	100.0%	100.0%	100.0%
		% of Total	83.0%	17.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.153[a]	9	.989
Likelihood Ratio	2.297	9	.986
N of Valid Cases	165		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.87.

8.7.6.4 *Crosstabulation Table by Company for Top Level 1 Measure "Formal methods"*

Crosstab

			Formal Methods		
			0	1	Total
Company	A	Count	9	5	14
		Expected Count	12.0	2.0	14.0
		% within Company	64.3%	35.7%	100.0%
		% within Formal Methods	6.3%	21.7%	8.5%
		% of Total	5.5%	3.0%	8.5%
	B	Count	10	3	13
		Expected Count	11.2	1.8	13.0
		% within Company	76.9%	23.1%	100.0%
		% within Formal Methods	7.0%	13.0%	7.9%
		% of Total	6.1%	1.8%	7.9%
	C	Count	20	1	21
		Expected Count	18.1	2.9	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Formal Methods	14.1%	4.3%	12.7%
		% of Total	12.1%	.6%	12.7%
	D	Count	13	2	15
		Expected Count	12.9	2.1	15.0
		% within Company	86.7%	13.3%	100.0%
		% within Formal Methods	9.2%	8.7%	9.1%
		% of Total	7.9%	1.2%	9.1%
	E	Count	14	2	16
		Expected Count	13.8	2.2	16.0
		% within Company	87.5%	12.5%	100.0%
		% within Formal Methods	9.9%	8.7%	9.7%
		% of Total	8.5%	1.2%	9.7%
	F	Count	17	2	19
		Expected Count	16.4	2.6	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Formal Methods	12.0%	8.7%	11.5%
		% of Total	10.3%	1.2%	11.5%
	G	Count	9	2	11
		Expected Count	9.5	1.5	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Formal Methods	6.3%	8.7%	6.7%
		% of Total	5.5%	1.2%	6.7%
	H	Count	17	1	18
		Expected Count	15.5	2.5	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Formal Methods	12.0%	4.3%	10.9%
		% of Total	10.3%	.6%	10.9%
	I	Count	13	1	14
		Expected Count	12.0	2.0	14.0
		% within Company	92.9%	7.1%	100.0%
		% within Formal Methods	9.2%	4.3%	8.5%
		% of Total	7.9%	.6%	8.5%
	J	Count	20	4	24
		Expected Count	20.7	3.3	24.0
		% within Company	83.3%	16.7%	100.0%
		% within Formal Methods	14.1%	17.4%	14.5%
		% of Total	12.1%	2.4%	14.5%
Total		Count	142	23	165
		Expected Count	142.0	23.0	165.0
		% within Company	86.1%	13.9%	100.0%
		% within Formal Methods	100.0%	100.0%	100.0%
		% of Total	86.1%	13.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.037[a]	9	.348
Likelihood Ratio	9.328	9	.408
N of Valid Cases	165		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.53.

8.7.7 Top Level 2 Categories for Determination of Strong Systems Thinking

Top Level 2 Categories for Determination of Strong Systems Thinking for All Participants (N=165)

Rank	Node Category	Number of Participants	Percent of Participants
1	Do not know	58	35%
2	Experience/demonstrate ability	39	24%
3	Not formal method in company	37	22%
4	Observation	31	19%
5	Look for certain characteristics	28	17%
6	Management identifies/evaluates	21	13%

Top Level 2 Categories for Determination of Strong Systems Thinking for Senior Systems Engineers (N=62)

Rank	Node Category	Number of Participants	Percent of Participants
1	Do not know	17	27%
1	Experience/demonstrate ability	17	27%
3	Observation	15	24%
4	Not formal method in company	14	23%
5	Look for certain characteristics	9	15%
5	Management identifies/evaluates	9	15%

Top Level 2 Categories for Determination of Strong Systems Thinking for Senior Technical Specialists (N=51)

Rank	Node Category	Number of Participants	Percent of Participants
1	Do not know	16	31%
2	Look for certain characteristics	12	24%
3	Not formal method in company	11	22%
3	Experience/demonstrate ability	11	22%
5	Observation	10	20%
6	Management identifies/evaluates	9	18%
7	Performance appraisals	7	14%

Top Level 2 Categories for Determination of Strong Systems Thinking for Junior Systems Engineers (N=52)

Rank	Node Category	Number of Participants	Percent of Participants
1	Do not know	25	48%
2	Not formal method in company	12	23%
3	Experience/demonstrate ability	11	21%
4	Look for certain characteristics	7	13%
5	Observation	6	12%
6	Artifacts/quality of work	5	10%
6	Performance appraisals	5	10%

8.7.8 Summary of Top Level 2 Coding for Determination of Strong Systems Thinking for All Classifications

Top Level 2 Determination of Strong Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=165)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=51)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Do not know	1	58	35%	1	17	27%	1	16	31%	1	25	48%	5.757	0.056
Experience/demonstrate ability	2	39	24%	1	17	27%	3	11	22%	3	11	21%	0.790	0.674
Not formal method in company	3	37	22%	4	14	23%	3	11	22%	2	12	23%	0.035	0.983
Observation	4	31	19%	3	15	24%	5	10	20%	5	6	12%	3.001	0.223
Look for certain characteristics	5	28	17%	5	9	15%	2	12	24%	4	7	13%	2.277	0.320
Management identifies/evaluates	6	21	13%	5	9	15%	6	9	18%	8	3	6%	3.557	0.169
Performance appraisals	7	15	9%	7	3	5%	7	7	14%	6	5	10%	2.699	0.259
Artifacts/quality of work	8	9	5%	7	3	5%	12	1	2%	6	5	10%	2.998	0.223

8.7.9 Crosstabulation Tables by Classification for Top Level 2 Coding for Strong Systems Thinking

8.7.9.1 Crosstabulation Table by Classification for Top Level 2 Measure of "Do not know"

Translated Classification * Do not know Crosstabulation

			Do not know		Total
			0	1	
Translated Classification	2_Senior Systems Engineer	Count	45	17	62
		Expected Count	40.2	21.8	62.0
		% within Translated Classification	72.6%	27.4%	100.0%
		% within Do not know	42.1%	29.3%	37.6%
		% of Total	27.3%	10.3%	37.6%
	3_Senior Tech Specialist	Count	35	16	51
		Expected Count	33.1	17.9	51.0
		% within Translated Classification	68.6%	31.4%	100.0%
		% within Do not know	32.7%	27.6%	30.9%
		% of Total	21.2%	9.7%	30.9%
	4_Junior Systems Engineer	Count	27	25	52
		Expected Count	33.7	18.3	52.0
		% within Translated Classification	51.9%	48.1%	100.0%
		% within Do not know	25.2%	43.1%	31.5%
		% of Total	16.4%	15.2%	31.5%
Total		Count	107	58	165
		Expected Count	107.0	58.0	165.0
		% within Translated Classification	64.8%	35.2%	100.0%
		% within Do not know	100.0%	100.0%	100.0%
		% of Total	64.8%	35.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.757[a]	2	.056
Likelihood Ratio	5.670	2	.059
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 17.93.

8.7.9.2 Crosstabulation Table by Classification for Top Level 2 Measure of "Experience/demonstrate ability"

Translated Classification * Experience/demonstrate ability Crosstabulation

			Experience/demonstrate ability		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	45	17	62
		Expected Count	47.3	14.7	62.0
		% within Translated Classification	72.6%	27.4%	100.0%
		% within Experience/demonstrate ability	35.7%	43.6%	37.6%
		% of Total	27.3%	10.3%	37.6%
	3_Senior Tech Specialist	Count	40	11	51
		Expected Count	38.9	12.1	51.0
		% within Translated Classification	78.4%	21.6%	100.0%
		% within Experience/demonstrate ability	31.7%	28.2%	30.9%
		% of Total	24.2%	6.7%	30.9%
	4_Junior Systems Engineer	Count	41	11	52
		Expected Count	39.7	12.3	52.0
		% within Translated Classification	78.8%	21.2%	100.0%
		% within Experience/demonstrate ability	32.5%	28.2%	31.5%
		% of Total	24.8%	6.7%	31.5%
Total		Count	126	39	165
		Expected Count	126.0	39.0	165.0
		% within Translated Classification	76.4%	23.6%	100.0%
		% within Experience/demonstrate ability	100.0%	100.0%	100.0%
		% of Total	76.4%	23.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.790[a]	2	.674
Likelihood Ratio	.780	2	.677
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.05.

8.7.9.3 Crosstabulation Table by Classification for Top Level 2 Measure of "Not formal method in company"

Translated Classification * Not formal method in company Crosstabulation

			Not formal method in company		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	48	14	62
		Expected Count	48.1	13.9	62.0
		% within Translated Classification	77.4%	22.6%	100.0%
		% within Not formal method in company	37.5%	37.8%	37.6%
		% of Total	29.1%	8.5%	37.6%
	3_Senior Tech Specialist	Count	40	11	51
		Expected Count	39.6	11.4	51.0
		% within Translated Classification	78.4%	21.6%	100.0%
		% within Not formal method in company	31.3%	29.7%	30.9%
		% of Total	24.2%	6.7%	30.9%
	4_Junior Systems Engineer	Count	40	12	52
		Expected Count	40.3	11.7	52.0
		% within Translated Classification	76.9%	23.1%	100.0%
		% within Not formal method in company	31.3%	32.4%	31.5%
		% of Total	24.2%	7.3%	31.5%
Total		Count	128	37	165
		Expected Count	128.0	37.0	165.0
		% within Translated Classification	77.6%	22.4%	100.0%
		% within Not formal method in company	100.0%	100.0%	100.0%
		% of Total	77.6%	22.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.035[a]	2	.983
Likelihood Ratio	.035	2	.983
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.44.

8.7.9.4 Crosstabulation Table by Classification for Top Level 2 Measure of "Observation"

Translated Classification * Observation Crosstabulation

			Observation		Total
			0	1	
Translated Classification	2_Senior Systems Engineer	Count	47	15	62
		Expected Count	50.4	11.6	62.0
		% within Translated Classification	75.8%	24.2%	100.0%
		% within Observation	35.1%	48.4%	37.6%
		% of Total	28.5%	9.1%	37.6%
	3_Senior Tech Specialist	Count	41	10	51
		Expected Count	41.4	9.6	51.0
		% within Translated Classification	80.4%	19.6%	100.0%
		% within Observation	30.6%	32.3%	30.9%
		% of Total	24.8%	6.1%	30.9%
	4_Junior Systems Engineer	Count	46	6	52
		Expected Count	42.2	9.8	52.0
		% within Translated Classification	88.5%	11.5%	100.0%
		% within Observation	34.3%	19.4%	31.5%
		% of Total	27.9%	3.6%	31.5%
Total		Count	134	31	165
		Expected Count	134.0	31.0	165.0
		% within Translated Classification	81.2%	18.8%	100.0%
		% within Observation	100.0%	100.0%	100.0%
		% of Total	81.2%	18.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.001[a]	2	.223
Likelihood Ratio	3.150	2	.207
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.58.

8.7.9.5 Crosstabulation Table by Classification for Top Level 2 Measure of "Look for certain characteristics"

Translated Classification * Look for certain characteristics Crosstabulation

			Look for certain characteristics		Total
			0	1	
Translated Classification	2_Senior Systems Engineer	Count	53	9	62
		Expected Count	51.5	10.5	62.0
		% within Translated Classification	85.5%	14.5%	100.0%
		% within Look for certain characteristics	38.7%	32.1%	37.6%
		% of Total	32.1%	5.5%	37.6%
	3_Senior Tech Specialist	Count	39	12	51
		Expected Count	42.3	8.7	51.0
		% within Translated Classification	76.5%	23.5%	100.0%
		% within Look for certain characteristics	28.5%	42.9%	30.9%
		% of Total	23.6%	7.3%	30.9%
	4_Junior Systems Engineer	Count	45	7	52
		Expected Count	43.2	8.8	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Look for certain characteristics	32.8%	25.0%	31.5%
		% of Total	27.3%	4.2%	31.5%
Total		Count	137	28	165
		Expected Count	137.0	28.0	165.0
		% within Translated Classification	83.0%	17.0%	100.0%
		% within Look for certain characteristics	100.0%	100.0%	100.0%
		% of Total	83.0%	17.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.277[a]	2	.320
Likelihood Ratio	2.182	2	.336
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.65.

8.7.9.6 Crosstabulation Table by Classification for Top Level 2 Measure of "Management identifies/evaluates"

Translated Classification * Management identifies/evaluates Crosstabulation

			Management identifies/evaluates		
			0	1	Total
Translated Classification	2_Senior Systems Engineer	Count	53	9	62
		Expected Count	54.1	7.9	62.0
		% within Translated Classification	85.5%	14.5%	100.0%
		% within Management identifies/evaluates	36.8%	42.9%	37.6%
		% of Total	32.1%	5.5%	37.6%
	3_Senior Tech Specialist	Count	42	9	51
		Expected Count	44.5	6.5	51.0
		% within Translated Classification	82.4%	17.6%	100.0%
		% within Management identifies/evaluates	29.2%	42.9%	30.9%
		% of Total	25.5%	5.5%	30.9%
	4_Junior Systems Engineer	Count	49	3	52
		Expected Count	45.4	6.6	52.0
		% within Translated Classification	94.2%	5.8%	100.0%
		% within Management identifies/evaluates	34.0%	14.3%	31.5%
		% of Total	29.7%	1.8%	31.5%
Total		Count	144	21	165
		Expected Count	144.0	21.0	165.0
		% within Translated Classification	87.3%	12.7%	100.0%
		% within Management identifies/evaluates	100.0%	100.0%	100.0%
		% of Total	87.3%	12.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.557[a]	2	.169
Likelihood Ratio	3.951	2	.139
N of Valid Cases	165		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.49.

8.7.10 Crosstabulation Tables by Company for Top Level 2 Coding for Strong Systems Thinking

8.7.10.1 Crosstabulation Table by Company for Top Level 2 Measure of "Do not know"

Crosstab

			Do not know		
			0	1	Total
Company	A	Count	13	1	14
		Expected Count	9.1	4.9	14.0
		% within Company	92.9%	7.1%	100.0%
		% within Do not know	12.1%	1.7%	8.5%
		% of Total	7.9%	.6%	8.5%
	B	Count	10	3	13
		Expected Count	8.4	4.6	13.0
		% within Company	76.9%	23.1%	100.0%
		% within Do not know	9.3%	5.2%	7.9%
		% of Total	6.1%	1.8%	7.9%
	C	Count	12	9	21
		Expected Count	13.6	7.4	21.0
		% within Company	57.1%	42.9%	100.0%
		% within Do not know	11.2%	15.5%	12.7%
		% of Total	7.3%	5.5%	12.7%
	D	Count	7	8	15
		Expected Count	9.7	5.3	15.0
		% within Company	46.7%	53.3%	100.0%
		% within Do not know	6.5%	13.8%	9.1%
		% of Total	4.2%	4.8%	9.1%
	E	Count	10	6	16
		Expected Count	10.4	5.6	16.0
		% within Company	62.5%	37.5%	100.0%
		% within Do not know	9.3%	10.3%	9.7%
		% of Total	6.1%	3.6%	9.7%
	F	Count	15	4	19
		Expected Count	12.3	6.7	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Do not know	14.0%	6.9%	11.5%
		% of Total	9.1%	2.4%	11.5%
	G	Count	8	3	11
		Expected Count	7.1	3.9	11.0
		% within Company	72.7%	27.3%	100.0%
		% within Do not know	7.5%	5.2%	6.7%
		% of Total	4.8%	1.8%	6.7%
	H	Count	10	8	18
		Expected Count	11.7	6.3	18.0
		% within Company	55.6%	44.4%	100.0%
		% within Do not know	9.3%	13.8%	10.9%
		% of Total	6.1%	4.8%	10.9%
	I	Count	7	7	14
		Expected Count	9.1	4.9	14.0
		% within Company	50.0%	50.0%	100.0%
		% within Do not know	6.5%	12.1%	8.5%
		% of Total	4.2%	4.2%	8.5%
	J	Count	15	9	24
		Expected Count	15.6	8.4	24.0
		% within Company	62.5%	37.5%	100.0%
		% within Do not know	14.0%	15.5%	14.5%
		% of Total	9.1%	5.5%	14.5%
Total		Count	107	58	165
		Expected Count	107.0	58.0	165.0
		% within Company	64.8%	35.2%	100.0%
		% within Do not know	100.0%	100.0%	100.0%
		% of Total	64.8%	35.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.461[a]	9	.189
Likelihood Ratio	13.794	9	.130
N of Valid Cases	165		

a. 4 cells (20.0%) have expected count less than 5. The minimum expected count is 3.87.

8.7.10.2 Crosstabulation Table by Company for Top Level 2 Measure of "Experience/demonstrate ability"

Crosstab

			Experience/demonstrate ability 0	Experience/demonstrate ability 1	Total
Company	A	Count	10	4	14
		Expected Count	10.7	3.3	14.0
		% within Company	71.4%	28.6%	100.0%
		% within Experience/demonstrate ability	7.9%	10.3%	8.5%
		% of Total	6.1%	2.4%	8.5%
	B	Count	7	6	13
		Expected Count	9.9	3.1	13.0
		% within Company	53.8%	46.2%	100.0%
		% within Experience/demonstrate ability	5.6%	15.4%	7.9%
		% of Total	4.2%	3.6%	7.9%
	C	Count	15	6	21
		Expected Count	16.0	5.0	21.0
		% within Company	71.4%	28.6%	100.0%
		% within Experience/demonstrate ability	11.9%	15.4%	12.7%
		% of Total	9.1%	3.6%	12.7%
	D	Count	12	3	15
		Expected Count	11.5	3.5	15.0
		% within Company	80.0%	20.0%	100.0%
		% within Experience/demonstrate ability	9.5%	7.7%	9.1%
		% of Total	7.3%	1.8%	9.1%
	E	Count	15	1	16
		Expected Count	12.2	3.8	16.0
		% within Company	93.8%	6.3%	100.0%
		% within Experience/demonstrate ability	11.9%	2.6%	9.7%
		% of Total	9.1%	.6%	9.7%
	F	Count	13	6	19
		Expected Count	14.5	4.5	19.0
		% within Company	68.4%	31.6%	100.0%
		% within Experience/demonstrate ability	10.3%	15.4%	11.5%
		% of Total	7.9%	3.6%	11.5%
	G	Count	9	2	11
		Expected Count	8.4	2.6	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Experience/demonstrate ability	7.1%	5.1%	6.7%
		% of Total	5.5%	1.2%	6.7%
	H	Count	12	6	18
		Expected Count	13.7	4.3	18.0
		% within Company	66.7%	33.3%	100.0%
		% within Experience/demonstrate ability	9.5%	15.4%	10.9%
		% of Total	7.3%	3.6%	10.9%
	I	Count	12	2	14
		Expected Count	10.7	3.3	14.0
		% within Company	85.7%	14.3%	100.0%
		% within Experience/demonstrate ability	9.5%	5.1%	8.5%
		% of Total	7.3%	1.2%	8.5%
	J	Count	21	3	24
		Expected Count	18.3	5.7	24.0
		% within Company	87.5%	12.5%	100.0%
		% within Experience/demonstrate ability	16.7%	7.7%	14.5%
		% of Total	12.7%	1.8%	14.5%
Total		Count	126	39	165
		Expected Count	126.0	39.0	165.0
		% within Company	76.4%	23.6%	100.0%
		% within Experience/demonstrate ability	100.0%	100.0%	100.0%
		% of Total	76.4%	23.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.024[a]	9	.274
Likelihood Ratio	11.531	9	.241
N of Valid Cases	165		

a. 9 cells (45.0%) have expected count less than 5. The minimum expected count is 2.60.

8.7.10.3 Crosstabulation Table by Company for Top Level 2 Measure of "Not formal method in company"

Crosstab

			Not formal method in company		
			0	1	Total
Company	A	Count	11	3	14
		Expected Count	10.9	3.1	14.0
		% within Company	78.6%	21.4%	100.0%
		% within Not formal method in company	8.6%	8.1%	8.5%
		% of Total	6.7%	1.8%	8.5%
	B	Count	10	3	13
		Expected Count	10.1	2.9	13.0
		% within Company	76.9%	23.1%	100.0%
		% within Not formal method in company	7.8%	8.1%	7.9%
		% of Total	6.1%	1.8%	7.9%
	C	Count	15	6	21
		Expected Count	16.3	4.7	21.0
		% within Company	71.4%	28.6%	100.0%
		% within Not formal method in company	11.7%	16.2%	12.7%
		% of Total	9.1%	3.6%	12.7%
	D	Count	10	5	15
		Expected Count	11.6	3.4	15.0
		% within Company	66.7%	33.3%	100.0%
		% within Not formal method in company	7.8%	13.5%	9.1%
		% of Total	6.1%	3.0%	9.1%
	E	Count	14	2	16
		Expected Count	12.4	3.6	16.0
		% within Company	87.5%	12.5%	100.0%
		% within Not formal method in company	10.9%	5.4%	9.7%
		% of Total	8.5%	1.2%	9.7%
	F	Count	15	4	19
		Expected Count	14.7	4.3	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Not formal method in company	11.7%	10.8%	11.5%
		% of Total	9.1%	2.4%	11.5%
	G	Count	9	2	11
		Expected Count	8.5	2.5	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Not formal method in company	7.0%	5.4%	6.7%
		% of Total	5.5%	1.2%	6.7%
	H	Count	16	2	18
		Expected Count	14.0	4.0	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Not formal method in company	12.5%	5.4%	10.9%
		% of Total	9.7%	1.2%	10.9%
	I	Count	11	3	14
		Expected Count	10.9	3.1	14.0
		% within Company	78.6%	21.4%	100.0%
		% within Not formal method in company	8.6%	8.1%	8.5%
		% of Total	6.7%	1.8%	8.5%
	J	Count	17	7	24
		Expected Count	18.6	5.4	24.0
		% within Company	70.8%	29.2%	100.0%
		% within Not formal method in company	13.3%	18.9%	14.5%
		% of Total	10.3%	4.2%	14.5%
Total		Count	128	37	165
		Expected Count	128.0	37.0	165.0
		% within Company	77.6%	22.4%	100.0%
		% within Not formal method in company	100.0%	100.0%	100.0%
		% of Total	77.6%	22.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.493[a]	9	.876
Likelihood Ratio	4.693	9	.860
N of Valid Cases	165		

a. 9 cells (45.0%) have expected count less than 5. The minimum expected count is 2.47.

8.7.10.4 Crosstabulation Table by Company for Top Level 2 Measure of "Observation"

Crosstab

			Observation		
			0	1	Total
Company	A	Count	9	5	14
		Expected Count	11.4	2.6	14.0
		% within Company	64.3%	35.7%	100.0%
		% within Observation	6.7%	16.1%	8.5%
		% of Total	5.5%	3.0%	8.5%
	B	Count	12	1	13
		Expected Count	10.6	2.4	13.0
		% within Company	92.3%	7.7%	100.0%
		% within Observation	9.0%	3.2%	7.9%
		% of Total	7.3%	.6%	7.9%
	C	Count	19	2	21
		Expected Count	17.1	3.9	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Observation	14.2%	6.5%	12.7%
		% of Total	11.5%	1.2%	12.7%
	D	Count	14	1	15
		Expected Count	12.2	2.8	15.0
		% within Company	93.3%	6.7%	100.0%
		% within Observation	10.4%	3.2%	9.1%
		% of Total	8.5%	.6%	9.1%
	E	Count	13	3	16
		Expected Count	13.0	3.0	16.0
		% within Company	81.3%	18.8%	100.0%
		% within Observation	9.7%	9.7%	9.7%
		% of Total	7.9%	1.8%	9.7%
	F	Count	14	5	19
		Expected Count	15.4	3.6	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Observation	10.4%	16.1%	11.5%
		% of Total	8.5%	3.0%	11.5%
	G	Count	8	3	11
		Expected Count	8.9	2.1	11.0
		% within Company	72.7%	27.3%	100.0%
		% within Observation	6.0%	9.7%	6.7%
		% of Total	4.8%	1.8%	6.7%
	H	Count	14	4	18
		Expected Count	14.6	3.4	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Observation	10.4%	12.9%	10.9%
		% of Total	8.5%	2.4%	10.9%
	I	Count	10	4	14
		Expected Count	11.4	2.6	14.0
		% within Company	71.4%	28.6%	100.0%
		% within Observation	7.5%	12.9%	8.5%
		% of Total	6.1%	2.4%	8.5%
	J	Count	21	3	24
		Expected Count	19.5	4.5	24.0
		% within Company	87.5%	12.5%	100.0%
		% within Observation	15.7%	9.7%	14.5%
		% of Total	12.7%	1.8%	14.5%
Total		Count	134	31	165
		Expected Count	134.0	31.0	165.0
		% within Company	81.2%	18.8%	100.0%
		% within Observation	100.0%	100.0%	100.0%
		% of Total	81.2%	18.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.167[a]	9	.422
Likelihood Ratio	9.437	9	.398
N of Valid Cases	165		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 2.07.

8.7.10.5 Crosstabulation Table by Company for Top Level 2 Measure of "Look for certain characteristics"

Crosstab

			Look for certain characteristics		Total
			0	1	
Company	A	Count	11	3	14
		Expected Count	11.6	2.4	14.0
		% within Company	78.6%	21.4%	100.0%
		% within Look for certain characteristics	8.0%	10.7%	8.5%
		% of Total	6.7%	1.8%	8.5%
	B	Count	12	1	13
		Expected Count	10.8	2.2	13.0
		% within Company	92.3%	7.7%	100.0%
		% within Look for certain characteristics	8.8%	3.6%	7.9%
		% of Total	7.3%	.6%	7.9%
	C	Count	18	3	21
		Expected Count	17.4	3.6	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Look for certain characteristics	13.1%	10.7%	12.7%
		% of Total	10.9%	1.8%	12.7%
	D	Count	12	3	15
		Expected Count	12.5	2.5	15.0
		% within Company	80.0%	20.0%	100.0%
		% within Look for certain characteristics	8.8%	10.7%	9.1%
		% of Total	7.3%	1.8%	9.1%
	E	Count	13	3	16
		Expected Count	13.3	2.7	16.0
		% within Company	81.3%	18.8%	100.0%
		% within Look for certain characteristics	9.5%	10.7%	9.7%
		% of Total	7.9%	1.8%	9.7%
	F	Count	16	3	19
		Expected Count	15.8	3.2	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Look for certain characteristics	11.7%	10.7%	11.5%
		% of Total	9.7%	1.8%	11.5%
	G	Count	9	2	11
		Expected Count	9.1	1.9	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Look for certain characteristics	6.6%	7.1%	6.7%
		% of Total	5.5%	1.2%	6.7%
	H	Count	14	4	18
		Expected Count	14.9	3.1	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Look for certain characteristics	10.2%	14.3%	10.9%
		% of Total	8.5%	2.4%	10.9%
	I	Count	11	3	14
		Expected Count	11.6	2.4	14.0
		% within Company	78.6%	21.4%	100.0%
		% within Look for certain characteristics	8.0%	10.7%	8.5%
		% of Total	6.7%	1.8%	8.5%
	J	Count	21	3	24
		Expected Count	19.9	4.1	24.0
		% within Company	87.5%	12.5%	100.0%
		% within Look for certain characteristics	15.3%	10.7%	14.5%
		% of Total	12.7%	1.8%	14.5%
Total		Count	137	28	165
		Expected Count	137.0	28.0	165.0
		% within Company	83.0%	17.0%	100.0%
		% within Look for certain characteristics	100.0%	100.0%	100.0%
		% of Total	83.0%	17.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.153[a]	9	.989
Likelihood Ratio	2.297	9	.986
N of Valid Cases	165		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.87.

8.7.10.6 *Crosstabulation Table by Company for Top Level 2 Measure of "Management identifies/evaluates"*

Crosstab

			Management identifies/evaluates 0	Management identifies/evaluates 1	Total
Company	A	Count	13	1	14
		Expected Count	12.2	1.8	14.0
		% within Company	92.9%	7.1%	100.0%
		% within Management identifies/evaluates	9.0%	4.8%	8.5%
		% of Total	7.9%	.6%	8.5%
	B	Count	12	1	13
		Expected Count	11.3	1.7	13.0
		% within Company	92.3%	7.7%	100.0%
		% within Management identifies/evaluates	8.3%	4.8%	7.9%
		% of Total	7.3%	.6%	7.9%
	C	Count	19	2	21
		Expected Count	18.3	2.7	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Management identifies/evaluates	13.2%	9.5%	12.7%
		% of Total	11.5%	1.2%	12.7%
	D	Count	12	3	15
		Expected Count	13.1	1.9	15.0
		% within Company	80.0%	20.0%	100.0%
		% within Management identifies/evaluates	8.3%	14.3%	9.1%
		% of Total	7.3%	1.8%	9.1%
	E	Count	11	5	16
		Expected Count	14.0	2.0	16.0
		% within Company	68.8%	31.3%	100.0%
		% within Management identifies/evaluates	7.6%	23.8%	9.7%
		% of Total	6.7%	3.0%	9.7%
	F	Count	15	4	19
		Expected Count	16.6	2.4	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Management identifies/evaluates	10.4%	19.0%	11.5%
		% of Total	9.1%	2.4%	11.5%
	G	Count	11	0	11
		Expected Count	9.6	1.4	11.0
		% within Company	100.0%	.0%	100.0%
		% within Management identifies/evaluates	7.6%	.0%	6.7%
		% of Total	6.7%	.0%	6.7%
	H	Count	17	1	18
		Expected Count	15.7	2.3	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Management identifies/evaluates	11.8%	4.8%	10.9%
		% of Total	10.3%	.6%	10.9%
	I	Count	12	2	14
		Expected Count	12.2	1.8	14.0
		% within Company	85.7%	14.3%	100.0%
		% within Management identifies/evaluates	8.3%	9.5%	8.5%
		% of Total	7.3%	1.2%	8.5%
	J	Count	22	2	24
		Expected Count	20.9	3.1	24.0
		% within Company	91.7%	8.3%	100.0%
		% within Management identifies/evaluates	15.3%	9.5%	14.5%
		% of Total	13.3%	1.2%	14.5%
Total		Count	144	21	165
		Expected Count	144.0	21.0	165.0
		% within Company	87.3%	12.7%	100.0%
		% within Management identifies/evaluates	100.0%	100.0%	100.0%
		% of Total	87.3%	12.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.611[a]	9	.303
Likelihood Ratio	10.902	9	.282
N of Valid Cases	165		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.40.

8.8 Key Steps to the Development of Systems Thinking

8.8.1 Coding for Key Steps to the Development of Systems Thinking

Key Steps in Life to Develop Systems Thinking	Total
Life experiences outside work	
- Family	25
- Farm	5
- Early life experiences	23
- Cross cultures	2
- House	1
- Life	1
- Fraternity	1
- Exposure outside work	1
- Diversity, variety in personal life	9
- Therapy	1
- Religion	3
- Hobbies	21
Individual characteristics	
- Analytical	2
- Problem solving	3
- Self-confidence	3
- Personal desires	2
- Natural/innate	14
- Frustration came to a head	1
- Personal mastery/realizations	5
- Leadership	1
- Organizational skills	2
- Attitude	2
- Creative	3
- Overall awareness	1
- Inquisitive/asks why	5
- Thinking	11
- Interest in teaching	1
- Socially conscious/right thing to do	2
- Motivated/enthusiastic	5
- Bored easily/hate to be bored	5
- Personality in general	1
- Courage/not afraid to take risks	2
- Overcame introversion	1

- Overcame shyness	1
- Alpha male	1
- Easy going/flexible	1
- Curiosity/wants more understanding	15
- Personality to have task and break it down	1
- Analyze and think out-of-box	1
- Logical thinking	2
- Interest in learning	4
- Interest in reading	2
- Mindset	5
Interpersonal	
- Network	2
- Great people to work with	2
- Teams	10
- Communication	4
- Encouraged by others	2
- Mimic those you respect	1
- Utilize knowledge of others	1
- Gain confidence of others	1
- Ensure users heard	1
- Talk to system architects	1
- Not mentoring	1
- Mentoring	16
- Working with others	4
SE field	2
Luck	2
Not training	1
Professional society/conferences	4
Physical move	1
Internet	1
Training	16
Learning from mistakes	3
Education	
- Specific book/reading	4
- Sign engineering oath	1
- Teaching	3
- Case studies	2
- Graduate work	11
- Education in general	10
- Broad education	4
- Specific program	6
-- College in general	8

- Cross cultural	1
- Theory based school	1
- Specific teacher	3
- Military	3
- Physics	3
- Ethics class	1
- Non-conventional 7-12	1
- Systems courses/degree	13
- Engineering training in general	4
- Controls engineering	1
- Project work/open-ended problems	5
- Mechatronics	1
- Learned the importance of teamwork	1
- Interdisciplinary	2
- Education directly related to work	1
- Gaining knowledge in general	1
- Liberal arts/humanities	3
- Business classes	4
- Problem with engineering education	1
- Modeling and simulation	2
- Labs	1
- Mathematics	3
- Informatics	1
- Stochastic processes	1
- Early education in abstractions	1
- Class on philosophy of design	1
- Classes on creativity and thinking	1
- Aviation college	1
- Balanced education	1
- Utility theory	1
- Mechanical engineering	1
- Psychology and human factors training	1
- Studying organizational studies	1
- Anthropological training	1
- Computer science	3
- K-12	1
- Life sciences	1
Work Experiences	
- Not much negative criticism	1
- Systems jobs/experiences	29
- Particular organization/company	18
- General experience	16

- Managers and structure	5
- Pretend I own the company	1
- Mechanical drafting	1
- Allowed to go out-of-the-box	1
- Leadership/responsibility	11
- Planning and program issues	2
- Work on diverse things	41
- Specific project	12
- Driven	5
- Process/quality work	7
- Software/programming	2
- Complicated situations	2
- Working in the U.S.	1
- Co-op at future employer	1
- Work environments	1
- Hands-on learning	1
- Hard analysis	1
- Probability analysis	1
- Successful work experience	1
- Work with people	1
- Do things you like	1
- Developed skill for doing many things at - once	1
- Flight experience	1
- Flight instructor	1
- Field service/maintenance	4
- Not able to get into details	1
- Test	3
- Opportunity to learn about system	1
- Work at research institute	1
- International collaboration	1
- Working in networking	1
- Focus group moderator	1
- Advanced design	1
- Proposal work	1
- Military	13

8.8.2 Level 1 Coding for Key Steps to the Development of Systems Thinking

Level 1 Key Steps in Life to Develop Systems Thinking	Total
Life experiences outside work	72
Individual characteristics	64
Interpersonal	37
SE field	2
Luck	2
Not training	1
Professional society/conferences	4
Physical move	1
Internet	1
Training	16
Learning from mistakes	3
Education	80
Work Experiences	139

8.8.3 Top Level 1 Key Steps to the Development of Systems Thinking

Top Level 1 Key Steps to the Development of Systems Thinking for All Participants (N=202)

Rank	Node Category	Number	Percent
1	Work Experiences	139	69%
2	Education	80	40%
3	Life experiences outside work	72	36%
4	Individual characteristics	64	32%
5	Interpersonal	37	18%

Top Level 1 Key Steps to the Development of Systems Thinking for Expert Panelists (N=37)

Rank	Node Category	Number	Percent
1	Work Experiences	35	95%
2	Individual characteristics	16	43%
3	Education	13	35%
4	Life experiences outside work	5	14%
4	Interpersonal	5	14%
6	Training	4	11%

Top Level 1 Key Steps to the Development of Systems Thinking for Senior Systems Engineers (N=61)

Rank	Node Category	Number	Percent
1	Work Experiences	36	59%
2	Life experiences outside work	27	44%
3	Education	22	36%
4	Individual characteristics	16	26%
5	Interpersonal	13	21%
6	Training	7	11%

Top Level 1 Key Steps to the Development of Systems Thinking for Senior Technical Specialists (N=52)

Rank	Node Category	Number	Percent
1	Work Experiences	38	73%
2	Life experiences outside work	19	37%
3	Education	17	33%
4	Individual characteristics	11	21%
4	Interpersonal	11	21%

Top Level 1 Key Steps to the Development of Systems Thinking for Junior Systems Engineers (N=52)

Rank	Node Category	Number	Percent
1	Work Experiences	30	58%
2	Education	28	54%
3	Life experiences outside work	21	40%
3	Individual characteristics	21	40%
5	Interpersonal	8	15%

8.8.4 Summary of Top Level 1 Key Steps to the Development of Systems Thinking for All Classifications

Top Level 1 Key Steps to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=202)			Expert Panelists (N=37)			Senior Systems Engineers (N=61)			Senior Technical Specialists (N=52)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Work Experiences	1	139	69%	1	35	95%	1	36	59%	1	38	73%	1	30	58%	17.625	0.001
Education	2	80	40%	3	13	35%	3	22	36%	3	17	33%	2	28	54%	6.076	0.108
Individual characteristics	4	64	32%	2	16	43%	4	16	26%	4	11	21%	3	21	40%	7.605	0.055
Life experiences outside work	3	72	36%	4	5	14%	2	27	44%	2	19	37%	3	21	40%	10.402	0.015
Interpersonal	5	37	18%	4	5	14%	5	13	21%	4	11	21%	5	8	15%	1.515	0.679
Training	6	16	8%	6	4	11%	6	7	11%	6	2	4%	6	3	6%	2.994	0.393

8.8.5 Crosstabulation Tables by Classification for Top Level 1 Key Steps to the Development of Systems Thinking

8.8.5.1 Crosstabulation Table by Classification for Top Level 1 Key Step "Work experiences"

Translated Classification * Work Experiences Crosstabulation

			Work Experiences		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	2	35	37
		Expected Count	11.5	25.5	37.0
		% within Translated Classification	5.4%	94.6%	100.0%
		% within Work Experiences	3.2%	25.2%	18.3%
		% of Total	1.0%	17.3%	18.3%
	2_Senior Systems Engineer	Count	25	36	61
		Expected Count	19.0	42.0	61.0
		% within Translated Classification	41.0%	59.0%	100.0%
		% within Work Experiences	39.7%	25.9%	30.2%
		% of Total	12.4%	17.8%	30.2%
	3_Senior Tech Specialist	Count	14	38	52
		Expected Count	16.2	35.8	52.0
		% within Translated Classification	26.9%	73.1%	100.0%
		% within Work Experiences	22.2%	27.3%	25.7%
		% of Total	6.9%	18.8%	25.7%
	4_Junior Systems Engineer	Count	22	30	52
		Expected Count	16.2	35.8	52.0
		% within Translated Classification	42.3%	57.7%	100.0%
		% within Work Experiences	34.9%	21.6%	25.7%
		% of Total	10.9%	14.9%	25.7%
Total		Count	63	139	202
		Expected Count	63.0	139.0	202.0
		% within Translated Classification	31.2%	68.8%	100.0%
		% within Work Experiences	100.0%	100.0%	100.0%
		% of Total	31.2%	68.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.625[a]	3	.001
Likelihood Ratio	21.160	3	.000
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.54.

8.8.5.2 Crosstabulation Table by Classification for Top Level 1 Key Step "Education"

Translated Classification * Education Crosstabulation

			Education		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	24	13	37
		Expected Count	22.3	14.7	37.0
		% within Translated Classification	64.9%	35.1%	100.0%
		% within Education	19.7%	16.3%	18.3%
		% of Total	11.9%	6.4%	18.3%
	2_Senior Systems Engineer	Count	39	22	61
		Expected Count	36.8	24.2	61.0
		% within Translated Classification	63.9%	36.1%	100.0%
		% within Education	32.0%	27.5%	30.2%
		% of Total	19.3%	10.9%	30.2%
	3_Senior Tech Specialist	Count	35	17	52
		Expected Count	31.4	20.6	52.0
		% within Translated Classification	67.3%	32.7%	100.0%
		% within Education	28.7%	21.3%	25.7%
		% of Total	17.3%	8.4%	25.7%
	4_Junior Systems Engineer	Count	24	28	52
		Expected Count	31.4	20.6	52.0
		% within Translated Classification	46.2%	53.8%	100.0%
		% within Education	19.7%	35.0%	25.7%
		% of Total	11.9%	13.9%	25.7%
Total		Count	122	80	202
		Expected Count	122.0	80.0	202.0
		% within Translated Classification	60.4%	39.6%	100.0%
		% within Education	100.0%	100.0%	100.0%
		% of Total	60.4%	39.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.076[a]	3	.108
Likelihood Ratio	5.994	3	.112
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.65.

8.8.5.3 *Crosstabulation Table by Classification for Top Level 1 Key Step "Individual characteristics"*

Translated Classification * Individual characteristics Crosstabulation

			Individual characteristics		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	21	16	37
		Expected Count	25.3	11.7	37.0
		% within Translated Classification	56.8%	43.2%	100.0%
		% within Individual characteristics	15.2%	25.0%	18.3%
		% of Total	10.4%	7.9%	18.3%
	2_Senior Systems Engineer	Count	45	16	61
		Expected Count	41.7	19.3	61.0
		% within Translated Classification	73.8%	26.2%	100.0%
		% within Individual characteristics	32.6%	25.0%	30.2%
		% of Total	22.3%	7.9%	30.2%
	3_Senior Tech Specialist	Count	41	11	52
		Expected Count	35.5	16.5	52.0
		% within Translated Classification	78.8%	21.2%	100.0%
		% within Individual characteristics	29.7%	17.2%	25.7%
		% of Total	20.3%	5.4%	25.7%
	4_Junior Systems Engineer	Count	31	21	52
		Expected Count	35.5	16.5	52.0
		% within Translated Classification	59.6%	40.4%	100.0%
		% within Individual characteristics	22.5%	32.8%	25.7%
		% of Total	15.3%	10.4%	25.7%
Total		Count	138	64	202
		Expected Count	138.0	64.0	202.0
		% within Translated Classification	68.3%	31.7%	100.0%
		% within Individual characteristics	100.0%	100.0%	100.0%
		% of Total	68.3%	31.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.605[a]	3	.055
Likelihood Ratio	7.647	3	.054
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.72.

8.8.5.4 *Crosstabulation Table by Classification for Top Level 1 Key Step "Life experiences outside work"*

Translated Classification * Life experiences outside work Crosstabulation

			Life experiences outside work		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	5	37
		Expected Count	23.8	13.2	37.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Life experiences outside work	24.6%	6.9%	18.3%
		% of Total	15.8%	2.5%	18.3%
	2_Senior Systems Engineer	Count	34	27	61
		Expected Count	39.3	21.7	61.0
		% within Translated Classification	55.7%	44.3%	100.0%
		% within Life experiences outside work	26.2%	37.5%	30.2%
		% of Total	16.8%	13.4%	30.2%
	3_Senior Tech Specialist	Count	33	19	52
		Expected Count	33.5	18.5	52.0
		% within Translated Classification	63.5%	36.5%	100.0%
		% within Life experiences outside work	25.4%	26.4%	25.7%
		% of Total	16.3%	9.4%	25.7%
	4_Junior Systems Engineer	Count	31	21	52
		Expected Count	33.5	18.5	52.0
		% within Translated Classification	59.6%	40.4%	100.0%
		% within Life experiences outside work	23.8%	29.2%	25.7%
		% of Total	15.3%	10.4%	25.7%
Total		Count	130	72	202
		Expected Count	130.0	72.0	202.0
		% within Translated Classification	64.4%	35.6%	100.0%
		% within Life experiences outside work	100.0%	100.0%	100.0%
		% of Total	64.4%	35.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.402[a]	3	.015
Likelihood Ratio	11.653	3	.009
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.19.

8.8.5.5 *Crosstabulation Table by Classification for Top Level 1 Key Step "Interpersonal"*

Translated Classification * Interpersonal Crosstabulation

			Interpersonal		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	5	37
		Expected Count	30.2	6.8	37.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Interpersonal	19.4%	13.5%	18.3%
		% of Total	15.8%	2.5%	18.3%
	2_Senior Systems Engineer	Count	48	13	61
		Expected Count	49.8	11.2	61.0
		% within Translated Classification	78.7%	21.3%	100.0%
		% within Interpersonal	29.1%	35.1%	30.2%
		% of Total	23.8%	6.4%	30.2%
	3_Senior Tech Specialist	Count	41	11	52
		Expected Count	42.5	9.5	52.0
		% within Translated Classification	78.8%	21.2%	100.0%
		% within Interpersonal	24.8%	29.7%	25.7%
		% of Total	20.3%	5.4%	25.7%
	4_Junior Systems Engineer	Count	44	8	52
		Expected Count	42.5	9.5	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Interpersonal	26.7%	21.6%	25.7%
		% of Total	21.8%	4.0%	25.7%
Total		Count	165	37	202
		Expected Count	165.0	37.0	202.0
		% within Translated Classification	81.7%	18.3%	100.0%
		% within Interpersonal	100.0%	100.0%	100.0%
		% of Total	81.7%	18.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.515[a]	3	.679
Likelihood Ratio	1.549	3	.671
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.78.

8.8.6 Crosstabulation Tables by Company for Top Level 1 Key Steps to the Development of Systems Thinking

8.8.6.1 Crosstabulation Table by Company for Top Level 1 Key Step "Work experiences"

Crosstab

			Work Experiences 0	Work Experiences 1	Total
Company	A	Count	5	13	18
		Expected Count	5.6	12.4	18.0
		% within Company	27.8%	72.2%	100.0%
		% within Work Experiences	7.9%	9.4%	8.9%
		% of Total	2.5%	6.4%	8.9%
	B	Count	6	12	18
		Expected Count	5.6	12.4	18.0
		% within Company	33.3%	66.7%	100.0%
		% within Work Experiences	9.5%	8.6%	8.9%
		% of Total	3.0%	5.9%	8.9%
	C	Count	5	19	24
		Expected Count	7.5	16.5	24.0
		% within Company	20.8%	79.2%	100.0%
		% within Work Experiences	7.9%	13.7%	11.9%
		% of Total	2.5%	9.4%	11.9%
	D	Count	9	12	21
		Expected Count	6.5	14.5	21.0
		% within Company	42.9%	57.1%	100.0%
		% within Work Experiences	14.3%	8.6%	10.4%
		% of Total	4.5%	5.9%	10.4%
	E	Count	5	15	20
		Expected Count	6.2	13.8	20.0
		% within Company	25.0%	75.0%	100.0%
		% within Work Experiences	7.9%	10.8%	9.9%
		% of Total	2.5%	7.4%	9.9%
	F	Count	11	12	23
		Expected Count	7.2	15.8	23.0
		% within Company	47.8%	52.2%	100.0%
		% within Work Experiences	17.5%	8.6%	11.4%
		% of Total	5.4%	5.9%	11.4%
	G	Count	0	11	11
		Expected Count	3.4	7.6	11.0
		% within Company	.0%	100.0%	100.0%
		% within Work Experiences	.0%	7.9%	5.4%
		% of Total	.0%	5.4%	5.4%
	H	Count	7	14	21
		Expected Count	6.5	14.5	21.0
		% within Company	33.3%	66.7%	100.0%
		% within Work Experiences	11.1%	10.1%	10.4%
		% of Total	3.5%	6.9%	10.4%
	I	Count	6	12	18
		Expected Count	5.6	12.4	18.0
		% within Company	33.3%	66.7%	100.0%
		% within Work Experiences	9.5%	8.6%	8.9%
		% of Total	3.0%	5.9%	8.9%
	J	Count	9	19	28
		Expected Count	8.7	19.3	28.0
		% within Company	32.1%	67.9%	100.0%
		% within Work Experiences	14.3%	13.7%	13.9%
		% of Total	4.5%	9.4%	13.9%
Total		Count	63	139	202
		Expected Count	63.0	139.0	202.0
		% within Company	31.2%	68.8%	100.0%
		% within Work Experiences	100.0%	100.0%	100.0%
		% of Total	31.2%	68.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.072[a]	9	.271
Likelihood Ratio	14.143	9	.117
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 3.43.

8.8.6.2 Crosstabulation Table by Company for Top Level 1 Key Step "Education"

Crosstab

			Education		
			0	1	Total
Company	A	Count	13	5	18
		Expected Count	10.9	7.1	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Education	10.7%	6.3%	8.9%
		% of Total	6.4%	2.5%	8.9%
	B	Count	11	7	18
		Expected Count	10.9	7.1	18.0
		% within Company	61.1%	38.9%	100.0%
		% within Education	9.0%	8.8%	8.9%
		% of Total	5.4%	3.5%	8.9%
	C	Count	13	11	24
		Expected Count	14.5	9.5	24.0
		% within Company	54.2%	45.8%	100.0%
		% within Education	10.7%	13.8%	11.9%
		% of Total	6.4%	5.4%	11.9%
	D	Count	11	10	21
		Expected Count	12.7	8.3	21.0
		% within Company	52.4%	47.6%	100.0%
		% within Education	9.0%	12.5%	10.4%
		% of Total	5.4%	5.0%	10.4%
	E	Count	11	9	20
		Expected Count	12.1	7.9	20.0
		% within Company	55.0%	45.0%	100.0%
		% within Education	9.0%	11.3%	9.9%
		% of Total	5.4%	4.5%	9.9%
	F	Count	13	10	23
		Expected Count	13.9	9.1	23.0
		% within Company	56.5%	43.5%	100.0%
		% within Education	10.7%	12.5%	11.4%
		% of Total	6.4%	5.0%	11.4%
	G	Count	6	5	11
		Expected Count	6.6	4.4	11.0
		% within Company	54.5%	45.5%	100.0%
		% within Education	4.9%	6.3%	5.4%
		% of Total	3.0%	2.5%	5.4%
	H	Count	13	8	21
		Expected Count	12.7	8.3	21.0
		% within Company	61.9%	38.1%	100.0%
		% within Education	10.7%	10.0%	10.4%
		% of Total	6.4%	4.0%	10.4%
	I	Count	13	5	18
		Expected Count	10.9	7.1	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Education	10.7%	6.3%	8.9%
		% of Total	6.4%	2.5%	8.9%
	J	Count	18	10	28
		Expected Count	16.9	11.1	28.0
		% within Company	64.3%	35.7%	100.0%
		% within Education	14.8%	12.5%	13.9%
		% of Total	8.9%	5.0%	13.9%
Total		Count	122	80	202
		Expected Count	122.0	80.0	202.0
		% within Company	60.4%	39.6%	100.0%
		% within Education	100.0%	100.0%	100.0%
		% of Total	60.4%	39.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.804[a]	9	.924
Likelihood Ratio	3.884	9	.919
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.36.

8.8.6.3 *Crosstabulation Table by Company for Top Level 1 Key Step "Individual characteristics"*

Crosstab

			Individual characteristics		
			0	1	Total
Company	A	Count	8	10	18
		Expected Count	12.3	5.7	18.0
		% within Company	44.4%	55.6%	100.0%
		% within Individual characteristics	5.8%	15.6%	8.9%
		% of Total	4.0%	5.0%	8.9%
	B	Count	9	9	18
		Expected Count	12.3	5.7	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Individual characteristics	6.5%	14.1%	8.9%
		% of Total	4.5%	4.5%	8.9%
	C	Count	19	5	24
		Expected Count	16.4	7.6	24.0
		% within Company	79.2%	20.8%	100.0%
		% within Individual characteristics	13.8%	7.8%	11.9%
		% of Total	9.4%	2.5%	11.9%
	D	Count	14	7	21
		Expected Count	14.3	6.7	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Individual characteristics	10.1%	10.9%	10.4%
		% of Total	6.9%	3.5%	10.4%
	E	Count	16	4	20
		Expected Count	13.7	6.3	20.0
		% within Company	80.0%	20.0%	100.0%
		% within Individual characteristics	11.6%	6.3%	9.9%
		% of Total	7.9%	2.0%	9.9%
	F	Count	14	9	23
		Expected Count	15.7	7.3	23.0
		% within Company	60.9%	39.1%	100.0%
		% within Individual characteristics	10.1%	14.1%	11.4%
		% of Total	6.9%	4.5%	11.4%
	G	Count	10	1	11
		Expected Count	7.5	3.5	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Individual characteristics	7.2%	1.6%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	13	8	21
		Expected Count	14.3	6.7	21.0
		% within Company	61.9%	38.1%	100.0%
		% within Individual characteristics	9.4%	12.5%	10.4%
		% of Total	6.4%	4.0%	10.4%
	I	Count	13	5	18
		Expected Count	12.3	5.7	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Individual characteristics	9.4%	7.8%	8.9%
		% of Total	6.4%	2.5%	8.9%
	J	Count	22	6	28
		Expected Count	19.1	8.9	28.0
		% within Company	78.6%	21.4%	100.0%
		% within Individual characteristics	15.9%	9.4%	13.9%
		% of Total	10.9%	3.0%	13.9%
Total		Count	138	64	202
		Expected Count	138.0	64.0	202.0
		% within Company	68.3%	31.7%	100.0%
		% within Individual characteristics	100.0%	100.0%	100.0%
		% of Total	68.3%	31.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.192[a]	9	.086
Likelihood Ratio	15.516	9	.078
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 3.49.

8.8.6.4 Crosstabulation Table by Company for Top Level 1 Key Step "Life experiences outside work"

Crosstab

			Life experiences outside work		
			0	1	Total
Company	A	Count	9	9	18
		Expected Count	11.6	6.4	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Life experiences outside work	6.9%	12.5%	8.9%
		% of Total	4.5%	4.5%	8.9%
	B	Count	13	5	18
		Expected Count	11.6	6.4	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Life experiences outside work	10.0%	6.9%	8.9%
		% of Total	6.4%	2.5%	8.9%
	C	Count	15	9	24
		Expected Count	15.4	8.6	24.0
		% within Company	62.5%	37.5%	100.0%
		% within Life experiences outside work	11.5%	12.5%	11.9%
		% of Total	7.4%	4.5%	11.9%
	D	Count	14	7	21
		Expected Count	13.5	7.5	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Life experiences outside work	10.8%	9.7%	10.4%
		% of Total	6.9%	3.5%	10.4%
	E	Count	15	5	20
		Expected Count	12.9	7.1	20.0
		% within Company	75.0%	25.0%	100.0%
		% within Life experiences outside work	11.5%	6.9%	9.9%
		% of Total	7.4%	2.5%	9.9%
	F	Count	11	12	23
		Expected Count	14.8	8.2	23.0
		% within Company	47.8%	52.2%	100.0%
		% within Life experiences outside work	8.5%	16.7%	11.4%
		% of Total	5.4%	5.9%	11.4%
	G	Count	8	3	11
		Expected Count	7.1	3.9	11.0
		% within Company	72.7%	27.3%	100.0%
		% within Life experiences outside work	6.2%	4.2%	5.4%
		% of Total	4.0%	1.5%	5.4%
	H	Count	15	6	21
		Expected Count	13.5	7.5	21.0
		% within Company	71.4%	28.6%	100.0%
		% within Life experiences outside work	11.5%	8.3%	10.4%
		% of Total	7.4%	3.0%	10.4%
	I	Count	9	9	18
		Expected Count	11.6	6.4	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Life experiences outside work	6.9%	12.5%	8.9%
		% of Total	4.5%	4.5%	8.9%
	J	Count	21	7	28
		Expected Count	18.0	10.0	28.0
		% within Company	75.0%	25.0%	100.0%
		% within Life experiences outside work	16.2%	9.7%	13.9%
		% of Total	10.4%	3.5%	13.9%
Total		Count	130	72	202
		Expected Count	130.0	72.0	202.0
		% within Company	64.4%	35.6%	100.0%
		% within Life experiences outside work	100.0%	100.0%	100.0%
		% of Total	64.4%	35.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.709[a]	9	.375
Likelihood Ratio	9.632	9	.381
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 3.92.

8.8.6.5 *Crosstabulation Table by Company for Top Level 1 Key Step "Interpersonal"*

Crosstab

			Interpersonal		
			0	1	Total
Company	A	Count	14	4	18
		Expected Count	14.7	3.3	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Interpersonal	8.5%	10.8%	8.9%
		% of Total	6.9%	2.0%	8.9%
	B	Count	15	3	18
		Expected Count	14.7	3.3	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Interpersonal	9.1%	8.1%	8.9%
		% of Total	7.4%	1.5%	8.9%
	C	Count	21	3	24
		Expected Count	19.6	4.4	24.0
		% within Company	87.5%	12.5%	100.0%
		% within Interpersonal	12.7%	8.1%	11.9%
		% of Total	10.4%	1.5%	11.9%
	D	Count	17	4	21
		Expected Count	17.2	3.8	21.0
		% within Company	81.0%	19.0%	100.0%
		% within Interpersonal	10.3%	10.8%	10.4%
		% of Total	8.4%	2.0%	10.4%
	E	Count	16	4	20
		Expected Count	16.3	3.7	20.0
		% within Company	80.0%	20.0%	100.0%
		% within Interpersonal	9.7%	10.8%	9.9%
		% of Total	7.9%	2.0%	9.9%
	F	Count	21	2	23
		Expected Count	18.8	4.2	23.0
		% within Company	91.3%	8.7%	100.0%
		% within Interpersonal	12.7%	5.4%	11.4%
		% of Total	10.4%	1.0%	11.4%
	G	Count	7	4	11
		Expected Count	9.0	2.0	11.0
		% within Company	63.6%	36.4%	100.0%
		% within Interpersonal	4.2%	10.8%	5.4%
		% of Total	3.5%	2.0%	5.4%
	H	Count	18	3	21
		Expected Count	17.2	3.8	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Interpersonal	10.9%	8.1%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	14	4	18
		Expected Count	14.7	3.3	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Interpersonal	8.5%	10.8%	8.9%
		% of Total	6.9%	2.0%	8.9%
	J	Count	22	6	28
		Expected Count	22.9	5.1	28.0
		% within Company	78.6%	21.4%	100.0%
		% within Interpersonal	13.3%	16.2%	13.9%
		% of Total	10.9%	3.0%	13.9%
Total		Count	165	37	202
		Expected Count	165.0	37.0	202.0
		% within Company	81.7%	18.3%	100.0%
		% within Interpersonal	100.0%	100.0%	100.0%
		% of Total	81.7%	18.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.215[a]	9	.815
Likelihood Ratio	5.128	9	.823
N of Valid Cases	202		

a. 9 cells (45.0%) have expected count less than 5. The minimum expected count is 2.01.

8.8.7 Top Level 2 Key Steps to the Development of Systems Thinking

Top Level 2 Key Steps to the Development of Systems Thinking for All Participants (N=202)

Rank	Node Category	Number	Percent
1	Work on diverse things	41	20%
2	Systems jobs/experiences	29	14%
3	Family	25	12%
4	Early life experiences	23	11%
5	Hobbies	21	10%

Top Level 2 Key Steps to the Development of Systems Thinking for Expert Panelists (N=37)

Rank	Node Category	Number	Percent
1	Work on diverse things	11	30%
2	Systems jobs/experiences	9	24%
3	Curiosity/wants more understanding	5	14%
3	Specific project	5	14%
5	Training	4	11%
5	Project work/open-ended problems	4	11%
5	Leadership/responsibility	4	11%

Top Level 2 Key Steps to the Development of Systems Thinking for Senior Systems Engineers (N=61)

Rank	Node Category	Number	Percent
1	Hobbies	13	21%
2	Work on diverse things	11	18%
3	Family	9	15%
3	Particular organization/company	9	15%
5	Training	7	11%
6	Diversity, variety in personal life	6	10%
6	Systems jobs/experiences	6	10%

Top Level 2 Key Steps to the Development of Systems Thinking for Senior Technical Specialists (N=52)

Rank	Node Category	Number	Percent
1	Family	10	19%
2	General experience	9	17%
3	Early life experiences	8	15%
3	Systems jobs/experiences	8	15%
3	Work on diverse things	8	15%
6	Mentoring	7	13%
7	Curiosity/wants more understanding	5	10%
7	Particular organization/company	5	10%

Top Level 2 Key Steps to the Development of Systems Thinking for Junior Systems Engineers (N=52)

Rank	Node Category	Number	Percent
1	Work on diverse things	11	21%
2	Early life experiences	8	15%
2	Natural/innate	8	15%
4	Thinking	7	13%
4	Systems courses/degree	7	13%
6	Systems jobs/experiences	6	12%
7	Family	5	10%
7	Hobbies	5	10%
7	Teams	5	10%

8.8.8 Summary of Top Level 2 Key Steps to the Development of Systems Thinking

Top Level 2 Key Steps to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=202)			Expert Panelists (N=37)			Senior Systems Engineers (N=61)			Senior Technical Specialists (N=52)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Work on diverse things	1	41	20%	1	11	30%	2	11	18%	3	8	15%	1	11	21%	3.028	0.387
Systems jobs/experiences	2	29	14%	2	9	24%	6	6	10%	3	8	15%	6	6	12%	4.384	0.223
Family	3	25	12%	24	1	3%	3	9	15%	1	10	19%	7	5	10%	6.129	0.105
Early life experiences	4	23	11%	8	3	8%	9	4	7%	3	8	15%	2	8	15%	3.452	0.327
Hobbies	5	21	10%	24	1	3%	1	13	21%	13	2	4%	7	5	10%	12.582	0.006
Curiosity/wants more understanding	10	15	7%	3	5	14%	17	3	5%	7	5	10%	19	2	4%	3.885	0.274
Specific project	14	12	6%	3	5	14%	9	4	7%	24	1	2%	19	2	4%	5.749	0.124
Training	7	16	8%	5	4	11%	5	7	11%	13	2	4%	13	3	6%	2.994	0.393
Project work/open-ended problems	24	5	2%	5	4	11%	75	0	0%	69	0	0%	33	1	2%	13.583	0.004
Leadership/responsibility	15	11	5%	5	4	11%	9	4	7%	24	1	2%	19	2	4%	3.726	0.293
Particular organization/company	6	18	9%	8	3	8%	3	9	15%	7	5	10%	33	1	2%	5.755	0.124
General experience	7	16	8%	24	1	3%	20	2	3%	2	9	17%	10	4	8%	9.470	0.024
Mentoring	7	16	8%	8	3	8%	8	5	8%	6	7	13%	33	1	2%	4.762	0.190
Natural/innate	11	14	7%	13	2	5%	17	3	5%	24	1	2%	2	8	15%	8.300	0.040
Thinking	15	11	5%	64	0	0%	29	1	2%	9	3	6%	4	7	13%	10.347	0.016
Systems courses/degree	12	13	6%	24	1	3%	9	4	7%	24	1	2%	4	7	13%	6.879	0.076
Teams	18	10	5%	24	1	3%	9	4	7%	69	0	0%	7	5	10%	5.845	0.119

8.8.9 Crosstabulation Tables by Classification for Top Level 2 Key Steps to the Development of Systems Thinking

8.8.9.1 Crosstabulation Table by Classification for Top Level 2 Key Step "Work on diverse things"

Translated Classification * Work on diverse things Crosstabulation

			Work on diverse things 0	Work on diverse things 1	Total
Translated Classification	1_Expert Panelist	Count	26	11	37
		Expected Count	29.5	7.5	37.0
		% within Translated Classification	70.3%	29.7%	100.0%
		% within Work on diverse things	16.1%	26.8%	18.3%
		% of Total	12.9%	5.4%	18.3%
	2_Senior Systems Engineer	Count	50	11	61
		Expected Count	48.6	12.4	61.0
		% within Translated Classification	82.0%	18.0%	100.0%
		% within Work on diverse things	31.1%	26.8%	30.2%
		% of Total	24.8%	5.4%	30.2%
	3_Senior Tech Specialist	Count	44	8	52
		Expected Count	41.4	10.6	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Work on diverse things	27.3%	19.5%	25.7%
		% of Total	21.8%	4.0%	25.7%
	4_Junior Systems Engineer	Count	41	11	52
		Expected Count	41.4	10.6	52.0
		% within Translated Classification	78.8%	21.2%	100.0%
		% within Work on diverse things	25.5%	26.8%	25.7%
		% of Total	20.3%	5.4%	25.7%
Total		Count	161	41	202
		Expected Count	161.0	41.0	202.0
		% within Translated Classification	79.7%	20.3%	100.0%
		% within Work on diverse things	100.0%	100.0%	100.0%
		% of Total	79.7%	20.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.028[a]	3	.387
Likelihood Ratio	2.899	3	.407
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.51.

8.8.9.2 *Crosstabulation Table by Classification for Top Level 2 Key Step "Systems jobs/experiences"*

Translated Classification * Systems jobs/experiences Crosstabulation

			Systems jobs/experiences		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	28	9	37
		Expected Count	31.7	5.3	37.0
		% within Translated Classification	75.7%	24.3%	100.0%
		% within Systems jobs/experiences	16.2%	31.0%	18.3%
		% of Total	13.9%	4.5%	18.3%
	2_Senior Systems Engineer	Count	55	6	61
		Expected Count	52.2	8.8	61.0
		% within Translated Classification	90.2%	9.8%	100.0%
		% within Systems jobs/experiences	31.8%	20.7%	30.2%
		% of Total	27.2%	3.0%	30.2%
	3_Senior Tech Specialist	Count	44	8	52
		Expected Count	44.5	7.5	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Systems jobs/experiences	25.4%	27.6%	25.7%
		% of Total	21.8%	4.0%	25.7%
	4_Junior Systems Engineer	Count	46	6	52
		Expected Count	44.5	7.5	52.0
		% within Translated Classification	88.5%	11.5%	100.0%
		% within Systems jobs/experiences	26.6%	20.7%	25.7%
		% of Total	22.8%	3.0%	25.7%
Total		Count	173	29	202
		Expected Count	173.0	29.0	202.0
		% within Translated Classification	85.6%	14.4%	100.0%
		% within Systems jobs/experiences	100.0%	100.0%	100.0%
		% of Total	85.6%	14.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.384[a]	3	.223
Likelihood Ratio	4.082	3	.253
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.31.

8.8.9.3 Crosstabulation Table by Classification for Top Level 2 Key Step "Family"

Translated Classification * Family Crosstabulation

			Family		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	36	1	37
		Expected Count	32.4	4.6	37.0
		% within Translated Classification	97.3%	2.7%	100.0%
		% within Family	20.3%	4.0%	18.3%
		% of Total	17.8%	.5%	18.3%
	2_Senior Systems Engineer	Count	52	9	61
		Expected Count	53.5	7.5	61.0
		% within Translated Classification	85.2%	14.8%	100.0%
		% within Family	29.4%	36.0%	30.2%
		% of Total	25.7%	4.5%	30.2%
	3_Senior Tech Specialist	Count	42	10	52
		Expected Count	45.6	6.4	52.0
		% within Translated Classification	80.8%	19.2%	100.0%
		% within Family	23.7%	40.0%	25.7%
		% of Total	20.8%	5.0%	25.7%
	4_Junior Systems Engineer	Count	47	5	52
		Expected Count	45.6	6.4	52.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Family	26.6%	20.0%	25.7%
		% of Total	23.3%	2.5%	25.7%
Total		Count	177	25	202
		Expected Count	177.0	25.0	202.0
		% within Translated Classification	87.6%	12.4%	100.0%
		% within Family	100.0%	100.0%	100.0%
		% of Total	87.6%	12.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.129[a]	3	.105
Likelihood Ratio	7.163	3	.067
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.58.

8.8.9.4 *Crosstabulation Table by Classification for Top Level 2 Key Step "Early life experiences"*

Translated Classification * Early life experiences Crosstabulation

			Early life experiences		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	34	3	37
		Expected Count	32.8	4.2	37.0
		% within Translated Classification	91.9%	8.1%	100.0%
		% within Early life experiences	19.0%	13.0%	18.3%
		% of Total	16.8%	1.5%	18.3%
	2_Senior Systems Engineer	Count	57	4	61
		Expected Count	54.1	6.9	61.0
		% within Translated Classification	93.4%	6.6%	100.0%
		% within Early life experiences	31.8%	17.4%	30.2%
		% of Total	28.2%	2.0%	30.2%
	3_Senior Tech Specialist	Count	44	8	52
		Expected Count	46.1	5.9	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Early life experiences	24.6%	34.8%	25.7%
		% of Total	21.8%	4.0%	25.7%
	4_Junior Systems Engineer	Count	44	8	52
		Expected Count	46.1	5.9	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Early life experiences	24.6%	34.8%	25.7%
		% of Total	21.8%	4.0%	25.7%
Total		Count	179	23	202
		Expected Count	179.0	23.0	202.0
		% within Translated Classification	88.6%	11.4%	100.0%
		% within Early life experiences	100.0%	100.0%	100.0%
		% of Total	88.6%	11.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.452[a]	3	.327
Likelihood Ratio	3.572	3	.312
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.21.

8.8.9.5 Crosstabulation Table by Classification for Top Level 2 Key Step "Hobbies"

Translated Classification * Hobbies Crosstabulation

			Hobbies		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	36	1	37
		Expected Count	33.2	3.8	37.0
		% within Translated Classification	97.3%	2.7%	100.0%
		% within Hobbies	19.9%	4.8%	18.3%
		% of Total	17.8%	.5%	18.3%
	2_Senior Systems Engineer	Count	48	13	61
		Expected Count	54.7	6.3	61.0
		% within Translated Classification	78.7%	21.3%	100.0%
		% within Hobbies	26.5%	61.9%	30.2%
		% of Total	23.8%	6.4%	30.2%
	3_Senior Tech Specialist	Count	50	2	52
		Expected Count	46.6	5.4	52.0
		% within Translated Classification	96.2%	3.8%	100.0%
		% within Hobbies	27.6%	9.5%	25.7%
		% of Total	24.8%	1.0%	25.7%
	4_Junior Systems Engineer	Count	47	5	52
		Expected Count	46.6	5.4	52.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Hobbies	26.0%	23.8%	25.7%
		% of Total	23.3%	2.5%	25.7%
Total		Count	181	21	202
		Expected Count	181.0	21.0	202.0
		% within Translated Classification	89.6%	10.4%	100.0%
		% within Hobbies	100.0%	100.0%	100.0%
		% of Total	89.6%	10.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.582[a]	3	.006
Likelihood Ratio	12.542	3	.006
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 3.85.

8.8.10 Crosstabulation Tables by Company for Top Level 2 Key Steps to the Development of Systems Thinking

8.8.10.1 Crosstabulation Table by Company for Top Level 2 Key Step "Work on diverse things"

Crosstab

			Work on diverse things		
			0	1	Total
Company	A	Count	16	2	18
		Expected Count	14.3	3.7	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Work on diverse things	9.9%	4.9%	8.9%
		% of Total	7.9%	1.0%	8.9%
	B	Count	12	6	18
		Expected Count	14.3	3.7	18.0
		% within Company	66.7%	33.3%	100.0%
		% within Work on diverse things	7.5%	14.6%	8.9%
		% of Total	5.9%	3.0%	8.9%
	C	Count	24	0	24
		Expected Count	19.1	4.9	24.0
		% within Company	100.0%	.0%	100.0%
		% within Work on diverse things	14.9%	.0%	11.9%
		% of Total	11.9%	.0%	11.9%
	D	Count	17	4	21
		Expected Count	16.7	4.3	21.0
		% within Company	81.0%	19.0%	100.0%
		% within Work on diverse things	10.6%	9.8%	10.4%
		% of Total	8.4%	2.0%	10.4%
	E	Count	14	6	20
		Expected Count	15.9	4.1	20.0
		% within Company	70.0%	30.0%	100.0%
		% within Work on diverse things	8.7%	14.6%	9.9%
		% of Total	6.9%	3.0%	9.9%
	F	Count	18	5	23
		Expected Count	18.3	4.7	23.0
		% within Company	78.3%	21.7%	100.0%
		% within Work on diverse things	11.2%	12.2%	11.4%
		% of Total	8.9%	2.5%	11.4%
	G	Count	7	4	11
		Expected Count	8.8	2.2	11.0
		% within Company	63.6%	36.4%	100.0%
		% within Work on diverse things	4.3%	9.8%	5.4%
		% of Total	3.5%	2.0%	5.4%
	H	Count	16	5	21
		Expected Count	16.7	4.3	21.0
		% within Company	76.2%	23.8%	100.0%
		% within Work on diverse things	9.9%	12.2%	10.4%
		% of Total	7.9%	2.5%	10.4%
	I	Count	14	4	18
		Expected Count	14.3	3.7	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Work on diverse things	8.7%	9.8%	8.9%
		% of Total	6.9%	2.0%	8.9%
	J	Count	23	5	28
		Expected Count	22.3	5.7	28.0
		% within Company	82.1%	17.9%	100.0%
		% within Work on diverse things	14.3%	12.2%	13.9%
		% of Total	11.4%	2.5%	13.9%
Total		Count	161	41	202
		Expected Count	161.0	41.0	202.0
		% within Company	79.7%	20.3%	100.0%
		% within Work on diverse things	100.0%	100.0%	100.0%
		% of Total	79.7%	20.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.215[a]	9	.201
Likelihood Ratio	16.554	9	.056
N of Valid Cases	202		

a. 9 cells (45.0%) have expected count less than 5. The minimum expected count is 2.23.

8.8.10.2 Crosstabulation Table by Company for Top Level 2 Key Step "Systems jobs/experiences"

Crosstab

			Systems jobs/experiences		
			0	1	Total
Company	A	Count	14	4	18
		Expected Count	15.4	2.6	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Systems jobs/experiences	8.1%	13.8%	8.9%
		% of Total	6.9%	2.0%	8.9%
	B	Count	15	3	18
		Expected Count	15.4	2.6	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Systems jobs/experiences	8.7%	10.3%	8.9%
		% of Total	7.4%	1.5%	8.9%
	C	Count	20	4	24
		Expected Count	20.6	3.4	24.0
		% within Company	83.3%	16.7%	100.0%
		% within Systems jobs/experiences	11.6%	13.8%	11.9%
		% of Total	9.9%	2.0%	11.9%
	D	Count	18	3	21
		Expected Count	18.0	3.0	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Systems jobs/experiences	10.4%	10.3%	10.4%
		% of Total	8.9%	1.5%	10.4%
	E	Count	17	3	20
		Expected Count	17.1	2.9	20.0
		% within Company	85.0%	15.0%	100.0%
		% within Systems jobs/experiences	9.8%	10.3%	9.9%
		% of Total	8.4%	1.5%	9.9%
	F	Count	22	1	23
		Expected Count	19.7	3.3	23.0
		% within Company	95.7%	4.3%	100.0%
		% within Systems jobs/experiences	12.7%	3.4%	11.4%
		% of Total	10.9%	.5%	11.4%
	G	Count	7	4	11
		Expected Count	9.4	1.6	11.0
		% within Company	63.6%	36.4%	100.0%
		% within Systems jobs/experiences	4.0%	13.8%	5.4%
		% of Total	3.5%	2.0%	5.4%
	H	Count	19	2	21
		Expected Count	18.0	3.0	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Systems jobs/experiences	11.0%	6.9%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	16	2	18
		Expected Count	15.4	2.6	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Systems jobs/experiences	9.2%	6.9%	8.9%
		% of Total	7.9%	1.0%	8.9%
	J	Count	25	3	28
		Expected Count	24.0	4.0	28.0
		% within Company	89.3%	10.7%	100.0%
		% within Systems jobs/experiences	14.5%	10.3%	13.9%
		% of Total	12.4%	1.5%	13.9%
Total		Count	173	29	202
		Expected Count	173.0	29.0	202.0
		% within Company	85.6%	14.4%	100.0%
		% within Systems jobs/experiences	100.0%	100.0%	100.0%
		% of Total	85.6%	14.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.157[a]	9	.518
Likelihood Ratio	7.666	9	.568
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.58.

8.8.10.3 Crosstabulation Table by Company for Top Level 2 Key Step "Family"

Crosstab

			Family		Total
			0	1	
Company	A	Count	15	3	18
		Expected Count	15.8	2.2	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Family	8.5%	12.0%	8.9%
		% of Total	7.4%	1.5%	8.9%
	B	Count	16	2	18
		Expected Count	15.8	2.2	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Family	9.0%	8.0%	8.9%
		% of Total	7.9%	1.0%	8.9%
	C	Count	20	4	24
		Expected Count	21.0	3.0	24.0
		% within Company	83.3%	16.7%	100.0%
		% within Family	11.3%	16.0%	11.9%
		% of Total	9.9%	2.0%	11.9%
	D	Count	19	2	21
		Expected Count	18.4	2.6	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Family	10.7%	8.0%	10.4%
		% of Total	9.4%	1.0%	10.4%
	E	Count	17	3	20
		Expected Count	17.5	2.5	20.0
		% within Company	85.0%	15.0%	100.0%
		% within Family	9.6%	12.0%	9.9%
		% of Total	8.4%	1.5%	9.9%
	F	Count	21	2	23
		Expected Count	20.2	2.8	23.0
		% within Company	91.3%	8.7%	100.0%
		% within Family	11.9%	8.0%	11.4%
		% of Total	10.4%	1.0%	11.4%
	G	Count	10	1	11
		Expected Count	9.6	1.4	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Family	5.6%	4.0%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	19	2	21
		Expected Count	18.4	2.6	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Family	10.7%	8.0%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	14	4	18
		Expected Count	15.8	2.2	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Family	7.9%	16.0%	8.9%
		% of Total	6.9%	2.0%	8.9%
	J	Count	26	2	28
		Expected Count	24.5	3.5	28.0
		% within Company	92.9%	7.1%	100.0%
		% within Family	14.7%	8.0%	13.9%
		% of Total	12.9%	1.0%	13.9%
Total		Count	177	25	202
		Expected Count	177.0	25.0	202.0
		% within Company	87.6%	12.4%	100.0%
		% within Family	100.0%	100.0%	100.0%
		% of Total	87.6%	12.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.895[a]	9	.918
Likelihood Ratio	3.737	9	.928
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.36.

8.8.10.4 Crosstabulation Table by Company for Top Level 2 Key Step "Early life experiences"

Crosstab

			Early life experiences		
			0	1	Total
Company	A	Count	14	4	18
		Expected Count	16.0	2.0	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Early life experiences	7.8%	17.4%	8.9%
		% of Total	6.9%	2.0%	8.9%
	B	Count	17	1	18
		Expected Count	16.0	2.0	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Early life experiences	9.5%	4.3%	8.9%
		% of Total	8.4%	.5%	8.9%
	C	Count	20	4	24
		Expected Count	21.3	2.7	24.0
		% within Company	83.3%	16.7%	100.0%
		% within Early life experiences	11.2%	17.4%	11.9%
		% of Total	9.9%	2.0%	11.9%
	D	Count	17	4	21
		Expected Count	18.6	2.4	21.0
		% within Company	81.0%	19.0%	100.0%
		% within Early life experiences	9.5%	17.4%	10.4%
		% of Total	8.4%	2.0%	10.4%
	E	Count	19	1	20
		Expected Count	17.7	2.3	20.0
		% within Company	95.0%	5.0%	100.0%
		% within Early life experiences	10.6%	4.3%	9.9%
		% of Total	9.4%	.5%	9.9%
	F	Count	19	4	23
		Expected Count	20.4	2.6	23.0
		% within Company	82.6%	17.4%	100.0%
		% within Early life experiences	10.6%	17.4%	11.4%
		% of Total	9.4%	2.0%	11.4%
	G	Count	9	2	11
		Expected Count	9.7	1.3	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Early life experiences	5.0%	8.7%	5.4%
		% of Total	4.5%	1.0%	5.4%
	H	Count	20	1	21
		Expected Count	18.6	2.4	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Early life experiences	11.2%	4.3%	10.4%
		% of Total	9.9%	.5%	10.4%
	I	Count	17	1	18
		Expected Count	16.0	2.0	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Early life experiences	9.5%	4.3%	8.9%
		% of Total	8.4%	.5%	8.9%
	J	Count	27	1	28
		Expected Count	24.8	3.2	28.0
		% within Company	96.4%	3.6%	100.0%
		% within Early life experiences	15.1%	4.3%	13.9%
		% of Total	13.4%	.5%	13.9%
Total		Count	179	23	202
		Expected Count	179.0	23.0	202.0
		% within Company	88.6%	11.4%	100.0%
		% within Early life experiences	100.0%	100.0%	100.0%
		% of Total	88.6%	11.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.935[a]	9	.356
Likelihood Ratio	10.334	9	.324
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.25.

8.8.10.5 Crosstabulation Table by Company for Top Level 2 Key Step "Hobbies"

Crosstab

			Hobbies		
			0	1	Total
Company	A	Count	16	2	18
		Expected Count	16.1	1.9	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Hobbies	8.8%	9.5%	8.9%
		% of Total	7.9%	1.0%	8.9%
	B	Count	16	2	18
		Expected Count	16.1	1.9	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Hobbies	8.8%	9.5%	8.9%
		% of Total	7.9%	1.0%	8.9%
	C	Count	21	3	24
		Expected Count	21.5	2.5	24.0
		% within Company	87.5%	12.5%	100.0%
		% within Hobbies	11.6%	14.3%	11.9%
		% of Total	10.4%	1.5%	11.9%
	D	Count	19	2	21
		Expected Count	18.8	2.2	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Hobbies	10.5%	9.5%	10.4%
		% of Total	9.4%	1.0%	10.4%
	E	Count	20	0	20
		Expected Count	17.9	2.1	20.0
		% within Company	100.0%	.0%	100.0%
		% within Hobbies	11.0%	.0%	9.9%
		% of Total	9.9%	.0%	9.9%
	F	Count	19	4	23
		Expected Count	20.6	2.4	23.0
		% within Company	82.6%	17.4%	100.0%
		% within Hobbies	10.5%	19.0%	11.4%
		% of Total	9.4%	2.0%	11.4%
	G	Count	11	0	11
		Expected Count	9.9	1.1	11.0
		% within Company	100.0%	.0%	100.0%
		% within Hobbies	6.1%	.0%	5.4%
		% of Total	5.4%	.0%	5.4%
	H	Count	18	3	21
		Expected Count	18.8	2.2	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Hobbies	9.9%	14.3%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	15	3	18
		Expected Count	16.1	1.9	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Hobbies	8.3%	14.3%	8.9%
		% of Total	7.4%	1.5%	8.9%
	J	Count	26	2	28
		Expected Count	25.1	2.9	28.0
		% within Company	92.9%	7.1%	100.0%
		% within Hobbies	14.4%	9.5%	13.9%
		% of Total	12.9%	1.0%	13.9%
Total		Count	181	21	202
		Expected Count	181.0	21.0	202.0
		% within Company	89.6%	10.4%	100.0%
		% within Hobbies	100.0%	100.0%	100.0%
		% of Total	89.6%	10.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.375[a]	9	.702
Likelihood Ratio	9.296	9	.410
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.14.

8.9 Enablers to Systems Thinking Development

8.9.1 Coding for Enablers to Systems Thinking Development

Enablers to Systems Thinking Development	Total
Experience	
- Lessons learned	3
- Technical depth	4
- Experience in general	17
- Time spent working at different scales	1
- Broad experience base	37
- Work on things interested in	1
- First job	1
- Proven problem solving	1
- Job/opportunity to see systems view	35
Tools & Methodology	
- Organized system for documents	1
- Models	2
- Translation of abstraction to something real	1
- Trade study	5
- Standard terminology	1
- Tools	9
- Methods for SE/ST	3
Interventions	
- Education	17
- Books	1
- INCOSE	3
- Training	23
Individual Skills & Traits	
- Motivated	2
- Enthusiastic	1
- Basic project management skills	1
- Multi-tasking	1
- Step outside own box/comfort zone	10
- Social skills	4
- Inquisitive/curious	5
- Creative	2
- Leadership	6
- Wisdom	1
- Passion	1
- Self-confidence	2
- Innate	17
- Take ownership	1
- Technical skill	1

- Style	1
- Strong intellect	1
- Think full circle	1
- Interrogate assumptions	1
- Tackle projects around house	1
- Abstraction/transfer knowledge	3
- Attitude	2
- Certain level of technical expertise	1
- A person's interests	3
- Analyze	2
- Thrive on pressure	1
- Takes new challenges	1
- Decision oriented	2
- Objective	1
- Artistic ability	1
- Recognize path to resolve problem	1
- Understanding	2
- Understand system constraints and components	1
- Freethinking	1
- Open-minded	3
- Understand purpose	2
- Understand systems need to be flexible and adaptable	1
- Both big picture & detail thinker	4
- Broad perspective	17
- People have different ways of looking at things	2
- Critical thinking	2
- World view	1
- Understand what could go wrong	1
Time	2
Interpersonal	
- Encourage participation	2
- Communication	12
- Customer/end user	5
- Cross disciplines	7
- Networks	2
- Collective ownership	1
- Influence of co-workers	7
- Teams	13
- Meeting structure	2
- Social dynamics	2
- Mentors	13
Life experience as a child	1
Current trends	12
Organization	

- Encourage ST	4
- Working environment/culture	10
- Process conferences & initiatives	5
- Common vision	1
- Incentives	4
- Organizational structure	8
- Organizational support	4
- Company focus on SE	2
- Exposure	1
- Organization in general	2
- Functional support	1
- Managers	6
- Metrics	1
- Make SE legitimate discipline	1
- Language	1
- Physical space	3
- Empowerment and encouragement	1
- Competition	1
- Access to data	1

8.9.2 Level 1 Coding for Enablers to Systems Thinking Development

Level 1 Enablers to the Development of Systems Thinking	Total
Experience	81
Tools & Methodology	18
Interventions	39
Individual Skills & Traits	76
Time	2
Interpersonal	49
Life experience as a child	1
Current trends	12
Organization	45

8.9.3 Top Level 1 Enablers to the Development of Systems Thinking

Top Level 1 Enablers to the Development of Systems Thinking for All Participants (N=177)

Rank	Node Category	Number	Percent
1	Experience	81	46%
2	Individual Skills & Traits	76	43%
3	Interpersonal	49	28%
4	Organization	45	25%
5	Interventions	39	22%
6	Tools & Methodology	18	10%

Top Level 1 Enablers to the Development of Systems Thinking for Expert Panelists (N=35)

Rank	Node Category	Number	Percent
1	Experience	16	46%
2	Individual Skills & Traits	13	37%
2	Organization	13	37%
4	Interpersonal	6	17%
5	Interventions	5	14%
6	Current trends	4	11%

Top Level 1 Enablers to the Development of Systems Thinking for Senior Systems Engineers (N=52)

Rank	Node Category	Number	Percent
1	Experience	28	54%
2	Individual Skills & Traits	25	48%
3	Interventions	16	31%
4	Organization	13	25%
5	Interpersonal	10	19%
6	Tools & Methodology	9	17%

Top Level 1 Enablers to the Development of Systems Thinking for Junior Systems Engineers (N=47)

Rank	Node Category	Number	Percent
1	Interpersonal	20	43%
2	Individual Skills & Traits	18	38%
3	Experience	16	34%
4	Organization	10	21%
5	Interventions	9	19%

Top Level 1 Enablers to the Development of Systems Thinking for Senior Technical Specialists (N=43)

Rank	Node Category	Number	Percent
1	Experience	21	49%
2	Individual Skills & Traits	20	47%
3	Interpersonal	13	30%
4	Interventions	9	21%
4	Organization	9	21%

8.9.4 Summary of Top Level 1 Enablers to the Development of Systems Thinking for All Classifications

Top Level 1 Enablers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=177)			Expert Panelists (N=35)			Senior Systems Engineers (N=52)			Senior Technical Specialists (N=43)			Junior Systems Engineers (N=47)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Experience	1	81	46%	1	16	46%	1	28	54%	1	21	49%	3	16	34%	4.134	0.247
Individual Skills & Traits	2	76	43%	2	13	37%	2	25	48%	2	20	47%	2	18	38%	1.677	0.642
Interpersonal	3	49	28%	4	6	17%	5	10	19%	3	13	30%	1	20	43%	9.129	0.028
Organization	4	45	25%	2	13	37%	4	13	25%	4	9	21%	4	10	21%	3.424	0.331
Interventions	5	39	22%	5	5	14%	3	16	31%	4	9	21%	5	9	19%	3.791	0.285
Tools & Methodology	6	18	10%	7	3	9%	6	9	17%	6	2	5%	6	4	9%	4.573	0.206
Current trends	7	12	7%	6	4	11%	7	4	8%	7	1	2%	7	3	6%	2.627	0.453

8.9.5 Crosstabulation Tables by Classification for Top Level 1 Enablers

8.9.5.1 Crosstabulation Table by Classification for Top Level 1 Enabler "Experience"

Translated Classification * Experience Crosstabulation

			Experience		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	19	16	35
		Expected Count	19.0	16.0	35.0
		% within Translated Classification	54.3%	45.7%	100.0%
		% within Experience	19.8%	19.8%	19.8%
		% of Total	10.7%	9.0%	19.8%
	2_Senior Systems Engineer	Count	24	28	52
		Expected Count	28.2	23.8	52.0
		% within Translated Classification	46.2%	53.8%	100.0%
		% within Experience	25.0%	34.6%	29.4%
		% of Total	13.6%	15.8%	29.4%
	3_Senior Tech Specialist	Count	22	21	43
		Expected Count	23.3	19.7	43.0
		% within Translated Classification	51.2%	48.8%	100.0%
		% within Experience	22.9%	25.9%	24.3%
		% of Total	12.4%	11.9%	24.3%
	4_Junior Systems Engineer	Count	31	16	47
		Expected Count	25.5	21.5	47.0
		% within Translated Classification	66.0%	34.0%	100.0%
		% within Experience	32.3%	19.8%	26.6%
		% of Total	17.5%	9.0%	26.6%
Total		Count	96	81	177
		Expected Count	96.0	81.0	177.0
		% within Translated Classification	54.2%	45.8%	100.0%
		% within Experience	100.0%	100.0%	100.0%
		% of Total	54.2%	45.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.134[a]	3	.247
Likelihood Ratio	4.188	3	.242
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.02.

8.9.5.2 *Crosstabulation Table by Classification for Top Level 1 Enabler "Individual Skills & Traits"*

Translated Classification * Individual Skills & Traits Crosstabulation

			Individual Skills & Traits		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	22	13	35
		Expected Count	20.0	15.0	35.0
		% within Translated Classification	62.9%	37.1%	100.0%
		% within Individual Skills & Traits	21.8%	17.1%	19.8%
		% of Total	12.4%	7.3%	19.8%
	2_Senior Systems Engineer	Count	27	25	52
		Expected Count	29.7	22.3	52.0
		% within Translated Classification	51.9%	48.1%	100.0%
		% within Individual Skills & Traits	26.7%	32.9%	29.4%
		% of Total	15.3%	14.1%	29.4%
	3_Senior Tech Specialist	Count	23	20	43
		Expected Count	24.5	18.5	43.0
		% within Translated Classification	53.5%	46.5%	100.0%
		% within Individual Skills & Traits	22.8%	26.3%	24.3%
		% of Total	13.0%	11.3%	24.3%
	4_Junior Systems Engineer	Count	29	18	47
		Expected Count	26.8	20.2	47.0
		% within Translated Classification	61.7%	38.3%	100.0%
		% within Individual Skills & Traits	28.7%	23.7%	26.6%
		% of Total	16.4%	10.2%	26.6%
Total		Count	101	76	177
		Expected Count	101.0	76.0	177.0
		% within Translated Classification	57.1%	42.9%	100.0%
		% within Individual Skills & Traits	100.0%	100.0%	100.0%
		% of Total	57.1%	42.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.677[a]	3	.642
Likelihood Ratio	1.682	3	.641
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.03.

8.9.5.3 Crosstabulation Table by Classification for Top Level 1 Enabler "Interpersonal"

Translated Classification * Interpersonal Crosstabulation

			Interpersonal		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	29	6	35
		Expected Count	25.3	9.7	35.0
		% within Translated Classification	82.9%	17.1%	100.0%
		% within Interpersonal	22.7%	12.2%	19.8%
		% of Total	16.4%	3.4%	19.8%
	2_Senior Systems Engineer	Count	42	10	52
		Expected Count	37.6	14.4	52.0
		% within Translated Classification	80.8%	19.2%	100.0%
		% within Interpersonal	32.8%	20.4%	29.4%
		% of Total	23.7%	5.6%	29.4%
	3_Senior Tech Specialist	Count	30	13	43
		Expected Count	31.1	11.9	43.0
		% within Translated Classification	69.8%	30.2%	100.0%
		% within Interpersonal	23.4%	26.5%	24.3%
		% of Total	16.9%	7.3%	24.3%
	4_Junior Systems Engineer	Count	27	20	47
		Expected Count	34.0	13.0	47.0
		% within Translated Classification	57.4%	42.6%	100.0%
		% within Interpersonal	21.1%	40.8%	26.6%
		% of Total	15.3%	11.3%	26.6%
Total		Count	128	49	177
		Expected Count	128.0	49.0	177.0
		% within Translated Classification	72.3%	27.7%	100.0%
		% within Interpersonal	100.0%	100.0%	100.0%
		% of Total	72.3%	27.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.129[a]	3	.028
Likelihood Ratio	9.043	3	.029
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.69.

8.9.5.4 Crosstabulation Table by Classification for Top Level 1 Enabler "Organization"

Translated Classification * Organization Crosstabulation

			Organization		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	22	13	35
		Expected Count	26.1	8.9	35.0
		% within Translated Classification	62.9%	37.1%	100.0%
		% within Organization	16.7%	28.9%	19.8%
		% of Total	12.4%	7.3%	19.8%
	2_Senior Systems Engineer	Count	39	13	52
		Expected Count	38.8	13.2	52.0
		% within Translated Classification	75.0%	25.0%	100.0%
		% within Organization	29.5%	28.9%	29.4%
		% of Total	22.0%	7.3%	29.4%
	3_Senior Tech Specialist	Count	34	9	43
		Expected Count	32.1	10.9	43.0
		% within Translated Classification	79.1%	20.9%	100.0%
		% within Organization	25.8%	20.0%	24.3%
		% of Total	19.2%	5.1%	24.3%
	4_Junior Systems Engineer	Count	37	10	47
		Expected Count	35.1	11.9	47.0
		% within Translated Classification	78.7%	21.3%	100.0%
		% within Organization	28.0%	22.2%	26.6%
		% of Total	20.9%	5.6%	26.6%
Total		Count	132	45	177
		Expected Count	132.0	45.0	177.0
		% within Translated Classification	74.6%	25.4%	100.0%
		% within Organization	100.0%	100.0%	100.0%
		% of Total	74.6%	25.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.424[a]	3	.331
Likelihood Ratio	3.260	3	.353
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.90.

8.9.5.5 Crosstabulation Table by Classification for Top Level 1 Enabler "Interventions"

Translated Classification * Interventions Crosstabulation

			Interventions		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	30	5	35
		Expected Count	27.3	7.7	35.0
		% within Translated Classification	85.7%	14.3%	100.0%
		% within Interventions	21.7%	12.8%	19.8%
		% of Total	16.9%	2.8%	19.8%
	2_Senior Systems Engineer	Count	36	16	52
		Expected Count	40.5	11.5	52.0
		% within Translated Classification	69.2%	30.8%	100.0%
		% within Interventions	26.1%	41.0%	29.4%
		% of Total	20.3%	9.0%	29.4%
	3_Senior Tech Specialist	Count	34	9	43
		Expected Count	33.5	9.5	43.0
		% within Translated Classification	79.1%	20.9%	100.0%
		% within Interventions	24.6%	23.1%	24.3%
		% of Total	19.2%	5.1%	24.3%
	4_Junior Systems Engineer	Count	38	9	47
		Expected Count	36.6	10.4	47.0
		% within Translated Classification	80.9%	19.1%	100.0%
		% within Interventions	27.5%	23.1%	26.6%
		% of Total	21.5%	5.1%	26.6%
Total		Count	138	39	177
		Expected Count	138.0	39.0	177.0
		% within Translated Classification	78.0%	22.0%	100.0%
		% within Interventions	100.0%	100.0%	100.0%
		% of Total	78.0%	22.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.791[a]	3	.285
Likelihood Ratio	3.748	3	.290
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.71.

8.9.5.6 Crosstabulation Table by Classification for Top Level 1 Enabler "Tools & Methodology"

Translated Classification * Tools & Methodology Crosstabulation

			Tools & Methodology		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	3	35
		Expected Count	31.4	3.6	35.0
		% within Translated Classification	91.4%	8.6%	100.0%
		% within Tools & Methodology	20.1%	16.7%	19.8%
		% of Total	18.1%	1.7%	19.8%
	2_Senior Systems Engineer	Count	43	9	52
		Expected Count	46.7	5.3	52.0
		% within Translated Classification	82.7%	17.3%	100.0%
		% within Tools & Methodology	27.0%	50.0%	29.4%
		% of Total	24.3%	5.1%	29.4%
	3_Senior Tech Specialist	Count	41	2	43
		Expected Count	38.6	4.4	43.0
		% within Translated Classification	95.3%	4.7%	100.0%
		% within Tools & Methodology	25.8%	11.1%	24.3%
		% of Total	23.2%	1.1%	24.3%
	4_Junior Systems Engineer	Count	43	4	47
		Expected Count	42.2	4.8	47.0
		% within Translated Classification	91.5%	8.5%	100.0%
		% within Tools & Methodology	27.0%	22.2%	26.6%
		% of Total	24.3%	2.3%	26.6%
Total		Count	159	18	177
		Expected Count	159.0	18.0	177.0
		% within Translated Classification	89.8%	10.2%	100.0%
		% within Tools & Methodology	100.0%	100.0%	100.0%
		% of Total	89.8%	10.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.573[a]	3	.206
Likelihood Ratio	4.462	3	.216
N of Valid Cases	177		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 3.56.

8.9.6 Crosstabulation Tables by Company for Top Level 1 Enablers

8.9.6.1 Crosstabulation Table by Company for Top Level 1 Enabler "Experience"

Company * Experience Crosstabulation

			Experience		
			0	1	Total
Company	A	Count	11	6	17
		Expected Count	9.2	7.8	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Experience	11.5%	7.4%	9.6%
		% of Total	6.2%	3.4%	9.6%
	B	Count	6	11	17
		Expected Count	9.2	7.8	17.0
		% within Company	35.3%	64.7%	100.0%
		% within Experience	6.3%	13.6%	9.6%
		% of Total	3.4%	6.2%	9.6%
	C	Count	7	10	17
		Expected Count	9.2	7.8	17.0
		% within Company	41.2%	58.8%	100.0%
		% within Experience	7.3%	12.3%	9.6%
		% of Total	4.0%	5.6%	9.6%
	D	Count	14	5	19
		Expected Count	10.3	8.7	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Experience	14.6%	6.2%	10.7%
		% of Total	7.9%	2.8%	10.7%
	E	Count	12	6	18
		Expected Count	9.8	8.2	18.0
		% within Company	66.7%	33.3%	100.0%
		% within Experience	12.5%	7.4%	10.2%
		% of Total	6.8%	3.4%	10.2%
	F	Count	7	14	21
		Expected Count	11.4	9.6	21.0
		% within Company	33.3%	66.7%	100.0%
		% within Experience	7.3%	17.3%	11.9%
		% of Total	4.0%	7.9%	11.9%
	G	Count	6	3	9
		Expected Count	4.9	4.1	9.0
		% within Company	66.7%	33.3%	100.0%
		% within Experience	6.3%	3.7%	5.1%
		% of Total	3.4%	1.7%	5.1%
	H	Count	13	6	19
		Expected Count	10.3	8.7	19.0
		% within Company	68.4%	31.6%	100.0%
		% within Experience	13.5%	7.4%	10.7%
		% of Total	7.3%	3.4%	10.7%
	I	Count	5	10	15
		Expected Count	8.1	6.9	15.0
		% within Company	33.3%	66.7%	100.0%
		% within Experience	5.2%	12.3%	8.5%
		% of Total	2.8%	5.6%	8.5%
	J	Count	15	10	25
		Expected Count	13.6	11.4	25.0
		% within Company	60.0%	40.0%	100.0%
		% within Experience	15.6%	12.3%	14.1%
		% of Total	8.5%	5.6%	14.1%
Total		Count	96	81	177
		Expected Count	96.0	81.0	177.0
		% within Company	54.2%	45.8%	100.0%
		% within Experience	100.0%	100.0%	100.0%
		% of Total	54.2%	45.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.165[a]	9	.046
Likelihood Ratio	17.467	9	.042
N of Valid Cases	177		

a. 2 cells (10.0%) have expected count less than 5. The minimum expected count is 4.12.

8.9.6.2 *Crosstabulation Table by Company for Top Level 1 Enabler "Individual Skills & Traits"*

Company * Individual Skills & Traits Crosstabulation

			Individual Skills & Traits		
			0	1	Total
Company	A	Count	12	5	17
		Expected Count	9.7	7.3	17.0
		% within Company	70.6%	29.4%	100.0%
		% within Individual Skills & Traits	11.9%	6.6%	9.6%
		% of Total	6.8%	2.8%	9.6%
	B	Count	11	6	17
		Expected Count	9.7	7.3	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Individual Skills & Traits	10.9%	7.9%	9.6%
		% of Total	6.2%	3.4%	9.6%
	C	Count	10	7	17
		Expected Count	9.7	7.3	17.0
		% within Company	58.8%	41.2%	100.0%
		% within Individual Skills & Traits	9.9%	9.2%	9.6%
		% of Total	5.6%	4.0%	9.6%
	D	Count	9	10	19
		Expected Count	10.8	8.2	19.0
		% within Company	47.4%	52.6%	100.0%
		% within Individual Skills & Traits	8.9%	13.2%	10.7%
		% of Total	5.1%	5.6%	10.7%
	E	Count	9	9	18
		Expected Count	10.3	7.7	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Individual Skills & Traits	8.9%	11.8%	10.2%
		% of Total	5.1%	5.1%	10.2%
	F	Count	13	8	21
		Expected Count	12.0	9.0	21.0
		% within Company	61.9%	38.1%	100.0%
		% within Individual Skills & Traits	12.9%	10.5%	11.9%
		% of Total	7.3%	4.5%	11.9%
	G	Count	5	4	9
		Expected Count	5.1	3.9	9.0
		% within Company	55.6%	44.4%	100.0%
		% within Individual Skills & Traits	5.0%	5.3%	5.1%
		% of Total	2.8%	2.3%	5.1%
	H	Count	10	9	19
		Expected Count	10.8	8.2	19.0
		% within Company	52.6%	47.4%	100.0%
		% within Individual Skills & Traits	9.9%	11.8%	10.7%
		% of Total	5.6%	5.1%	10.7%
	I	Count	9	6	15
		Expected Count	8.6	6.4	15.0
		% within Company	60.0%	40.0%	100.0%
		% within Individual Skills & Traits	8.9%	7.9%	8.5%
		% of Total	5.1%	3.4%	8.5%
	J	Count	13	12	25
		Expected Count	14.3	10.7	25.0
		% within Company	52.0%	48.0%	100.0%
		% within Individual Skills & Traits	12.9%	15.8%	14.1%
		% of Total	7.3%	6.8%	14.1%
Total		Count	101	76	177
		Expected Count	101.0	76.0	177.0
		% within Company	57.1%	42.9%	100.0%
		% within Individual Skills & Traits	100.0%	100.0%	100.0%
		% of Total	57.1%	42.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.467[a]	9	.943
Likelihood Ratio	3.514	9	.940
N of Valid Cases	177		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 3.86.

8.9.6.3 Crosstabulation Table by Company for Top Level 1 Enabler "Interpersonal"

Company * Interpersonal Crosstabulation

			Interpersonal 0	Interpersonal 1	Total
Company	A	Count	9	8	17
		Expected Count	12.3	4.7	17.0
		% within Company	52.9%	47.1%	100.0%
		% within Interpersonal	7.0%	16.3%	9.6%
		% of Total	5.1%	4.5%	9.6%
	B	Count	11	6	17
		Expected Count	12.3	4.7	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Interpersonal	8.6%	12.2%	9.6%
		% of Total	6.2%	3.4%	9.6%
	C	Count	12	5	17
		Expected Count	12.3	4.7	17.0
		% within Company	70.6%	29.4%	100.0%
		% within Interpersonal	9.4%	10.2%	9.6%
		% of Total	6.8%	2.8%	9.6%
	D	Count	15	4	19
		Expected Count	13.7	5.3	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Interpersonal	11.7%	8.2%	10.7%
		% of Total	8.5%	2.3%	10.7%
	E	Count	14	4	18
		Expected Count	13.0	5.0	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Interpersonal	10.9%	8.2%	10.2%
		% of Total	7.9%	2.3%	10.2%
	F	Count	17	4	21
		Expected Count	15.2	5.8	21.0
		% within Company	81.0%	19.0%	100.0%
		% within Interpersonal	13.3%	8.2%	11.9%
		% of Total	9.6%	2.3%	11.9%
	G	Count	7	2	9
		Expected Count	6.5	2.5	9.0
		% within Company	77.8%	22.2%	100.0%
		% within Interpersonal	5.5%	4.1%	5.1%
		% of Total	4.0%	1.1%	5.1%
	H	Count	14	5	19
		Expected Count	13.7	5.3	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Interpersonal	10.9%	10.2%	10.7%
		% of Total	7.9%	2.8%	10.7%
	I	Count	13	2	15
		Expected Count	10.8	4.2	15.0
		% within Company	86.7%	13.3%	100.0%
		% within Interpersonal	10.2%	4.1%	8.5%
		% of Total	7.3%	1.1%	8.5%
	J	Count	16	9	25
		Expected Count	18.1	6.9	25.0
		% within Company	64.0%	36.0%	100.0%
		% within Interpersonal	12.5%	18.4%	14.1%
		% of Total	9.0%	5.1%	14.1%
Total		Count	128	49	177
		Expected Count	128.0	49.0	177.0
		% within Company	72.3%	27.7%	100.0%
		% within Interpersonal	100.0%	100.0%	100.0%
		% of Total	72.3%	27.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.731[a]	9	.561
Likelihood Ratio	7.696	9	.565
N of Valid Cases	177		

a. 6 cells (30.0%) have expected count less than 5. The minimum expected count is 2.49.

8.9.6.4 *Crosstabulation Table by Company for Top Level 1 Enabler "Organization"*

Company * Organization Crosstabulation

			Organization		
			0	1	Total
Company	A	Count	13	4	17
		Expected Count	12.7	4.3	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Organization	9.8%	8.9%	9.6%
		% of Total	7.3%	2.3%	9.6%
	B	Count	11	6	17
		Expected Count	12.7	4.3	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Organization	8.3%	13.3%	9.6%
		% of Total	6.2%	3.4%	9.6%
	C	Count	16	1	17
		Expected Count	12.7	4.3	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Organization	12.1%	2.2%	9.6%
		% of Total	9.0%	.6%	9.6%
	D	Count	15	4	19
		Expected Count	14.2	4.8	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Organization	11.4%	8.9%	10.7%
		% of Total	8.5%	2.3%	10.7%
	E	Count	11	7	18
		Expected Count	13.4	4.6	18.0
		% within Company	61.1%	38.9%	100.0%
		% within Organization	8.3%	15.6%	10.2%
		% of Total	6.2%	4.0%	10.2%
	F	Count	14	7	21
		Expected Count	15.7	5.3	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Organization	10.6%	15.6%	11.9%
		% of Total	7.9%	4.0%	11.9%
	G	Count	8	1	9
		Expected Count	6.7	2.3	9.0
		% within Company	88.9%	11.1%	100.0%
		% within Organization	6.1%	2.2%	5.1%
		% of Total	4.5%	.6%	5.1%
	H	Count	14	5	19
		Expected Count	14.2	4.8	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Organization	10.6%	11.1%	10.7%
		% of Total	7.9%	2.8%	10.7%
	I	Count	14	1	15
		Expected Count	11.2	3.8	15.0
		% within Company	93.3%	6.7%	100.0%
		% within Organization	10.6%	2.2%	8.5%
		% of Total	7.9%	.6%	8.5%
	J	Count	16	9	25
		Expected Count	18.6	6.4	25.0
		% within Company	64.0%	36.0%	100.0%
		% within Organization	12.1%	20.0%	14.1%
		% of Total	9.0%	5.1%	14.1%
Total		Count	132	45	177
		Expected Count	132.0	45.0	177.0
		% within Company	74.6%	25.4%	100.0%
		% within Organization	100.0%	100.0%	100.0%
		% of Total	74.6%	25.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.174[a]	9	.204
Likelihood Ratio	13.921	9	.125
N of Valid Cases	177		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is 2.29.

8.9.6.5 Crosstabulation Table by Company for Top Level 1 Enabler "Interventions"

Company * Interventions Crosstabulation

			Interventions 0	Interventions 1	Total
Company	A	Count	15	2	17
		Expected Count	13.3	3.7	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Interventions	10.9%	5.1%	9.6%
		% of Total	8.5%	1.1%	9.6%
	B	Count	11	6	17
		Expected Count	13.3	3.7	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Interventions	8.0%	15.4%	9.6%
		% of Total	6.2%	3.4%	9.6%
	C	Count	13	4	17
		Expected Count	13.3	3.7	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Interventions	9.4%	10.3%	9.6%
		% of Total	7.3%	2.3%	9.6%
	D	Count	13	6	19
		Expected Count	14.8	4.2	19.0
		% within Company	68.4%	31.6%	100.0%
		% within Interventions	9.4%	15.4%	10.7%
		% of Total	7.3%	3.4%	10.7%
	E	Count	14	4	18
		Expected Count	14.0	4.0	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Interventions	10.1%	10.3%	10.2%
		% of Total	7.9%	2.3%	10.2%
	F	Count	19	2	21
		Expected Count	16.4	4.6	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Interventions	13.8%	5.1%	11.9%
		% of Total	10.7%	1.1%	11.9%
	G	Count	8	1	9
		Expected Count	7.0	2.0	9.0
		% within Company	88.9%	11.1%	100.0%
		% within Interventions	5.8%	2.6%	5.1%
		% of Total	4.5%	.6%	5.1%
	H	Count	15	4	19
		Expected Count	14.8	4.2	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Interventions	10.9%	10.3%	10.7%
		% of Total	8.5%	2.3%	10.7%
	I	Count	10	5	15
		Expected Count	11.7	3.3	15.0
		% within Company	66.7%	33.3%	100.0%
		% within Interventions	7.2%	12.8%	8.5%
		% of Total	5.6%	2.8%	8.5%
	J	Count	20	5	25
		Expected Count	19.5	5.5	25.0
		% within Company	80.0%	20.0%	100.0%
		% within Interventions	14.5%	12.8%	14.1%
		% of Total	11.3%	2.8%	14.1%
Total		Count	138	39	177
		Expected Count	138.0	39.0	177.0
		% within Company	78.0%	22.0%	100.0%
		% within Interventions	100.0%	100.0%	100.0%
		% of Total	78.0%	22.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.538[a]	9	.581
Likelihood Ratio	7.809	9	.553
N of Valid Cases	177		

a. 9 cells (45.0%) have expected count less than 5. The minimum expected count is 1.98.

8.9.6.6 Crosstabulation Table by Company for Top Level 1 Enabler "Tools & Methodology"

Company * Tools & Methodology Crosstabulation

			Tools & Methodology		
			0	1	Total
Company	A	Count	11	6	17
		Expected Count	15.3	1.7	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Tools & Methodology	6.9%	33.3%	9.6%
		% of Total	6.2%	3.4%	9.6%
	B	Count	16	1	17
		Expected Count	15.3	1.7	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Tools & Methodology	10.1%	5.6%	9.6%
		% of Total	9.0%	.6%	9.6%
	C	Count	15	2	17
		Expected Count	15.3	1.7	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Tools & Methodology	9.4%	11.1%	9.6%
		% of Total	8.5%	1.1%	9.6%
	D	Count	18	1	19
		Expected Count	17.1	1.9	19.0
		% within Company	94.7%	5.3%	100.0%
		% within Tools & Methodology	11.3%	5.6%	10.7%
		% of Total	10.2%	.6%	10.7%
	E	Count	16	2	18
		Expected Count	16.2	1.8	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Tools & Methodology	10.1%	11.1%	10.2%
		% of Total	9.0%	1.1%	10.2%
	F	Count	20	1	21
		Expected Count	18.9	2.1	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Tools & Methodology	12.6%	5.6%	11.9%
		% of Total	11.3%	.6%	11.9%
	G	Count	8	1	9
		Expected Count	8.1	.9	9.0
		% within Company	88.9%	11.1%	100.0%
		% within Tools & Methodology	5.0%	5.6%	5.1%
		% of Total	4.5%	.6%	5.1%
	H	Count	19	0	19
		Expected Count	17.1	1.9	19.0
		% within Company	100.0%	.0%	100.0%
		% within Tools & Methodology	11.9%	.0%	10.7%
		% of Total	10.7%	.0%	10.7%
	I	Count	13	2	15
		Expected Count	13.5	1.5	15.0
		% within Company	86.7%	13.3%	100.0%
		% within Tools & Methodology	8.2%	11.1%	8.5%
		% of Total	7.3%	1.1%	8.5%
	J	Count	23	2	25
		Expected Count	22.5	2.5	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Tools & Methodology	14.5%	11.1%	14.1%
		% of Total	13.0%	1.1%	14.1%
Total		Count	159	18	177
		Expected Count	159.0	18.0	177.0
		% within Company	89.8%	10.2%	100.0%
		% within Tools & Methodology	100.0%	100.0%	100.0%
		% of Total	89.8%	10.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.780[a]	9	.072
Likelihood Ratio	13.964	9	.124
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .92.

8.9.7 Top Level 2 Enablers to the Development of Systems Thinking

Top Level 2 Enablers to the Development of Systems Thinking for All Participants (N=177)

Rank	Node Category	Number	Percent
1	Broad experience base	37	21%
2	Job/opportunity to see systems view	35	20%
3	Training	23	13%
4	Experience in general	17	10%
4	Education	17	10%
4	Innate	17	10%
4	Broad perspective	17	10%

Top Level 2 Enablers to the Development of Systems Thinking for Expert Panelists (N=35)

Rank	Node Category	Number	Percent
1	Job/opportunity to see systems view	8	23%
2	Broad experience base	7	20%
3	Current trends	4	11%

Top Level 2 Enablers to the Development of Systems Thinking for Senior Systems Engineers (N=52)

Rank	Node Category	Number	Percent
1	Broad experience base	18	35%
2	Training	11	21%
3	Job/opportunity to see systems view	8	15%
4	Innate	7	13%
4	Broad perspective	7	13%
6	Experience in general	6	12%
7	Step outside own box/comfort zone	5	10%

Top Level 2 Enablers to the Development of Systems Thinking for Senior Technical Specialists (N=43)

Rank	Node Category	Number	Percent
1	Job/opportunity to see systems view	10	23%
2	Broad experience base	8	19%
3	Experience in general	7	16%
4	Education	6	14%
4	Innate	6	14%
6	Broad perspective	5	12%
6	Mentors	5	12%

Top Level 2 Enablers to the Development of Systems Thinking for Junior Systems Engineers (N=47)

Rank	Node Category	Number	Percent
1	Job/opportunity to see systems view	9	19%
2	Teams	6	13%
3	Education	5	11%
3	Training	5	11%
3	Communication	5	11%
3	Cross disciplines	5	11%

8.9.8 Summary of Top Level 2 Enablers to the Development of Systems Thinking for All Classifications

Top Level 2 Enablers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=177)			Expert Panelists (N=35)			Senior Systems Engineers (N=52)			Senior Technical Specialists (N=43)			Junior Systems Engineers (N=47)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Broad experience base	1	37	21%	2	7	20%	1	18	35%	2	8	19%	7	4	9%	10.434	0.015
Job/opportunity to see systems view	2	35	20%	1	8	23%	3	8	15%	1	10	23%	1	9	19%	1.181	0.757
Training	3	23	13%	4	3	9%	2	11	21%	8	4	9%	3	5	11%	4.417	0.220
Experience in general	4	17	10%	16	1	3%	6	6	12%	3	7	16%	9	3	6%	4.828	0.185
Education	4	17	10%	10	2	6%	8	4	8%	4	6	14%	3	5	11%	1.824	0.610
Innate	4	17	10%	10	2	6%	4	7	13%	4	6	14%	13	2	4%	3.987	0.263
Broad perspective	4	17	10%	4	3	9%	4	7	13%	6	5	12%	13	2	4%	2.686	0.443
Current trends	10	12	7%	3	4	11%	8	4	8%	16	1	2%	9	3	6%	2.627	0.453
Step outside own box/comfort zone	12	10	6%	35	0	0%	7	5	10%	11	2	5%	9	3	6%	3.758	0.289
Mentors	8	13	7%	16	1	3%	14	3	6%	6	5	12%	7	4	9%	2.479	0.479
Teams	8	13	7%	16	1	3%	14	3	6%	9	3	7%	2	6	13%	3.264	0.353
Communication	10	12	7%	10	2	6%	8	4	8%	16	1	2%	3	5	11%	2.588	0.460
Cross disciplines	16	7	4%	35	0	0%	27	1	2%	16	1	2%	3	5	11%	7.834	0.050

8.9.9 Crosstabulation Tables by Classification for Top Level 2 Enablers

8.9.9.1 Crosstabulation Table by Classification for Top Level 2 Enabler "Broad Experience Base"

Translated Classification * Broad experience base Crosstabulation

			Broad experience base		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	28	7	35
		Expected Count	27.7	7.3	35.0
		% within Translated Classification	80.0%	20.0%	100.0%
		% within Broad experience base	20.0%	18.9%	19.8%
		% of Total	15.8%	4.0%	19.8%
	2_Senior Systems Engineer	Count	34	18	52
		Expected Count	41.1	10.9	52.0
		% within Translated Classification	65.4%	34.6%	100.0%
		% within Broad experience base	24.3%	48.6%	29.4%
		% of Total	19.2%	10.2%	29.4%
	3_Senior Tech Specialist	Count	35	8	43
		Expected Count	34.0	9.0	43.0
		% within Translated Classification	81.4%	18.6%	100.0%
		% within Broad experience base	25.0%	21.6%	24.3%
		% of Total	19.8%	4.5%	24.3%
	4_Junior Systems Engineer	Count	43	4	47
		Expected Count	37.2	9.8	47.0
		% within Translated Classification	91.5%	8.5%	100.0%
		% within Broad experience base	30.7%	10.8%	26.6%
		% of Total	24.3%	2.3%	26.6%
Total		Count	140	37	177
		Expected Count	140.0	37.0	177.0
		% within Translated Classification	79.1%	20.9%	100.0%
		% within Broad experience base	100.0%	100.0%	100.0%
		% of Total	79.1%	20.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.434[a]	3	.015
Likelihood Ratio	10.699	3	.013
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.32.

8.9.9.2 *Crosstabulation Table by Classification for Top Level 2 Enabler "Job/Opportunity to See Systems View"*

Translated Classification * Job/opportunity to see systems view Crosstabulation

			Job/opportunity to see systems view		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	27	8	35
		Expected Count	28.1	6.9	35.0
		% within Translated Classification	77.1%	22.9%	100.0%
		% within Job/opportunity to see systems view	19.0%	22.9%	19.8%
		% of Total	15.3%	4.5%	19.8%
	2_Senior Systems Engineer	Count	44	8	52
		Expected Count	41.7	10.3	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Job/opportunity to see systems view	31.0%	22.9%	29.4%
		% of Total	24.9%	4.5%	29.4%
	3_Senior Tech Specialist	Count	33	10	43
		Expected Count	34.5	8.5	43.0
		% within Translated Classification	76.7%	23.3%	100.0%
		% within Job/opportunity to see systems view	23.2%	28.6%	24.3%
		% of Total	18.6%	5.6%	24.3%
	4_Junior Systems Engineer	Count	38	9	47
		Expected Count	37.7	9.3	47.0
		% within Translated Classification	80.9%	19.1%	100.0%
		% within Job/opportunity to see systems view	26.8%	25.7%	26.6%
		% of Total	21.5%	5.1%	26.6%
Total		Count	142	35	177
		Expected Count	142.0	35.0	177.0
		% within Translated Classification	80.2%	19.8%	100.0%
		% within Job/opportunity to see systems view	100.0%	100.0%	100.0%
		% of Total	80.2%	19.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.181[a]	3	.757
Likelihood Ratio	1.201	3	.753
N of Valid Cases	177		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.92.

8.9.9.3 Crosstabulation Table by Classification for Top Level 2 Enabler "Training"

Translated Classification * Training Crosstabulation

			Training		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	3	35
		Expected Count	30.5	4.5	35.0
		% within Translated Classification	91.4%	8.6%	100.0%
		% within Training	20.8%	13.0%	19.8%
		% of Total	18.1%	1.7%	19.8%
	2_Senior Systems Engineer	Count	41	11	52
		Expected Count	45.2	6.8	52.0
		% within Translated Classification	78.8%	21.2%	100.0%
		% within Training	26.6%	47.8%	29.4%
		% of Total	23.2%	6.2%	29.4%
	3_Senior Tech Specialist	Count	39	4	43
		Expected Count	37.4	5.6	43.0
		% within Translated Classification	90.7%	9.3%	100.0%
		% within Training	25.3%	17.4%	24.3%
		% of Total	22.0%	2.3%	24.3%
	4_Junior Systems Engineer	Count	42	5	47
		Expected Count	40.9	6.1	47.0
		% within Translated Classification	89.4%	10.6%	100.0%
		% within Training	27.3%	21.7%	26.6%
		% of Total	23.7%	2.8%	26.6%
Total		Count	154	23	177
		Expected Count	154.0	23.0	177.0
		% within Translated Classification	87.0%	13.0%	100.0%
		% within Training	100.0%	100.0%	100.0%
		% of Total	87.0%	13.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.417[a]	3	.220
Likelihood Ratio	4.134	3	.247
N of Valid Cases	177		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.55.

8.9.9.4 Crosstabulation Table by Classification for Top Level 2 Enabler "Experience in General"

Translated Classification * Experience in general Crosstabulation

			Experience in general		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	34	1	35
		Expected Count	31.6	3.4	35.0
		% within Translated Classification	97.1%	2.9%	100.0%
		% within Experience in general	21.3%	5.9%	19.8%
		% of Total	19.2%	.6%	19.8%
	2_Senior Systems Engineer	Count	46	6	52
		Expected Count	47.0	5.0	52.0
		% within Translated Classification	88.5%	11.5%	100.0%
		% within Experience in general	28.8%	35.3%	29.4%
		% of Total	26.0%	3.4%	29.4%
	3_Senior Tech Specialist	Count	36	7	43
		Expected Count	38.9	4.1	43.0
		% within Translated Classification	83.7%	16.3%	100.0%
		% within Experience in general	22.5%	41.2%	24.3%
		% of Total	20.3%	4.0%	24.3%
	4_Junior Systems Engineer	Count	44	3	47
		Expected Count	42.5	4.5	47.0
		% within Translated Classification	93.6%	6.4%	100.0%
		% within Experience in general	27.5%	17.6%	26.6%
		% of Total	24.9%	1.7%	26.6%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Experience in general	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.828[a]	3	.185
Likelihood Ratio	5.176	3	.159
N of Valid Cases	177		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.36.

8.9.9.5 Crosstabulation Table by Classification for Top Level 2 Enabler "Education"

Translated Classification * Education Crosstabulation

			Education		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	33	2	35
		Expected Count	31.6	3.4	35.0
		% within Translated Classification	94.3%	5.7%	100.0%
		% within Education	20.6%	11.8%	19.8%
		% of Total	18.6%	1.1%	19.8%
	2_Senior Systems Engineer	Count	48	4	52
		Expected Count	47.0	5.0	52.0
		% within Translated Classification	92.3%	7.7%	100.0%
		% within Education	30.0%	23.5%	29.4%
		% of Total	27.1%	2.3%	29.4%
	3_Senior Tech Specialist	Count	37	6	43
		Expected Count	38.9	4.1	43.0
		% within Translated Classification	86.0%	14.0%	100.0%
		% within Education	23.1%	35.3%	24.3%
		% of Total	20.9%	3.4%	24.3%
	4_Junior Systems Engineer	Count	42	5	47
		Expected Count	42.5	4.5	47.0
		% within Translated Classification	89.4%	10.6%	100.0%
		% within Education	26.3%	29.4%	26.6%
		% of Total	23.7%	2.8%	26.6%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Education	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.824[a]	3	.610
Likelihood Ratio	1.827	3	.609
N of Valid Cases	177		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.36.

8.9.9.6 Crosstabulation Table by Classification for Top Level 2 Enabler "Innate"

Translated Classification * Innate Crosstabulation

			Innate		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	33	2	35
		Expected Count	31.6	3.4	35.0
		% within Translated Classification	94.3%	5.7%	100.0%
		% within Innate	20.6%	11.8%	19.8%
		% of Total	18.6%	1.1%	19.8%
	2_Senior Systems Engineer	Count	45	7	52
		Expected Count	47.0	5.0	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Innate	28.1%	41.2%	29.4%
		% of Total	25.4%	4.0%	29.4%
	3_Senior Tech Specialist	Count	37	6	43
		Expected Count	38.9	4.1	43.0
		% within Translated Classification	86.0%	14.0%	100.0%
		% within Innate	23.1%	35.3%	24.3%
		% of Total	20.9%	3.4%	24.3%
	4_Junior Systems Engineer	Count	45	2	47
		Expected Count	42.5	4.5	47.0
		% within Translated Classification	95.7%	4.3%	100.0%
		% within Innate	28.1%	11.8%	26.6%
		% of Total	25.4%	1.1%	26.6%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Innate	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.987[a]	3	.263
Likelihood Ratio	4.257	3	.235
N of Valid Cases	177		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.36.

8.9.9.7 Crosstabulation Table by Classification for Top Level 2 Enabler "Broad Perspective"

Translated Classification * Broad perspective Crosstabulation

			Broad perspective		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	3	35
		Expected Count	31.6	3.4	35.0
		% within Translated Classification	91.4%	8.6%	100.0%
		% within Broad perspective	20.0%	17.6%	19.8%
		% of Total	18.1%	1.7%	19.8%
	2_Senior Systems Engineer	Count	45	7	52
		Expected Count	47.0	5.0	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Broad perspective	28.1%	41.2%	29.4%
		% of Total	25.4%	4.0%	29.4%
	3_Senior Tech Specialist	Count	38	5	43
		Expected Count	38.9	4.1	43.0
		% within Translated Classification	88.4%	11.6%	100.0%
		% within Broad perspective	23.8%	29.4%	24.3%
		% of Total	21.5%	2.8%	24.3%
	4_Junior Systems Engineer	Count	45	2	47
		Expected Count	42.5	4.5	47.0
		% within Translated Classification	95.7%	4.3%	100.0%
		% within Broad perspective	28.1%	11.8%	26.6%
		% of Total	25.4%	1.1%	26.6%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Broad perspective	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.686[a]	3	.443
Likelihood Ratio	2.956	3	.399
N of Valid Cases	177		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.36.

8.9.10 Crosstabulation Tables by Company for Top Level 2 Enablers

8.9.10.1 Crosstabulation Table by Company for Top Level 2 Enabler "Broad Experience Base"

Company * Broad experience base Crosstabulation

			Broad experience base 0	Broad experience base 1	Total
Company	A	Count	14	3	17
		Expected Count	13.4	3.6	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Broad experience base	10.0%	8.1%	9.6%
		% of Total	7.9%	1.7%	9.6%
	B	Count	13	4	17
		Expected Count	13.4	3.6	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Broad experience base	9.3%	10.8%	9.6%
		% of Total	7.3%	2.3%	9.6%
	C	Count	15	2	17
		Expected Count	13.4	3.6	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Broad experience base	10.7%	5.4%	9.6%
		% of Total	8.5%	1.1%	9.6%
	D	Count	17	2	19
		Expected Count	15.0	4.0	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Broad experience base	12.1%	5.4%	10.7%
		% of Total	9.6%	1.1%	10.7%
	E	Count	15	3	18
		Expected Count	14.2	3.8	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Broad experience base	10.7%	8.1%	10.2%
		% of Total	8.5%	1.7%	10.2%
	F	Count	14	7	21
		Expected Count	16.6	4.4	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Broad experience base	10.0%	18.9%	11.9%
		% of Total	7.9%	4.0%	11.9%
	G	Count	7	2	9
		Expected Count	7.1	1.9	9.0
		% within Company	77.8%	22.2%	100.0%
		% within Broad experience base	5.0%	5.4%	5.1%
		% of Total	4.0%	1.1%	5.1%
	H	Count	16	3	19
		Expected Count	15.0	4.0	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Broad experience base	11.4%	8.1%	10.7%
		% of Total	9.0%	1.7%	10.7%
	I	Count	11	4	15
		Expected Count	11.9	3.1	15.0
		% within Company	73.3%	26.7%	100.0%
		% within Broad experience base	7.9%	10.8%	8.5%
		% of Total	6.2%	2.3%	8.5%
	J	Count	18	7	25
		Expected Count	19.8	5.2	25.0
		% within Company	72.0%	28.0%	100.0%
		% within Broad experience base	12.9%	18.9%	14.1%
		% of Total	10.2%	4.0%	14.1%
Total		Count	140	37	177
		Expected Count	140.0	37.0	177.0
		% within Company	79.1%	20.9%	100.0%
		% within Broad experience base	100.0%	100.0%	100.0%
		% of Total	79.1%	20.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.807[a]	9	.759
Likelihood Ratio	5.885	9	.751
N of Valid Cases	177		

a. 9 cells (45.0%) have expected count less than 5. The minimum expected count is 1.88.

8.9.10.2 Crosstabulation Table by Company for Top Level 2 Enabler "Job/Opportunity to See Systems View"

Company * Job/opportunity to see systems view Crosstabulation

			Job/opportunity to see systems view		
			0	1	Total
Company	A	Count	15	2	17
		Expected Count	13.6	3.4	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Job/opportunity to see systems view	10.6%	5.7%	9.6%
		% of Total	8.5%	1.1%	9.6%
	B	Count	11	6	17
		Expected Count	13.6	3.4	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Job/opportunity to see systems view	7.7%	17.1%	9.6%
		% of Total	6.2%	3.4%	9.6%
	C	Count	12	5	17
		Expected Count	13.6	3.4	17.0
		% within Company	70.6%	29.4%	100.0%
		% within Job/opportunity to see systems view	8.5%	14.3%	9.6%
		% of Total	6.8%	2.8%	9.6%
	D	Count	16	3	19
		Expected Count	15.2	3.8	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Job/opportunity to see systems view	11.3%	8.6%	10.7%
		% of Total	9.0%	1.7%	10.7%
	E	Count	16	2	18
		Expected Count	14.4	3.6	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Job/opportunity to see systems view	11.3%	5.7%	10.2%
		% of Total	9.0%	1.1%	10.2%
	F	Count	13	8	21
		Expected Count	16.8	4.2	21.0
		% within Company	61.9%	38.1%	100.0%
		% within Job/opportunity to see systems view	9.2%	22.9%	11.9%
		% of Total	7.3%	4.5%	11.9%
	G	Count	9	0	9
		Expected Count	7.2	1.8	9.0
		% within Company	100.0%	.0%	100.0%
		% within Job/opportunity to see systems view	6.3%	.0%	5.1%
		% of Total	5.1%	.0%	5.1%
	H	Count	15	4	19
		Expected Count	15.2	3.8	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Job/opportunity to see systems view	10.6%	11.4%	10.7%
		% of Total	8.5%	2.3%	10.7%
	I	Count	11	4	15
		Expected Count	12.0	3.0	15.0
		% within Company	73.3%	26.7%	100.0%
		% within Job/opportunity to see systems view	7.7%	11.4%	8.5%
		% of Total	6.2%	2.3%	8.5%
	J	Count	24	1	25
		Expected Count	20.1	4.9	25.0
		% within Company	96.0%	4.0%	100.0%
		% within Job/opportunity to see systems view	16.9%	2.9%	14.1%
		% of Total	13.6%	.6%	14.1%
Total		Count	142	35	177
		Expected Count	142.0	35.0	177.0
		% within Company	80.2%	19.8%	100.0%
		% within Job/opportunity to see systems view	100.0%	100.0%	100.0%
		% of Total	80.2%	19.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.357[a]	9	.060
Likelihood Ratio	18.647	9	.028
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.78.

8.9.10.3 Crosstabulation Table by Company for Top Level 2 Enabler "Training"

Company * Training Crosstabulation

			Training		
			0	1	Total
Company	A	Count	15	2	17
		Expected Count	14.8	2.2	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Training	9.7%	8.7%	9.6%
		% of Total	8.5%	1.1%	9.6%
	B	Count	13	4	17
		Expected Count	14.8	2.2	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Training	8.4%	17.4%	9.6%
		% of Total	7.3%	2.3%	9.6%
	C	Count	14	3	17
		Expected Count	14.8	2.2	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Training	9.1%	13.0%	9.6%
		% of Total	7.9%	1.7%	9.6%
	D	Count	15	4	19
		Expected Count	16.5	2.5	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Training	9.7%	17.4%	10.7%
		% of Total	8.5%	2.3%	10.7%
	E	Count	17	1	18
		Expected Count	15.7	2.3	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Training	11.0%	4.3%	10.2%
		% of Total	9.6%	.6%	10.2%
	F	Count	19	2	21
		Expected Count	18.3	2.7	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Training	12.3%	8.7%	11.9%
		% of Total	10.7%	1.1%	11.9%
	G	Count	8	1	9
		Expected Count	7.8	1.2	9.0
		% within Company	88.9%	11.1%	100.0%
		% within Training	5.2%	4.3%	5.1%
		% of Total	4.5%	.6%	5.1%
	H	Count	17	2	19
		Expected Count	16.5	2.5	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Training	11.0%	8.7%	10.7%
		% of Total	9.6%	1.1%	10.7%
	I	Count	13	2	15
		Expected Count	13.1	1.9	15.0
		% within Company	86.7%	13.3%	100.0%
		% within Training	8.4%	8.7%	8.5%
		% of Total	7.3%	1.1%	8.5%
	J	Count	23	2	25
		Expected Count	21.8	3.2	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Training	14.9%	8.7%	14.1%
		% of Total	13.0%	1.1%	14.1%
Total		Count	154	23	177
		Expected Count	154.0	23.0	177.0
		% within Company	87.0%	13.0%	100.0%
		% within Training	100.0%	100.0%	100.0%
		% of Total	87.0%	13.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.897[a]	9	.843
Likelihood Ratio	4.759	9	.855
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.17.

8.9.10.4 Crosstabulation Table by Company for Top Level 2 Enabler "Experience in General"

Company * Experience in general Crosstabulation

			Experience in general		
			0	1	Total
Company	A	Count	14	3	17
		Expected Count	15.4	1.6	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Experience in general	8.8%	17.6%	9.6%
		% of Total	7.9%	1.7%	9.6%
	B	Count	16	1	17
		Expected Count	15.4	1.6	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Experience in general	10.0%	5.9%	9.6%
		% of Total	9.0%	.6%	9.6%
	C	Count	14	3	17
		Expected Count	15.4	1.6	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Experience in general	8.8%	17.6%	9.6%
		% of Total	7.9%	1.7%	9.6%
	D	Count	19	0	19
		Expected Count	17.2	1.8	19.0
		% within Company	100.0%	.0%	100.0%
		% within Experience in general	11.9%	.0%	10.7%
		% of Total	10.7%	.0%	10.7%
	E	Count	16	2	18
		Expected Count	16.3	1.7	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Experience in general	10.0%	11.8%	10.2%
		% of Total	9.0%	1.1%	10.2%
	F	Count	20	1	21
		Expected Count	19.0	2.0	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Experience in general	12.5%	5.9%	11.9%
		% of Total	11.3%	.6%	11.9%
	G	Count	8	1	9
		Expected Count	8.1	.9	9.0
		% within Company	88.9%	11.1%	100.0%
		% within Experience in general	5.0%	5.9%	5.1%
		% of Total	4.5%	.6%	5.1%
	H	Count	18	1	19
		Expected Count	17.2	1.8	19.0
		% within Company	94.7%	5.3%	100.0%
		% within Experience in general	11.3%	5.9%	10.7%
		% of Total	10.2%	.6%	10.7%
	I	Count	12	3	15
		Expected Count	13.6	1.4	15.0
		% within Company	80.0%	20.0%	100.0%
		% within Experience in general	7.5%	17.6%	8.5%
		% of Total	6.8%	1.7%	8.5%
	J	Count	23	2	25
		Expected Count	22.6	2.4	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Experience in general	14.4%	11.8%	14.1%
		% of Total	13.0%	1.1%	14.1%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Company	90.4%	9.6%	100.0%
		% within Experience in general	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.815[a]	9	.553
Likelihood Ratio	9.014	9	.436
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .86.

8.9.10.5 Crosstabulation Table by Company for Top Level 2 Enabler "Education"

Company * Education Crosstabulation

			Education		
			0	1	Total
Company	A	Count	17	0	17
		Expected Count	15.4	1.6	17.0
		% within Company	100.0%	.0%	100.0%
		% within Education	10.6%	.0%	9.6%
		% of Total	9.6%	.0%	9.6%
	B	Count	15	2	17
		Expected Count	15.4	1.6	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Education	9.4%	11.8%	9.6%
		% of Total	8.5%	1.1%	9.6%
	C	Count	16	1	17
		Expected Count	15.4	1.6	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Education	10.0%	5.9%	9.6%
		% of Total	9.0%	.6%	9.6%
	D	Count	17	2	19
		Expected Count	17.2	1.8	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Education	10.6%	11.8%	10.7%
		% of Total	9.6%	1.1%	10.7%
	E	Count	14	4	18
		Expected Count	16.3	1.7	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Education	8.8%	23.5%	10.2%
		% of Total	7.9%	2.3%	10.2%
	F	Count	21	0	21
		Expected Count	19.0	2.0	21.0
		% within Company	100.0%	.0%	100.0%
		% within Education	13.1%	.0%	11.9%
		% of Total	11.9%	.0%	11.9%
	G	Count	9	0	9
		Expected Count	8.1	.9	9.0
		% within Company	100.0%	.0%	100.0%
		% within Education	5.6%	.0%	5.1%
		% of Total	5.1%	.0%	5.1%
	H	Count	18	1	19
		Expected Count	17.2	1.8	19.0
		% within Company	94.7%	5.3%	100.0%
		% within Education	11.3%	5.9%	10.7%
		% of Total	10.2%	.6%	10.7%
	I	Count	12	3	15
		Expected Count	13.6	1.4	15.0
		% within Company	80.0%	20.0%	100.0%
		% within Education	7.5%	17.6%	8.5%
		% of Total	6.8%	1.7%	8.5%
	J	Count	21	4	25
		Expected Count	22.6	2.4	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Education	13.1%	23.5%	14.1%
		% of Total	11.9%	2.3%	14.1%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Company	90.4%	9.6%	100.0%
		% within Education	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.133[a]	9	.206
Likelihood Ratio	15.363	9	.081
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .86.

8.9.10.6 Crosstabulation Table by Company for Top Level 2 Enabler "Innate"

Company * Innate Crosstabulation

			Innate 0	Innate 1	Total
Company	A	Count	17	0	17
		Expected Count	15.4	1.6	17.0
		% within Company	100.0%	.0%	100.0%
		% within Innate	10.6%	.0%	9.6%
		% of Total	9.6%	.0%	9.6%
	B	Count	15	2	17
		Expected Count	15.4	1.6	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Innate	9.4%	11.8%	9.6%
		% of Total	8.5%	1.1%	9.6%
	C	Count	15	2	17
		Expected Count	15.4	1.6	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Innate	9.4%	11.8%	9.6%
		% of Total	8.5%	1.1%	9.6%
	D	Count	14	5	19
		Expected Count	17.2	1.8	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Innate	8.8%	29.4%	10.7%
		% of Total	7.9%	2.8%	10.7%
	E	Count	18	0	18
		Expected Count	16.3	1.7	18.0
		% within Company	100.0%	.0%	100.0%
		% within Innate	11.3%	.0%	10.2%
		% of Total	10.2%	.0%	10.2%
	F	Count	18	3	21
		Expected Count	19.0	2.0	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Innate	11.3%	17.6%	11.9%
		% of Total	10.2%	1.7%	11.9%
	G	Count	8	1	9
		Expected Count	8.1	.9	9.0
		% within Company	88.9%	11.1%	100.0%
		% within Innate	5.0%	5.9%	5.1%
		% of Total	4.5%	.6%	5.1%
	H	Count	18	1	19
		Expected Count	17.2	1.8	19.0
		% within Company	94.7%	5.3%	100.0%
		% within Innate	11.3%	5.9%	10.7%
		% of Total	10.2%	.6%	10.7%
	I	Count	14	1	15
		Expected Count	13.6	1.4	15.0
		% within Company	93.3%	6.7%	100.0%
		% within Innate	8.8%	5.9%	8.5%
		% of Total	7.9%	.6%	8.5%
	J	Count	23	2	25
		Expected Count	22.6	2.4	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Innate	14.4%	11.8%	14.1%
		% of Total	13.0%	1.1%	14.1%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Company	90.4%	9.6%	100.0%
		% within Innate	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.202[a]	9	.262
Likelihood Ratio	12.816	9	.171
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .86.

8.9.10.7 Crosstabulation Table by Company for Top Level 2 Enabler "Broad Perspective"

Company * Broad perspective Crosstabulation

			Broad perspective 0	Broad perspective 1	Total
Company	A	Count	15	2	17
		Expected Count	15.4	1.6	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Broad perspective	9.4%	11.8%	9.6%
		% of Total	8.5%	1.1%	9.6%
	B	Count	15	2	17
		Expected Count	15.4	1.6	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Broad perspective	9.4%	11.8%	9.6%
		% of Total	8.5%	1.1%	9.6%
	C	Count	16	1	17
		Expected Count	15.4	1.6	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Broad perspective	10.0%	5.9%	9.6%
		% of Total	9.0%	.6%	9.6%
	D	Count	19	0	19
		Expected Count	17.2	1.8	19.0
		% within Company	100.0%	.0%	100.0%
		% within Broad perspective	11.9%	.0%	10.7%
		% of Total	10.7%	.0%	10.7%
	E	Count	12	6	18
		Expected Count	16.3	1.7	18.0
		% within Company	66.7%	33.3%	100.0%
		% within Broad perspective	7.5%	35.3%	10.2%
		% of Total	6.8%	3.4%	10.2%
	F	Count	19	2	21
		Expected Count	19.0	2.0	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Broad perspective	11.9%	11.8%	11.9%
		% of Total	10.7%	1.1%	11.9%
	G	Count	9	0	9
		Expected Count	8.1	.9	9.0
		% within Company	100.0%	.0%	100.0%
		% within Broad perspective	5.6%	.0%	5.1%
		% of Total	5.1%	.0%	5.1%
	H	Count	16	3	19
		Expected Count	17.2	1.8	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Broad perspective	10.0%	17.6%	10.7%
		% of Total	9.0%	1.7%	10.7%
	I	Count	15	0	15
		Expected Count	13.6	1.4	15.0
		% within Company	100.0%	.0%	100.0%
		% within Broad perspective	9.4%	.0%	8.5%
		% of Total	8.5%	.0%	8.5%
	J	Count	24	1	25
		Expected Count	22.6	2.4	25.0
		% within Company	96.0%	4.0%	100.0%
		% within Broad perspective	15.0%	5.9%	14.1%
		% of Total	13.6%	.6%	14.1%
Total		Count	160	17	177
		Expected Count	160.0	17.0	177.0
		% within Company	90.4%	9.6%	100.0%
		% within Broad perspective	100.0%	100.0%	100.0%
		% of Total	90.4%	9.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.438[a]	9	.030
Likelihood Ratio	18.641	9	.028
N of Valid Cases	177		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .86.

8.10 Systems Thinking Individual Characteristics & Traits

8.10.1 Coding for Systems Thinking Individual Characteristics & Traits

Individual Characteristics and Traits	Total
Communication	27
Thinking	
- Even thinking	1
- Logical	8
- Longer-term view	4
- Independent thinking	1
- Synthesis	2
- Strategic thinking	1
- Connect knowledge you have	1
- Analytical	15
- Intuition	2
- Understand "why"	4
- Link external knowledge & disparate fields	3
- Abstract thinking	15
- Critical thinking	2
- Rationality	1
[redacted]	23
- -Think out-of-box	12
- - Creativity	7
- - Imagination	3
- - Innovative	1
- Skepticism	1
- Big picture AND detail thinking	6
- Enjoy complexity	1
- Challenging,probing mindset	2
- Rigorous thinking	1
- See similarities and differences	1
- Interpret results	1
- System as math function	1
- See pieces and how interoperate	3
- Ability to decompose	1
- Think on feet	2
- NOT thinking outside-the-box but expand box	1
- Natural way to think	1
- Thinkers	2
- Lateral thinking	1

- Particular mindset	4
- Diversity	1
- Technical wanderlust	2
[redacted]	71
- - Understand environment	3
- - Step outside comfort zone	1
- - Think outside component/discipline	4
- - Understand complete system	2
- - See system from outside	1
- - Wide view	1
- - Multiple perspectives	8
- - Generalist	5
- - Think broadly/big picture	46
- Systemic AND out-of-box thinking	1
- Think tech & social & time	1
- Strong intellect	7
Activities	
- Play with Legos	1
- Tinker/mechanical aptitude	8
- Play with computer mind worlds	1
- Farming	1
- Reading	2
- Arts	1
Problem Solving/Style	
- Change advocate	1
[redacted]	11
- - Ability to think shallow	1
- - Not anal	1
- - Not perfectionist	1
- - Lack deep technical understanding	1
- - Not detail focused	7
- Domain knowledge	5
- Navigate complexity	4
- Technical background	5
- Risk mitigation	1
[redacted]	27
- - Process	2
- - Detail oriented	4
- - Organized	8
- - Structured/methodical	11
- - Disciplined	2
- Assesses impact of statements	1

- Identify what's important	1
- Not hasty	3
- Explore various opinions and options	3
- Able to jump levels	3
- Empirical and intuitive	1
- Comfortable with lots of variables	1
- Multi-plex/multi-task	3
- Pragmatic	1
- Challenge ideas, never satisfied	5
- Results/answer oriented	2
- Ownership	2
- See answer right away	1
- Prevention focus	1
- No preconceived notions	2
- Operational sensitivity	1
- Propensities for BOTH premeditation AND action.	1
- Objective	2
- Compromise	2
- Type of worker	1
- Deal with issues as arise	1
- See correlations	1
- Start with requirements discussion	1
- Fearless	1
- Resistant to make assumptions	1
- Think failure modes	1
- Interested in solving problems and coming up with better designs	1
- Cause and effect	1
- Understand CONOPS	1
- See trade-offs and consequences	2
- Perseverance	1
- Boundaryless	2
- Doesn't want to work on same problem repeatedly	1
- Manage multiple issues quickly	1
- Insight	1
- Have a vision	1
[redacted]	13
- - Initiative/motivation	10
- - Takes on new challenges	1
- - Not afraid to take on any kind of problem	1
- - Want something new	1
Innate	7
No/not sure	11

Interventions	
- Training	3
- Education	17
Experience	
- Learn from mistakes	1
- One area of technical depth/exp with detail work	7
- Domain experience	2
- Experience in general	8
- Management experience	3
- Quick adjustment to new job	1
- System jobs/exposure	2
- Experience out of comfort zone	1
- Cultural	1
- Wide and varied background	12
Interpersonal	
- Networking	2
- Customer	4
- Understand politics	1
- Engage others	5
- Influence of others	1
- Knowledge transfer	1
- Strong interpersonal skills	22
- Leadership	4
- Teams	9
Personality	
- Attitude	1
- Outgoing/extrovert (not an introvert)	11
[redacted]	25
- - Tolerance for uncertainty	2
- - Tolerance for ambiguity	5
- - Adaptable/versatile	1
- - Flexible	7
- - Willing to take risks	8
- - Willing to accept change	2
- Open-minded	28
- Empathy	3
- Selflessness	1
- Open minded and anal retentive	1
- Compassionate	1
- Self-actualization	1
- Different personalities	1
- Humility	3

- Opinionated	1
- Good sense of humor	1
- Enthusiastic	5
- Cluster for questioning	36
- - Asks questions	24
- - Inquisitive, desire to question	12
- Stress-resistant/level-headed	2
- Gets bored easily	1
- Patience	4
- Hardworking	1
- Optimistic	1
- Willing to make mistakes	3
- Myers-Briggs/other	12
- Sensible/common-sense	2
- Aware	1
- Forward	1
- Not judgmental	2
- Introvert OR extrovert	2
- Competitive/don't like to fail	1
- Energetic	1
- Fearful	1
- Self-reliant	1
- Gut	1
- Cluster for Curiosity	45
- - Wants to know everything/how things work	6
- - Curiosity	39
- Courage	3
- Self-confidence	11
- Bizarre jokes	1
Wide range of interests	15
Listening	11

8.10.2 Level 1 Coding for Systems Thinking Individual Characteristics & Traits

Level 1 Systems Thinking Individual Characteristics and Traits	Total
Communication	27
Thinking	125
Activities	12
Problem Solving/Style	82
Innate	7
No/not sure	11
Interventions	19
Experience	32
Interpersonal	46
Personality	126
Wide range of interests	15
Listening	11

8.10.3 Top Level 1 Systems Thinking Individual Characteristics and Traits

Top Level 1 Systems Thinking Individual Characteristics and Traits for All Participants (N=202)

Rank	Node Category	Number	Percent
1	Personality	126	62%
2	Thinking	125	62%
3	Problem Solving/Style	82	41%
4	Interpersonal	46	23%
5	Experience	32	16%
6	Communication	27	13%
7	Interventions	19	9%

Top Level 1 Systems Thinking Individual Characteristics and Traits for Expert Panelists (N=37)

Rank	Node Category	Number	Percent
1	Personality	29	78%
2	Thinking	25	68%
3	Problem Solving/Style	15	41%
4	Interpersonal	12	32%
5	Communication	5	14%
6	Experience	4	11%

Top Level 1 Systems Thinking Individual Characteristics and Traits for Senior Systems Engineers (N=61)

Rank	Node Category	Number	Percent
1	Personality	39	64%
2	Thinking	34	56%
3	Problem Solving/Style	24	39%
4	Communication	11	18%
5	Interpersonal	10	16%
6	Interventions	8	13%
6	Experience	8	13%
8	Activities	7	11%

Top Level 1 Systems Thinking Individual Characteristics and Traits for Senior Technical Specialists (N=52)

Rank	Node Category	Number	Percent
1	Personality	32	62%
2	Thinking	29	56%
3	Problem Solving/Style	25	48%
4	Experience	10	19%
4	Interpersonal	10	19%
6	Wide range of interests	6	12%
7	No/not sure	5	10%

Top Level 1 Systems Thinking Individual Characteristics and Traits for Junior Systems Engineers (N=52)

Rank	Node Category	Number	Percent
1	Thinking	37	71%
2	Personality	26	50%
3	Problem Solving/Style	18	35%
4	Interpersonal	14	27%
5	Experience	10	19%
6	Communication	7	13%

8.10.4 Summary of Top Level 1 Systems Thinking Individual Characteristics and Traits for All Classifications

Top Level 1 Systems Thinking Individual Characteristics and Traits for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=165)			Expert Panelists (N=37)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=51)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Personality	1	126	62%	1	29	78%	1	39	64%	1	32	62%	2	26	50%	7.510	0.057
Thinking	2	125	62%	2	25	68%	2	34	56%	2	29	56%	1	37	71%	4.202	0.240
Problem Solving/Style	3	82	41%	3	15	41%	3	24	39%	3	25	48%	3	18	35%	2.018	0.569
Interpersonal	4	46	23%	4	12	32%	5	10	16%	4	10	19%	4	14	27%	4.255	0.235
Experience	5	32	16%	6	4	11%	6	8	13%	4	10	19%	5	10	19%	1.939	0.585
Communication	6	27	13%	5	5	14%	4	11	18%	9	4	8%	6	7	13%	2.594	0.459
Interventions	7	19	9%	10	2	5%	6	8	13%	7	5	10%	7	4	8%	1.861	0.602
Activities	9	12	6%	7	3	8%	8	7	11%	12	0	0%	11	2	4%	7.348	0.062
Wide range of interests	8	15	7%	10	2	5%	9	3	5%	6	6	12%	7	4	8%	2.063	0.560
No/not sure	10	11	5%	7	3	8%	10	2	3%	7	5	10%	12	1	2%	4.075	0.254

8.10.5 Crosstabulation Tables by Classification for Top Level 1 Systems Thinking Individual Characteristics and Traits

8.10.5.1 Crosstabulation Table by Classification for Top Level 1 Traits "Personality"

Translated Classification * Personality (Sum) Crosstabulation

			Personality (Sum)		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	8	29	37
		Expected Count	13.9	23.1	37.0
		% within Translated Classification	21.6%	78.4%	100.0%
		% within Personality (Sum)	10.5%	23.0%	18.3%
		% of Total	4.0%	14.4%	18.3%
	2_Senior Systems Engineer	Count	22	39	61
		Expected Count	23.0	38.0	61.0
		% within Translated Classification	36.1%	63.9%	100.0%
		% within Personality (Sum)	28.9%	31.0%	30.2%
		% of Total	10.9%	19.3%	30.2%
	3_Senior Tech Specialist	Count	20	32	52
		Expected Count	19.6	32.4	52.0
		% within Translated Classification	38.5%	61.5%	100.0%
		% within Personality (Sum)	26.3%	25.4%	25.7%
		% of Total	9.9%	15.8%	25.7%
	4_Junior Systems Engineer	Count	26	26	52
		Expected Count	19.6	32.4	52.0
		% within Translated Classification	50.0%	50.0%	100.0%
		% within Personality (Sum)	34.2%	20.6%	25.7%
		% of Total	12.9%	12.9%	25.7%
Total		Count	76	126	202
		Expected Count	76.0	126.0	202.0
		% within Translated Classification	37.6%	62.4%	100.0%
		% within Personality (Sum)	100.0%	100.0%	100.0%
		% of Total	37.6%	62.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.510[a]	3	.057
Likelihood Ratio	7.749	3	.052
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.92.

8.10.5.2 Crosstabulation Table by Classification for Top Level 1 Traits "Thinking"

Translated Classification * Thinking (Sum) Crosstabulation

			Thinking (Sum)		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	12	25	37
		Expected Count	14.1	22.9	37.0
		% within Translated Classification	32.4%	67.6%	100.0%
		% within Thinking (Sum)	15.6%	20.0%	18.3%
		% of Total	5.9%	12.4%	18.3%
	2_Senior Systems Engineer	Count	27	34	61
		Expected Count	23.3	37.7	61.0
		% within Translated Classification	44.3%	55.7%	100.0%
		% within Thinking (Sum)	35.1%	27.2%	30.2%
		% of Total	13.4%	16.8%	30.2%
	3_Senior Tech Specialist	Count	23	29	52
		Expected Count	19.8	32.2	52.0
		% within Translated Classification	44.2%	55.8%	100.0%
		% within Thinking (Sum)	29.9%	23.2%	25.7%
		% of Total	11.4%	14.4%	25.7%
	4_Junior Systems Engineer	Count	15	37	52
		Expected Count	19.8	32.2	52.0
		% within Translated Classification	28.8%	71.2%	100.0%
		% within Thinking (Sum)	19.5%	29.6%	25.7%
		% of Total	7.4%	18.3%	25.7%
Total		Count	77	125	202
		Expected Count	77.0	125.0	202.0
		% within Translated Classification	38.1%	61.9%	100.0%
		% within Thinking (Sum)	100.0%	100.0%	100.0%
		% of Total	38.1%	61.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.202[a]	3	.240
Likelihood Ratio	4.257	3	.235
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.10.

8.10.5.3 Crosstabulation Table by Classification for Top Level 1 Traits "Problem Solving/Style"

Translated Classification * Problem Solving/Style (Sum) Crosstabulation

			Problem Solving/Style (Sum)		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	22	15	37
		Expected Count	22.0	15.0	37.0
		% within Translated Classification	59.5%	40.5%	100.0%
		% within Problem Solving/Style (Sum)	18.3%	18.3%	18.3%
		% of Total	10.9%	7.4%	18.3%
	2_Senior Systems Engineer	Count	37	24	61
		Expected Count	36.2	24.8	61.0
		% within Translated Classification	60.7%	39.3%	100.0%
		% within Problem Solving/Style (Sum)	30.8%	29.3%	30.2%
		% of Total	18.3%	11.9%	30.2%
	3_Senior Tech Specialist	Count	27	25	52
		Expected Count	30.9	21.1	52.0
		% within Translated Classification	51.9%	48.1%	100.0%
		% within Problem Solving/Style (Sum)	22.5%	30.5%	25.7%
		% of Total	13.4%	12.4%	25.7%
	4_Junior Systems Engineer	Count	34	18	52
		Expected Count	30.9	21.1	52.0
		% within Translated Classification	65.4%	34.6%	100.0%
		% within Problem Solving/Style (Sum)	28.3%	22.0%	25.7%
		% of Total	16.8%	8.9%	25.7%
Total		Count	120	82	202
		Expected Count	120.0	82.0	202.0
		% within Translated Classification	59.4%	40.6%	100.0%
		% within Problem Solving/Style (Sum)	100.0%	100.0%	100.0%
		% of Total	59.4%	40.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.018[a]	3	.569
Likelihood Ratio	2.014	3	.570
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.02.

8.10.5.4 Crosstabulation Table by Classification for Top Level 1 Traits "Interpersonal"

Translated Classification * Interpersonal (Sum) Crosstabulation

			Interpersonal (Sum)		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	25	12	37
		Expected Count	28.6	8.4	37.0
		% within Translated Classification	67.6%	32.4%	100.0%
		% within Interpersonal (Sum)	16.0%	26.1%	18.3%
		% of Total	12.4%	5.9%	18.3%
	2_Senior Systems Engineer	Count	51	10	61
		Expected Count	47.1	13.9	61.0
		% within Translated Classification	83.6%	16.4%	100.0%
		% within Interpersonal (Sum)	32.7%	21.7%	30.2%
		% of Total	25.2%	5.0%	30.2%
	3_Senior Tech Specialist	Count	42	10	52
		Expected Count	40.2	11.8	52.0
		% within Translated Classification	80.8%	19.2%	100.0%
		% within Interpersonal (Sum)	26.9%	21.7%	25.7%
		% of Total	20.8%	5.0%	25.7%
	4_Junior Systems Engineer	Count	38	14	52
		Expected Count	40.2	11.8	52.0
		% within Translated Classification	73.1%	26.9%	100.0%
		% within Interpersonal (Sum)	24.4%	30.4%	25.7%
		% of Total	18.8%	6.9%	25.7%
Total		Count	156	46	202
		Expected Count	156.0	46.0	202.0
		% within Translated Classification	77.2%	22.8%	100.0%
		% within Interpersonal (Sum)	100.0%	100.0%	100.0%
		% of Total	77.2%	22.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.255[a]	3	.235
Likelihood Ratio	4.202	3	.240
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.43.

8.10.5.5 Crosstabulation Table by Classification for Top Level 1 Traits "Experience"

Translated Classification * Experience (Sum) Crosstabulation

			Experience (Sum)		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	33	4	37
		Expected Count	31.1	5.9	37.0
		% within Translated Classification	89.2%	10.8%	100.0%
		% within Experience (Sum)	19.4%	12.5%	18.3%
		% of Total	16.3%	2.0%	18.3%
	2_Senior Systems Engineer	Count	53	8	61
		Expected Count	51.3	9.7	61.0
		% within Translated Classification	86.9%	13.1%	100.0%
		% within Experience (Sum)	31.2%	25.0%	30.2%
		% of Total	26.2%	4.0%	30.2%
	3_Senior Tech Specialist	Count	42	10	52
		Expected Count	43.8	8.2	52.0
		% within Translated Classification	80.8%	19.2%	100.0%
		% within Experience (Sum)	24.7%	31.3%	25.7%
		% of Total	20.8%	5.0%	25.7%
	4_Junior Systems Engineer	Count	42	10	52
		Expected Count	43.8	8.2	52.0
		% within Translated Classification	80.8%	19.2%	100.0%
		% within Experience (Sum)	24.7%	31.3%	25.7%
		% of Total	20.8%	5.0%	25.7%
Total		Count	170	32	202
		Expected Count	170.0	32.0	202.0
		% within Translated Classification	84.2%	15.8%	100.0%
		% within Experience (Sum)	100.0%	100.0%	100.0%
		% of Total	84.2%	15.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.939[a]	3	.585
Likelihood Ratio	1.982	3	.576
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.86.

8.10.5.6 Crosstabulation Table by Classification for Top Level 1 Traits "Communication"

Translated Classification * Communication Crosstabulation

			Communication		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	32	5	37
		Expected Count	32.1	4.9	37.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Communication	18.3%	18.5%	18.3%
		% of Total	15.8%	2.5%	18.3%
	2_Senior Systems Engineer	Count	50	11	61
		Expected Count	52.8	8.2	61.0
		% within Translated Classification	82.0%	18.0%	100.0%
		% within Communication	28.6%	40.7%	30.2%
		% of Total	24.8%	5.4%	30.2%
	3_Senior Tech Specialist	Count	48	4	52
		Expected Count	45.0	7.0	52.0
		% within Translated Classification	92.3%	7.7%	100.0%
		% within Communication	27.4%	14.8%	25.7%
		% of Total	23.8%	2.0%	25.7%
	4_Junior Systems Engineer	Count	45	7	52
		Expected Count	45.0	7.0	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Communication	25.7%	25.9%	25.7%
		% of Total	22.3%	3.5%	25.7%
Total		Count	175	27	202
		Expected Count	175.0	27.0	202.0
		% within Translated Classification	86.6%	13.4%	100.0%
		% within Communication	100.0%	100.0%	100.0%
		% of Total	86.6%	13.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.594[a]	3	.459
Likelihood Ratio	2.722	3	.436
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.95.

8.10.6 Crosstabulation Tables by Company for Top Level 1 Systems Thinking Individual Characteristics and Traits

8.10.6.1 Crosstabulation Table by Company for Top Level 1 Traits "Personality"

Company * Personality (Sum) Crosstabulation

			Personality (Sum)		
			0	1	Total
Company	A	Count	7	11	18
		Expected Count	6.8	11.2	18.0
		% within Company	38.9%	61.1%	100.0%
		% within Personality (Sum)	9.2%	8.7%	8.9%
		% of Total	3.5%	5.4%	8.9%
	B	Count	6	11	17
		Expected Count	6.4	10.6	17.0
		% within Company	35.3%	64.7%	100.0%
		% within Personality (Sum)	7.9%	8.7%	8.4%
		% of Total	3.0%	5.4%	8.4%
	C	Count	10	15	25
		Expected Count	9.4	15.6	25.0
		% within Company	40.0%	60.0%	100.0%
		% within Personality (Sum)	13.2%	11.9%	12.4%
		% of Total	5.0%	7.4%	12.4%
	D	Count	7	14	21
		Expected Count	7.9	13.1	21.0
		% within Company	33.3%	66.7%	100.0%
		% within Personality (Sum)	9.2%	11.1%	10.4%
		% of Total	3.5%	6.9%	10.4%
	E	Count	6	14	20
		Expected Count	7.5	12.5	20.0
		% within Company	30.0%	70.0%	100.0%
		% within Personality (Sum)	7.9%	11.1%	9.9%
		% of Total	3.0%	6.9%	9.9%
	F	Count	6	17	23
		Expected Count	8.7	14.3	23.0
		% within Company	26.1%	73.9%	100.0%
		% within Personality (Sum)	7.9%	13.5%	11.4%
		% of Total	3.0%	8.4%	11.4%
	G	Count	5	6	11
		Expected Count	4.1	6.9	11.0
		% within Company	45.5%	54.5%	100.0%
		% within Personality (Sum)	6.6%	4.8%	5.4%
		% of Total	2.5%	3.0%	5.4%
	H	Count	10	11	21
		Expected Count	7.9	13.1	21.0
		% within Company	47.6%	52.4%	100.0%
		% within Personality (Sum)	13.2%	8.7%	10.4%
		% of Total	5.0%	5.4%	10.4%
	I	Count	9	9	18
		Expected Count	6.8	11.2	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Personality (Sum)	11.8%	7.1%	8.9%
		% of Total	4.5%	4.5%	8.9%
	J	Count	10	18	28
		Expected Count	10.5	17.5	28.0
		% within Company	35.7%	64.3%	100.0%
		% within Personality (Sum)	13.2%	14.3%	13.9%
		% of Total	5.0%	8.9%	13.9%
Total		Count	76	126	202
		Expected Count	76.0	126.0	202.0
		% within Company	37.6%	62.4%	100.0%
		% within Personality (Sum)	100.0%	100.0%	100.0%
		% of Total	37.6%	62.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.476[a]	9	.877
Likelihood Ratio	4.499	9	.876
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.14.

8.10.6.2 Crosstabulation Table by Company for Top Level 1 Traits "Thinking"

Company * Thinking (Sum) Crosstabulation

			Thinking (Sum)		
			0	1	Total
Company	A	Count	9	9	18
		Expected Count	6.9	11.1	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Thinking (Sum)	11.7%	7.2%	8.9%
		% of Total	4.5%	4.5%	8.9%
	B	Count	6	11	17
		Expected Count	6.5	10.5	17.0
		% within Company	35.3%	64.7%	100.0%
		% within Thinking (Sum)	7.8%	8.8%	8.4%
		% of Total	3.0%	5.4%	8.4%
	C	Count	12	13	25
		Expected Count	9.5	15.5	25.0
		% within Company	48.0%	52.0%	100.0%
		% within Thinking (Sum)	15.6%	10.4%	12.4%
		% of Total	5.9%	6.4%	12.4%
	D	Count	5	16	21
		Expected Count	8.0	13.0	21.0
		% within Company	23.8%	76.2%	100.0%
		% within Thinking (Sum)	6.5%	12.8%	10.4%
		% of Total	2.5%	7.9%	10.4%
	E	Count	8	12	20
		Expected Count	7.6	12.4	20.0
		% within Company	40.0%	60.0%	100.0%
		% within Thinking (Sum)	10.4%	9.6%	9.9%
		% of Total	4.0%	5.9%	9.9%
	F	Count	12	11	23
		Expected Count	8.8	14.2	23.0
		% within Company	52.2%	47.8%	100.0%
		% within Thinking (Sum)	15.6%	8.8%	11.4%
		% of Total	5.9%	5.4%	11.4%
	G	Count	3	8	11
		Expected Count	4.2	6.8	11.0
		% within Company	27.3%	72.7%	100.0%
		% within Thinking (Sum)	3.9%	6.4%	5.4%
		% of Total	1.5%	4.0%	5.4%
	H	Count	10	11	21
		Expected Count	8.0	13.0	21.0
		% within Company	47.6%	52.4%	100.0%
		% within Thinking (Sum)	13.0%	8.8%	10.4%
		% of Total	5.0%	5.4%	10.4%
	I	Count	2	16	18
		Expected Count	6.9	11.1	18.0
		% within Company	11.1%	88.9%	100.0%
		% within Thinking (Sum)	2.6%	12.8%	8.9%
		% of Total	1.0%	7.9%	8.9%
	J	Count	10	18	28
		Expected Count	10.7	17.3	28.0
		% within Company	35.7%	64.3%	100.0%
		% within Thinking (Sum)	13.0%	14.4%	13.9%
		% of Total	5.0%	8.9%	13.9%
Total		Count	77	125	202
		Expected Count	77.0	125.0	202.0
		% within Company	38.1%	61.9%	100.0%
		% within Thinking (Sum)	100.0%	100.0%	100.0%
		% of Total	38.1%	61.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.935[a]	9	.166
Likelihood Ratio	14.044	9	.121
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.19.

8.10.6.3 Crosstabulation Table by Company for Top Level 1 Traits "Problem Solving/Style"

Company * Problem Solving/Style (Sum) Crosstabulation

			Problem Solving/Style (Sum)		
			0	1	Total
Company	A	Count	10	8	18
		Expected Count	10.7	7.3	18.0
		% within Company	55.6%	44.4%	100.0%
		% within Problem Solving/Style (Sum)	8.3%	9.8%	8.9%
		% of Total	5.0%	4.0%	8.9%
	B	Count	12	5	17
		Expected Count	10.1	6.9	17.0
		% within Company	70.6%	29.4%	100.0%
		% within Problem Solving/Style (Sum)	10.0%	6.1%	8.4%
		% of Total	5.9%	2.5%	8.4%
	C	Count	14	11	25
		Expected Count	14.9	10.1	25.0
		% within Company	56.0%	44.0%	100.0%
		% within Problem Solving/Style (Sum)	11.7%	13.4%	12.4%
		% of Total	6.9%	5.4%	12.4%
	D	Count	14	7	21
		Expected Count	12.5	8.5	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Problem Solving/Style (Sum)	11.7%	8.5%	10.4%
		% of Total	6.9%	3.5%	10.4%
	E	Count	14	6	20
		Expected Count	11.9	8.1	20.0
		% within Company	70.0%	30.0%	100.0%
		% within Problem Solving/Style (Sum)	11.7%	7.3%	9.9%
		% of Total	6.9%	3.0%	9.9%
	F	Count	13	10	23
		Expected Count	13.7	9.3	23.0
		% within Company	56.5%	43.5%	100.0%
		% within Problem Solving/Style (Sum)	10.8%	12.2%	11.4%
		% of Total	6.4%	5.0%	11.4%
	G	Count	5	6	11
		Expected Count	6.5	4.5	11.0
		% within Company	45.5%	54.5%	100.0%
		% within Problem Solving/Style (Sum)	4.2%	7.3%	5.4%
		% of Total	2.5%	3.0%	5.4%
	H	Count	11	10	21
		Expected Count	12.5	8.5	21.0
		% within Company	52.4%	47.6%	100.0%
		% within Problem Solving/Style (Sum)	9.2%	12.2%	10.4%
		% of Total	5.4%	5.0%	10.4%
	I	Count	9	9	18
		Expected Count	10.7	7.3	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Problem Solving/Style (Sum)	7.5%	11.0%	8.9%
		% of Total	4.5%	4.5%	8.9%
	J	Count	18	10	28
		Expected Count	16.6	11.4	28.0
		% within Company	64.3%	35.7%	100.0%
		% within Problem Solving/Style (Sum)	15.0%	12.2%	13.9%
		% of Total	8.9%	5.0%	13.9%
Total		Count	120	82	202
		Expected Count	120.0	82.0	202.0
		% within Company	59.4%	40.6%	100.0%
		% within Problem Solving/Style (Sum)	100.0%	100.0%	100.0%
		% of Total	59.4%	40.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.836[a]	9	.848
Likelihood Ratio	4.881	9	.845
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.47.

8.10.6.4 Crosstabulation Table by Company for Top Level 1 Traits "Interpersonal"

Company * Interpersonal (Sum) Crosstabulation

			Interpersonal (Sum)		
			0	1	Total
Company	A	Count	13	5	18
		Expected Count	13.9	4.1	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Interpersonal (Sum)	8.3%	10.9%	8.9%
		% of Total	6.4%	2.5%	8.9%
	B	Count	14	3	17
		Expected Count	13.1	3.9	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Interpersonal (Sum)	9.0%	6.5%	8.4%
		% of Total	6.9%	1.5%	8.4%
	C	Count	19	6	25
		Expected Count	19.3	5.7	25.0
		% within Company	76.0%	24.0%	100.0%
		% within Interpersonal (Sum)	12.2%	13.0%	12.4%
		% of Total	9.4%	3.0%	12.4%
	D	Count	19	2	21
		Expected Count	16.2	4.8	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Interpersonal (Sum)	12.2%	4.3%	10.4%
		% of Total	9.4%	1.0%	10.4%
	E	Count	16	4	20
		Expected Count	15.4	4.6	20.0
		% within Company	80.0%	20.0%	100.0%
		% within Interpersonal (Sum)	10.3%	8.7%	9.9%
		% of Total	7.9%	2.0%	9.9%
	F	Count	17	6	23
		Expected Count	17.8	5.2	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Interpersonal (Sum)	10.9%	13.0%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	9	2	11
		Expected Count	8.5	2.5	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Interpersonal (Sum)	5.8%	4.3%	5.4%
		% of Total	4.5%	1.0%	5.4%
	H	Count	14	7	21
		Expected Count	16.2	4.8	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Interpersonal (Sum)	9.0%	15.2%	10.4%
		% of Total	6.9%	3.5%	10.4%
	I	Count	10	8	18
		Expected Count	13.9	4.1	18.0
		% within Company	55.6%	44.4%	100.0%
		% within Interpersonal (Sum)	6.4%	17.4%	8.9%
		% of Total	5.0%	4.0%	8.9%
	J	Count	25	3	28
		Expected Count	21.6	6.4	28.0
		% within Company	89.3%	10.7%	100.0%
		% within Interpersonal (Sum)	16.0%	6.5%	13.9%
		% of Total	12.4%	1.5%	13.9%
Total		Count	156	46	202
		Expected Count	156.0	46.0	202.0
		% within Company	77.2%	22.8%	100.0%
		% within Interpersonal (Sum)	100.0%	100.0%	100.0%
		% of Total	77.2%	22.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.445[a]	9	.246
Likelihood Ratio	11.491	9	.244
N of Valid Cases	202		

a. 7 cells (35.0%) have expected count less than 5. The minimum expected count is 2.50.

8.10.6.5 Crosstabulation Table by Company for Top Level 1 Traits "Experience"

Crosstab

			Experience (Sum)		
			0	1	Total
Company	A	Count	15	3	18
		Expected Count	15.1	2.9	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Experience (Sum)	8.8%	9.4%	8.9%
		% of Total	7.4%	1.5%	8.9%
	B	Count	13	4	17
		Expected Count	14.3	2.7	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Experience (Sum)	7.6%	12.5%	8.4%
		% of Total	6.4%	2.0%	8.4%
	C	Count	23	2	25
		Expected Count	21.0	4.0	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Experience (Sum)	13.5%	6.3%	12.4%
		% of Total	11.4%	1.0%	12.4%
	D	Count	19	2	21
		Expected Count	17.7	3.3	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Experience (Sum)	11.2%	6.3%	10.4%
		% of Total	9.4%	1.0%	10.4%
	E	Count	16	4	20
		Expected Count	16.8	3.2	20.0
		% within Company	80.0%	20.0%	100.0%
		% within Experience (Sum)	9.4%	12.5%	9.9%
		% of Total	7.9%	2.0%	9.9%
	F	Count	17	6	23
		Expected Count	19.4	3.6	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Experience (Sum)	10.0%	18.8%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	10	1	11
		Expected Count	9.3	1.7	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Experience (Sum)	5.9%	3.1%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	21	0	21
		Expected Count	17.7	3.3	21.0
		% within Company	100.0%	.0%	100.0%
		% within Experience (Sum)	12.4%	.0%	10.4%
		% of Total	10.4%	.0%	10.4%
	I	Count	12	6	18
		Expected Count	15.1	2.9	18.0
		% within Company	66.7%	33.3%	100.0%
		% within Experience (Sum)	7.1%	18.8%	8.9%
		% of Total	5.9%	3.0%	8.9%
	J	Count	24	4	28
		Expected Count	23.6	4.4	28.0
		% within Company	85.7%	14.3%	100.0%
		% within Experience (Sum)	14.1%	12.5%	13.9%
		% of Total	11.9%	2.0%	13.9%
Total		Count	170	32	202
		Expected Count	170.0	32.0	202.0
		% within Company	84.2%	15.8%	100.0%
		% within Experience (Sum)	100.0%	100.0%	100.0%
		% of Total	84.2%	15.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.126[a]	9	.157
Likelihood Ratio	15.643	9	.075
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.74.

8.10.6.6 Crosstabulation Table by Company for Top Level 1 Traits "Communication"

Company * Communication Crosstabulation

			Communication 0	Communication 1	Total
Company	A	Count	17	1	18
		Expected Count	15.6	2.4	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Communication	9.7%	3.7%	8.9%
		% of Total	8.4%	.5%	8.9%
	B	Count	16	1	17
		Expected Count	14.7	2.3	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Communication	9.1%	3.7%	8.4%
		% of Total	7.9%	.5%	8.4%
	C	Count	25	0	25
		Expected Count	21.7	3.3	25.0
		% within Company	100.0%	.0%	100.0%
		% within Communication	14.3%	.0%	12.4%
		% of Total	12.4%	.0%	12.4%
	D	Count	20	1	21
		Expected Count	18.2	2.8	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Communication	11.4%	3.7%	10.4%
		% of Total	9.9%	.5%	10.4%
	E	Count	18	2	20
		Expected Count	17.3	2.7	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Communication	10.3%	7.4%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	17	6	23
		Expected Count	19.9	3.1	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Communication	9.7%	22.2%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	10	1	11
		Expected Count	9.5	1.5	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Communication	5.7%	3.7%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	18	3	21
		Expected Count	18.2	2.8	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Communication	10.3%	11.1%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	13	5	18
		Expected Count	15.6	2.4	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Communication	7.4%	18.5%	8.9%
		% of Total	6.4%	2.5%	8.9%
	J	Count	21	7	28
		Expected Count	24.3	3.7	28.0
		% within Company	75.0%	25.0%	100.0%
		% within Communication	12.0%	25.9%	13.9%
		% of Total	10.4%	3.5%	13.9%
Total		Count	175	27	202
		Expected Count	175.0	27.0	202.0
		% within Company	86.6%	13.4%	100.0%
		% within Communication	100.0%	100.0%	100.0%
		% of Total	86.6%	13.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.070[a]	9	.048
Likelihood Ratio	19.425	9	.022
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.47.

8.10.7 Top Level 2 Systems Thinking Individual Characteristics and Traits

Top Level 2 Systems Thinking Individual Characteristics and Traits for All Participants (N=202)

Rank	Node Category	Number	Percent
1	Cluster for Thinking Broadly	65	32%
2	Cluster for Curiosity	43	21%
3	Cluster for questioning	34	17%
4	Open-minded	28	14%
5	Communication	27	13%
6	Cluster for tolerance for uncertainty	23	11%
7	Strong interpersonal skills	22	11%
8	Cluster for think out-of-box	20	10%

Top Level 2 Systems Thinking Individual Characteristics and Traits for Expert Panelists (N=37)

Rank	Node Category	Number	Percent
1	Cluster for Thinking Broadly	13	35%
1	Cluster for Curiosity	13	35%
3	Cluster for questioning	8	22%
4	Cluster for tolerance for uncertainty	7	19%
5	Communication	5	14%
5	Strong interpersonal skills	5	14%
7	Analytical	4	11%
7	Teams	4	11%

Top Level 2 Systems Thinking Individual Characteristics and Traits for Senior Systems Engineers (N=61)

Rank	Node Category	Number	Percent
1	Cluster for Thinking Broadly	15	25%
2	Open-minded	13	21%
3	Cluster for Curiosity	12	20%
4	Communication	11	18%
5	Abstract thinking	9	15%
5	Cluster for tolerance for uncertainty	9	15%
7	Cluster for questioning	8	13%
8	Cluster for disciplined	7	11%
8	Education	7	11%
8	Myers-Briggs/other	7	11%
11	Analytical	6	10%
11	Strong interpersonal skills	6	10%

Top Level 2 Systems Thinking Individual Characteristics and Traits for Senior Technical Specialists (N=52)

Rank	Node Category	Number	Percent
1	Cluster for Thinking Broadly	18	35%
2	Cluster for Curiosity	12	23%
3	Cluster for questioning	11	21%
4	Cluster for think out-of-box	9	17%
5	Strong interpersonal skills	6	12%
5	Wide range of interests	6	12%
7	Cluster for initiative/motivation	5	10%
7	No/not sure	5	10%

Top Level 2 Systems Thinking Individual Characteristics and Traits for Junior Systems Engineers (N=52)

Rank	Node Category	Number	Percent
1	Cluster for Thinking Broadly	19	37%
2	Open-minded	8	15%
3	Communication	7	13%
3	Cluster for questioning	7	13%
5	Cluster for disciplined	6	12%
5	Cluster for Curiosity	6	12%
7	Strong interpersonal skills	5	10%

8.10.8 Summary of Top Level 2 Systems Thinking Individual Characteristics and Traits for All Classifications

Top Level 2 Systems Thinking Individual Characteristics and Traits for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=165)			Expert Panelists (N=37)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=51)			Junior Systems Engineers (N=52)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Cluster for thinking broadly	1	65	32%	1	13	35%	1	15	25%	1	18	35%	1	19	37%	2.352	0.503
Cluster for curiosity	2	43	21%	1	13	35%	3	12	20%	2	12	23%	5	6	12%	7.378	0.061
Cluster for questioning	3	34	17%	3	8	22%	7	8	13%	3	11	21%	3	7	13%	2.324	0.508
Open-minded	4	28	14%	9	3	8%	2	13	21%	9	4	8%	2	8	15%	5.620	0.132
Communication	5	27	13%	5	5	14%	4	11	18%	9	4	8%	3	7	13%	2.594	0.459
Cluster for tolerance for uncertainty	6	23	11%	4	7	19%	5	9	15%	15	3	6%	8	4	8%	5.096	0.165
Strong interpersonal skills	7	22	11%	5	5	14%	11	6	10%	5	6	12%	7	5	10%	0.442	0.931
Cluster for think out-of-box	8	20	10%	9	3	8%	15	4	7%	4	9	17%	8	4	8%	4.380	0.223
Analytical	11	15	7%	7	4	11%	11	6	10%	29	1	2%	8	4	8%	3.428	0.330
Teams	22	9	4%	7	4	11%	20	3	5%	29	1	2%	38	1	2%	5.108	0.164
Cluster for disciplined	9	19	9%	14	2	5%	8	7	11%	9	4	8%	5	6	12%	1.458	0.692
Abstract thinking	11	15	7%	25	1	3%	5	9	15%	29	1	2%	8	4	8%	8.262	0.041
Education	10	17	8%	14	2	5%	8	7	11%	9	4	8%	8	4	8%	1.247	0.742
Myers-Briggs/other	15	12	6%	14	2	5%	8	7	11%	29	1	2%	21	2	4%	5.274	0.153
Wide range of interests	11	15	7%	14	2	5%	20	3	5%	5	6	12%	8	4	8%	2.063	0.560
Cluster for initiative/motivation	14	13	6%	9	3	8%	15	4	7%	7	5	10%	38	1	2%	2.805	0.423
No/not sure	17	11	5%	9	3	8%	24	2	3%	7	5	10%	38	1	2%	4.075	0.254

8.10.9 Crosstabulation Tables by Classification for Top Level 2 Systems Thinking Individual Characteristics and Traits

8.10.9.1 Crosstabulation Table by Classification for Top Level 2 Traits "Cluster for thinking broadly"

Translated Classification * Cluster for Thinking Broadly Crosstabulation

			Cluster for Thinking Broadly		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	24	13	37
		Expected Count	25.1	11.9	37.0
		% within Translated Classification	64.9%	35.1%	100.0%
		% within Cluster for Thinking Broadly	17.5%	20.0%	18.3%
		% of Total	11.9%	6.4%	18.3%
	2_Senior Systems Engineer	Count	46	15	61
		Expected Count	41.4	19.6	61.0
		% within Translated Classification	75.4%	24.6%	100.0%
		% within Cluster for Thinking Broadly	33.6%	23.1%	30.2%
		% of Total	22.8%	7.4%	30.2%
	3_Senior Tech Specialist	Count	34	18	52
		Expected Count	35.3	16.7	52.0
		% within Translated Classification	65.4%	34.6%	100.0%
		% within Cluster for Thinking Broadly	24.8%	27.7%	25.7%
		% of Total	16.8%	8.9%	25.7%
	4_Junior Systems Engineer	Count	33	19	52
		Expected Count	35.3	16.7	52.0
		% within Translated Classification	63.5%	36.5%	100.0%
		% within Cluster for Thinking Broadly	24.1%	29.2%	25.7%
		% of Total	16.3%	9.4%	25.7%
Total		Count	137	65	202
		Expected Count	137.0	65.0	202.0
		% within Translated Classification	67.8%	32.2%	100.0%
		% within Cluster for Thinking Broadly	100.0%	100.0%	100.0%
		% of Total	67.8%	32.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.352[a]	3	.503
Likelihood Ratio	2.418	3	.490
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.91.

8.10.9.2 Crosstabulation Table by Classification for Top Level 2 Traits "Cluster for curiosity"

Translated Classification * Cluster for Curiosity Crosstabulation

			Cluster for Curiosity		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	24	13	37
		Expected Count	29.1	7.9	37.0
		% within Translated Classification	64.9%	35.1%	100.0%
		% within Cluster for Curiosity	15.1%	30.2%	18.3%
		% of Total	11.9%	6.4%	18.3%
	2_Senior Systems Engineer	Count	49	12	61
		Expected Count	48.0	13.0	61.0
		% within Translated Classification	80.3%	19.7%	100.0%
		% within Cluster for Curiosity	30.8%	27.9%	30.2%
		% of Total	24.3%	5.9%	30.2%
	3_Senior Tech Specialist	Count	40	12	52
		Expected Count	40.9	11.1	52.0
		% within Translated Classification	76.9%	23.1%	100.0%
		% within Cluster for Curiosity	25.2%	27.9%	25.7%
		% of Total	19.8%	5.9%	25.7%
	4_Junior Systems Engineer	Count	46	6	52
		Expected Count	40.9	11.1	52.0
		% within Translated Classification	88.5%	11.5%	100.0%
		% within Cluster for Curiosity	28.9%	14.0%	25.7%
		% of Total	22.8%	3.0%	25.7%
Total		Count	159	43	202
		Expected Count	159.0	43.0	202.0
		% within Translated Classification	78.7%	21.3%	100.0%
		% within Cluster for Curiosity	100.0%	100.0%	100.0%
		% of Total	78.7%	21.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.378[a]	3	.061
Likelihood Ratio	7.328	3	.062
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.88.

8.10.9.3 Crosstabulation Table by Classification for Top Level 2 Traits "Cluster for questioning"

Translated Classification * Cluster for questioning Crosstabulation

			Cluster for questioning		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	29	8	37
		Expected Count	30.8	6.2	37.0
		% within Translated Classification	78.4%	21.6%	100.0%
		% within Cluster for questioning	17.3%	23.5%	18.3%
		% of Total	14.4%	4.0%	18.3%
	2_Senior Systems Engineer	Count	53	8	61
		Expected Count	50.7	10.3	61.0
		% within Translated Classification	86.9%	13.1%	100.0%
		% within Cluster for questioning	31.5%	23.5%	30.2%
		% of Total	26.2%	4.0%	30.2%
	3_Senior Tech Specialist	Count	41	11	52
		Expected Count	43.2	8.8	52.0
		% within Translated Classification	78.8%	21.2%	100.0%
		% within Cluster for questioning	24.4%	32.4%	25.7%
		% of Total	20.3%	5.4%	25.7%
	4_Junior Systems Engineer	Count	45	7	52
		Expected Count	43.2	8.8	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Cluster for questioning	26.8%	20.6%	25.7%
		% of Total	22.3%	3.5%	25.7%
Total		Count	168	34	202
		Expected Count	168.0	34.0	202.0
		% within Translated Classification	83.2%	16.8%	100.0%
		% within Cluster for questioning	100.0%	100.0%	100.0%
		% of Total	83.2%	16.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.324[a]	3	.508
Likelihood Ratio	2.308	3	.511
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.23.

8.10.9.4 Crosstabulation Table by Classification for Top Level 2 Traits "Open-minded"

Translated Classification * Open-minded Crosstabulation

			Open-minded		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	34	3	37
		Expected Count	31.9	5.1	37.0
		% within Translated Classification	91.9%	8.1%	100.0%
		% within Open-minded	19.5%	10.7%	18.3%
		% of Total	16.8%	1.5%	18.3%
	2_Senior Systems Engineer	Count	48	13	61
		Expected Count	52.5	8.5	61.0
		% within Translated Classification	78.7%	21.3%	100.0%
		% within Open-minded	27.6%	46.4%	30.2%
		% of Total	23.8%	6.4%	30.2%
	3_Senior Tech Specialist	Count	48	4	52
		Expected Count	44.8	7.2	52.0
		% within Translated Classification	92.3%	7.7%	100.0%
		% within Open-minded	27.6%	14.3%	25.7%
		% of Total	23.8%	2.0%	25.7%
	4_Junior Systems Engineer	Count	44	8	52
		Expected Count	44.8	7.2	52.0
		% within Translated Classification	84.6%	15.4%	100.0%
		% within Open-minded	25.3%	28.6%	25.7%
		% of Total	21.8%	4.0%	25.7%
Total		Count	174	28	202
		Expected Count	174.0	28.0	202.0
		% within Translated Classification	86.1%	13.9%	100.0%
		% within Open-minded	100.0%	100.0%	100.0%
		% of Total	86.1%	13.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.620[a]	3	.132
Likelihood Ratio	5.706	3	.127
N of Valid Cases	202		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.13.

8.10.9.5 Crosstabulation Table by Classification for Top Level 2 Traits "Communication"

Translated Classification * Communication Crosstabulation

			Communication		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	32	5	37
		Expected Count	32.1	4.9	37.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Communication	18.3%	18.5%	18.3%
		% of Total	15.8%	2.5%	18.3%
	2_Senior Systems Engineer	Count	50	11	61
		Expected Count	52.8	8.2	61.0
		% within Translated Classification	82.0%	18.0%	100.0%
		% within Communication	28.6%	40.7%	30.2%
		% of Total	24.8%	5.4%	30.2%
	3_Senior Tech Specialist	Count	48	4	52
		Expected Count	45.0	7.0	52.0
		% within Translated Classification	92.3%	7.7%	100.0%
		% within Communication	27.4%	14.8%	25.7%
		% of Total	23.8%	2.0%	25.7%
	4_Junior Systems Engineer	Count	45	7	52
		Expected Count	45.0	7.0	52.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Communication	25.7%	25.9%	25.7%
		% of Total	22.3%	3.5%	25.7%
Total		Count	175	27	202
		Expected Count	175.0	27.0	202.0
		% within Translated Classification	86.6%	13.4%	100.0%
		% within Communication	100.0%	100.0%	100.0%
		% of Total	86.6%	13.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.594[a]	3	.459
Likelihood Ratio	2.722	3	.436
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.95.

8.10.9.6 Crosstabulation Table by Classification for Top Level 2 Traits "Cluster for tolerance for uncertainty"

Translated Classification * Cluster for tolerance for uncertainty Crosstabulation

			Cluster for tolerance for uncertainty 0	1	Total
Translated Classification	1_Expert Panelist	Count	30	7	37
		Expected Count	32.8	4.2	37.0
		% within Translated Classification	81.1%	18.9%	100.0%
		% within Cluster for tolerance for uncertainty	16.8%	30.4%	18.3%
		% of Total	14.9%	3.5%	18.3%
	2_Senior Systems Engineer	Count	52	9	61
		Expected Count	54.1	6.9	61.0
		% within Translated Classification	85.2%	14.8%	100.0%
		% within Cluster for tolerance for uncertainty	29.1%	39.1%	30.2%
		% of Total	25.7%	4.5%	30.2%
	3_Senior Tech Specialist	Count	49	3	52
		Expected Count	46.1	5.9	52.0
		% within Translated Classification	94.2%	5.8%	100.0%
		% within Cluster for tolerance for uncertainty	27.4%	13.0%	25.7%
		% of Total	24.3%	1.5%	25.7%
	4_Junior Systems Engineer	Count	48	4	52
		Expected Count	46.1	5.9	52.0
		% within Translated Classification	92.3%	7.7%	100.0%
		% within Cluster for tolerance for uncertainty	26.8%	17.4%	25.7%
		% of Total	23.8%	2.0%	25.7%
Total		Count	179	23	202
		Expected Count	179.0	23.0	202.0
		% within Translated Classification	88.6%	11.4%	100.0%
		% within Cluster for tolerance for uncertainty	100.0%	100.0%	100.0%
		% of Total	88.6%	11.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.096[a]	3	.165
Likelihood Ratio	5.140	3	.162
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.21.

8.10.9.7 Crosstabulation Table by Classification for Top Level 2 Traits "Strong interpersonal skills"

Translated Classification * Strong interpersonal skills Crosstabulation

			Strong interpersonal skills		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	5	37
		Expected Count	33.0	4.0	37.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Strong interpersonal skills	17.8%	22.7%	18.3%
		% of Total	15.8%	2.5%	18.3%
	2_Senior Systems Engineer	Count	55	6	61
		Expected Count	54.4	6.6	61.0
		% within Translated Classification	90.2%	9.8%	100.0%
		% within Strong interpersonal skills	30.6%	27.3%	30.2%
		% of Total	27.2%	3.0%	30.2%
	3_Senior Tech Specialist	Count	46	6	52
		Expected Count	46.3	5.7	52.0
		% within Translated Classification	88.5%	11.5%	100.0%
		% within Strong interpersonal skills	25.6%	27.3%	25.7%
		% of Total	22.8%	3.0%	25.7%
	4_Junior Systems Engineer	Count	47	5	52
		Expected Count	46.3	5.7	52.0
		% within Translated Classification	90.4%	9.6%	100.0%
		% within Strong interpersonal skills	26.1%	22.7%	25.7%
		% of Total	23.3%	2.5%	25.7%
Total		Count	180	22	202
		Expected Count	180.0	22.0	202.0
		% within Translated Classification	89.1%	10.9%	100.0%
		% within Strong interpersonal skills	100.0%	100.0%	100.0%
		% of Total	89.1%	10.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.442[a]	3	.931
Likelihood Ratio	.430	3	.934
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.03.

8.10.9.8 Crosstabulation Table by Classification for Top Level 2 Traits "Cluster for think out-of-box"

Translated Classification * Cluster for think out-of-box Crosstabulation

			Cluster for think out-of-box		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	34	3	37
		Expected Count	33.3	3.7	37.0
		% within Translated Classification	91.9%	8.1%	100.0%
		% within Cluster for think out-of-box	18.7%	15.0%	18.3%
		% of Total	16.8%	1.5%	18.3%
	2_Senior Systems Engineer	Count	57	4	61
		Expected Count	55.0	6.0	61.0
		% within Translated Classification	93.4%	6.6%	100.0%
		% within Cluster for think out-of-box	31.3%	20.0%	30.2%
		% of Total	28.2%	2.0%	30.2%
	3_Senior Tech Specialist	Count	43	9	52
		Expected Count	46.9	5.1	52.0
		% within Translated Classification	82.7%	17.3%	100.0%
		% within Cluster for think out-of-box	23.6%	45.0%	25.7%
		% of Total	21.3%	4.5%	25.7%
	4_Junior Systems Engineer	Count	48	4	52
		Expected Count	46.9	5.1	52.0
		% within Translated Classification	92.3%	7.7%	100.0%
		% within Cluster for think out-of-box	26.4%	20.0%	25.7%
		% of Total	23.8%	2.0%	25.7%
Total		Count	182	20	202
		Expected Count	182.0	20.0	202.0
		% within Translated Classification	90.1%	9.9%	100.0%
		% within Cluster for think out-of-box	100.0%	100.0%	100.0%
		% of Total	90.1%	9.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.380[a]	3	.223
Likelihood Ratio	3.980	3	.264
N of Valid Cases	202		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 3.66.

8.10.10Crosstabulation Tables by Company for Top Level 2 Systems Thinking Individual Characteristics and Traits

8.10.10.1 Crosstabulation Table by Company for Top Level 2 Traits "Cluster for thinking broadly"

Crosstab

			Cluster for Thinking Broadly		
			0	1	Total
Company	A	Count	12	6	18
		Expected Count	12.2	5.8	18.0
		% within Company	66.7%	33.3%	100.0%
		% within Cluster for Thinking Broadly	8.8%	9.2%	8.9%
		% of Total	5.9%	3.0%	8.9%
	B	Count	9	8	17
		Expected Count	11.5	5.5	17.0
		% within Company	52.9%	47.1%	100.0%
		% within Cluster for Thinking Broadly	6.6%	12.3%	8.4%
		% of Total	4.5%	4.0%	8.4%
	C	Count	18	7	25
		Expected Count	17.0	8.0	25.0
		% within Company	72.0%	28.0%	100.0%
		% within Cluster for Thinking Broadly	13.1%	10.8%	12.4%
		% of Total	8.9%	3.5%	12.4%
	D	Count	14	7	21
		Expected Count	14.2	6.8	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Cluster for Thinking Broadly	10.2%	10.8%	10.4%
		% of Total	6.9%	3.5%	10.4%
	E	Count	17	3	20
		Expected Count	13.6	6.4	20.0
		% within Company	85.0%	15.0%	100.0%
		% within Cluster for Thinking Broadly	12.4%	4.6%	9.9%
		% of Total	8.4%	1.5%	9.9%
	F	Count	17	6	23
		Expected Count	15.6	7.4	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Cluster for Thinking Broadly	12.4%	9.2%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	7	4	11
		Expected Count	7.5	3.5	11.0
		% within Company	63.6%	36.4%	100.0%
		% within Cluster for Thinking Broadly	5.1%	6.2%	5.4%
		% of Total	3.5%	2.0%	5.4%
	H	Count	14	7	21
		Expected Count	14.2	6.8	21.0
		% within Company	66.7%	33.3%	100.0%
		% within Cluster for Thinking Broadly	10.2%	10.8%	10.4%
		% of Total	6.9%	3.5%	10.4%
	I	Count	8	10	18
		Expected Count	12.2	5.8	18.0
		% within Company	44.4%	55.6%	100.0%
		% within Cluster for Thinking Broadly	5.8%	15.4%	8.9%
		% of Total	4.0%	5.0%	8.9%
	J	Count	21	7	28
		Expected Count	19.0	9.0	28.0
		% within Company	75.0%	25.0%	100.0%
		% within Cluster for Thinking Broadly	15.3%	10.8%	13.9%
		% of Total	10.4%	3.5%	13.9%
Total		Count	137	65	202
		Expected Count	137.0	65.0	202.0
		% within Company	67.8%	32.2%	100.0%
		% within Cluster for Thinking Broadly	100.0%	100.0%	100.0%
		% of Total	67.8%	32.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.314[a]	9	.326
Likelihood Ratio	10.305	9	.326
N of Valid Cases	202		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 3.54.

8.10.10.2 Crosstabulation Table by Company for Top Level 2 Traits "Cluster for curiosity"

Crosstab

			Cluster for Curiosity		
			0	1	Total
Company	A	Count	15	3	18
		Expected Count	14.2	3.8	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Cluster for Curiosity	9.4%	7.0%	8.9%
		% of Total	7.4%	1.5%	8.9%
	B	Count	13	4	17
		Expected Count	13.4	3.6	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Cluster for Curiosity	8.2%	9.3%	8.4%
		% of Total	6.4%	2.0%	8.4%
	C	Count	22	3	25
		Expected Count	19.7	5.3	25.0
		% within Company	88.0%	12.0%	100.0%
		% within Cluster for Curiosity	13.8%	7.0%	12.4%
		% of Total	10.9%	1.5%	12.4%
	D	Count	17	4	21
		Expected Count	16.5	4.5	21.0
		% within Company	81.0%	19.0%	100.0%
		% within Cluster for Curiosity	10.7%	9.3%	10.4%
		% of Total	8.4%	2.0%	10.4%
	E	Count	16	4	20
		Expected Count	15.7	4.3	20.0
		% within Company	80.0%	20.0%	100.0%
		% within Cluster for Curiosity	10.1%	9.3%	9.9%
		% of Total	7.9%	2.0%	9.9%
	F	Count	16	7	23
		Expected Count	18.1	4.9	23.0
		% within Company	69.6%	30.4%	100.0%
		% within Cluster for Curiosity	10.1%	16.3%	11.4%
		% of Total	7.9%	3.5%	11.4%
	G	Count	8	3	11
		Expected Count	8.7	2.3	11.0
		% within Company	72.7%	27.3%	100.0%
		% within Cluster for Curiosity	5.0%	7.0%	5.4%
		% of Total	4.0%	1.5%	5.4%
	H	Count	18	3	21
		Expected Count	16.5	4.5	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Cluster for Curiosity	11.3%	7.0%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	15	3	18
		Expected Count	14.2	3.8	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Cluster for Curiosity	9.4%	7.0%	8.9%
		% of Total	7.4%	1.5%	8.9%
	J	Count	19	9	28
		Expected Count	22.0	6.0	28.0
		% within Company	67.9%	32.1%	100.0%
		% within Cluster for Curiosity	11.9%	20.9%	13.9%
		% of Total	9.4%	4.5%	13.9%
Total		Count	159	43	202
		Expected Count	159.0	43.0	202.0
		% within Company	78.7%	21.3%	100.0%
		% within Cluster for Curiosity	100.0%	100.0%	100.0%
		% of Total	78.7%	21.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.847[a]	9	.755
Likelihood Ratio	5.814	9	.758
N of Valid Cases	202		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is 2.34.

8.10.10.3 Crosstabulation Table by Company for Top Level 2 Traits "Cluster for questioning"

Crosstab

			Cluster for questioning		
			0	1	Total
Company	A	Count	14	4	18
		Expected Count	15.0	3.0	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Cluster for questioning	8.3%	11.8%	8.9%
		% of Total	6.9%	2.0%	8.9%
	B	Count	14	3	17
		Expected Count	14.1	2.9	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Cluster for questioning	8.3%	8.8%	8.4%
		% of Total	6.9%	1.5%	8.4%
	C	Count	22	3	25
		Expected Count	20.8	4.2	25.0
		% within Company	88.0%	12.0%	100.0%
		% within Cluster for questioning	13.1%	8.8%	12.4%
		% of Total	10.9%	1.5%	12.4%
	D	Count	17	4	21
		Expected Count	17.5	3.5	21.0
		% within Company	81.0%	19.0%	100.0%
		% within Cluster for questioning	10.1%	11.8%	10.4%
		% of Total	8.4%	2.0%	10.4%
	E	Count	18	2	20
		Expected Count	16.6	3.4	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Cluster for questioning	10.7%	5.9%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	17	6	23
		Expected Count	19.1	3.9	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Cluster for questioning	10.1%	17.6%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	10	1	11
		Expected Count	9.1	1.9	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Cluster for questioning	6.0%	2.9%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	19	2	21
		Expected Count	17.5	3.5	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Cluster for questioning	11.3%	5.9%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	14	4	18
		Expected Count	15.0	3.0	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Cluster for questioning	8.3%	11.8%	8.9%
		% of Total	6.9%	2.0%	8.9%
	J	Count	23	5	28
		Expected Count	23.3	4.7	28.0
		% within Company	82.1%	17.9%	100.0%
		% within Cluster for questioning	13.7%	14.7%	13.9%
		% of Total	11.4%	2.5%	13.9%
Total		Count	168	34	202
		Expected Count	168.0	34.0	202.0
		% within Company	83.2%	16.8%	100.0%
		% within Cluster for questioning	100.0%	100.0%	100.0%
		% of Total	83.2%	16.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.613[a]	9	.867
Likelihood Ratio	4.724	9	.858
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.85.

8.10.10.4 Crosstabulation Table by Company for Top Leve 2 Traits "Open-minded"

Crosstab

			Open-minded		
			0	1	Total
Company	A	Count	17	1	18
		Expected Count	15.5	2.5	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Open-minded	9.8%	3.6%	8.9%
		% of Total	8.4%	.5%	8.9%
	B	Count	15	2	17
		Expected Count	14.6	2.4	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Open-minded	8.6%	7.1%	8.4%
		% of Total	7.4%	1.0%	8.4%
	C	Count	20	5	25
		Expected Count	21.5	3.5	25.0
		% within Company	80.0%	20.0%	100.0%
		% within Open-minded	11.5%	17.9%	12.4%
		% of Total	9.9%	2.5%	12.4%
	D	Count	18	3	21
		Expected Count	18.1	2.9	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Open-minded	10.3%	10.7%	10.4%
		% of Total	8.9%	1.5%	10.4%
	E	Count	14	6	20
		Expected Count	17.2	2.8	20.0
		% within Company	70.0%	30.0%	100.0%
		% within Open-minded	8.0%	21.4%	9.9%
		% of Total	6.9%	3.0%	9.9%
	F	Count	17	6	23
		Expected Count	19.8	3.2	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Open-minded	9.8%	21.4%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	10	1	11
		Expected Count	9.5	1.5	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Open-minded	5.7%	3.6%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	18	3	21
		Expected Count	18.1	2.9	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Open-minded	10.3%	10.7%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	18	0	18
		Expected Count	15.5	2.5	18.0
		% within Company	100.0%	.0%	100.0%
		% within Open-minded	10.3%	.0%	8.9%
		% of Total	8.9%	.0%	8.9%
	J	Count	27	1	28
		Expected Count	24.1	3.9	28.0
		% within Company	96.4%	3.6%	100.0%
		% within Open-minded	15.5%	3.6%	13.9%
		% of Total	13.4%	.5%	13.9%
Total		Count	174	28	202
		Expected Count	174.0	28.0	202.0
		% within Company	86.1%	13.9%	100.0%
		% within Open-minded	100.0%	100.0%	100.0%
		% of Total	86.1%	13.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.729[a]	9	.099
Likelihood Ratio	16.909	9	.050
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.52.

8.10.10.5 Crosstabulation Table by Company for Top Level 2 Traits "Communication"

Crosstab

			Communication		
			0	1	Total
Company	A	Count	17	1	18
		Expected Count	15.6	2.4	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Communication	9.7%	3.7%	8.9%
		% of Total	8.4%	.5%	8.9%
	B	Count	16	1	17
		Expected Count	14.7	2.3	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Communication	9.1%	3.7%	8.4%
		% of Total	7.9%	.5%	8.4%
	C	Count	25	0	25
		Expected Count	21.7	3.3	25.0
		% within Company	100.0%	.0%	100.0%
		% within Communication	14.3%	.0%	12.4%
		% of Total	12.4%	.0%	12.4%
	D	Count	20	1	21
		Expected Count	18.2	2.8	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Communication	11.4%	3.7%	10.4%
		% of Total	9.9%	.5%	10.4%
	E	Count	18	2	20
		Expected Count	17.3	2.7	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Communication	10.3%	7.4%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	17	6	23
		Expected Count	19.9	3.1	23.0
		% within Company	73.9%	26.1%	100.0%
		% within Communication	9.7%	22.2%	11.4%
		% of Total	8.4%	3.0%	11.4%
	G	Count	10	1	11
		Expected Count	9.5	1.5	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Communication	5.7%	3.7%	5.4%
		% of Total	5.0%	.5%	5.4%
	H	Count	18	3	21
		Expected Count	18.2	2.8	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Communication	10.3%	11.1%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	13	5	18
		Expected Count	15.6	2.4	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Communication	7.4%	18.5%	8.9%
		% of Total	6.4%	2.5%	8.9%
	J	Count	21	7	28
		Expected Count	24.3	3.7	28.0
		% within Company	75.0%	25.0%	100.0%
		% within Communication	12.0%	25.9%	13.9%
		% of Total	10.4%	3.5%	13.9%
Total		Count	175	27	202
		Expected Count	175.0	27.0	202.0
		% within Company	86.6%	13.4%	100.0%
		% within Communication	100.0%	100.0%	100.0%
		% of Total	86.6%	13.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.070[a]	9	.048
Likelihood Ratio	19.425	9	.022
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.47.

8.10.10.6 Crosstabulation Table by Company for Top Level 2 Traits "Cluster for tolerance for uncertainty"

Crosstab

			Cluster for tolerance for uncertainty		
			0	1	Total
Company	A	Count	17	1	18
		Expected Count	16.0	2.0	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Cluster for tolerance for uncertainty	9.5%	4.3%	8.9%
		% of Total	8.4%	.5%	8.9%
	B	Count	17	0	17
		Expected Count	15.1	1.9	17.0
		% within Company	100.0%	.0%	100.0%
		% within Cluster for tolerance for uncertainty	9.5%	.0%	8.4%
		% of Total	8.4%	.0%	8.4%
	C	Count	23	2	25
		Expected Count	22.2	2.8	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Cluster for tolerance for uncertainty	12.8%	8.7%	12.4%
		% of Total	11.4%	1.0%	12.4%
	D	Count	16	5	21
		Expected Count	18.6	2.4	21.0
		% within Company	76.2%	23.8%	100.0%
		% within Cluster for tolerance for uncertainty	8.9%	21.7%	10.4%
		% of Total	7.9%	2.5%	10.4%
	E	Count	18	2	20
		Expected Count	17.7	2.3	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Cluster for tolerance for uncertainty	10.1%	8.7%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	21	2	23
		Expected Count	20.4	2.6	23.0
		% within Company	91.3%	8.7%	100.0%
		% within Cluster for tolerance for uncertainty	11.7%	8.7%	11.4%
		% of Total	10.4%	1.0%	11.4%
	G	Count	9	2	11
		Expected Count	9.7	1.3	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Cluster for tolerance for uncertainty	5.0%	8.7%	5.4%
		% of Total	4.5%	1.0%	5.4%
	H	Count	19	2	21
		Expected Count	18.6	2.4	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Cluster for tolerance for uncertainty	10.6%	8.7%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	17	1	18
		Expected Count	16.0	2.0	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Cluster for tolerance for uncertainty	9.5%	4.3%	8.9%
		% of Total	8.4%	.5%	8.9%
	J	Count	22	6	28
		Expected Count	24.8	3.2	28.0
		% within Company	78.6%	21.4%	100.0%
		% within Cluster for tolerance for uncertainty	12.3%	26.1%	13.9%
		% of Total	10.9%	3.0%	13.9%
Total		Count	179	23	202
		Expected Count	179.0	23.0	202.0
		% within Company	88.6%	11.4%	100.0%
		% within Cluster for tolerance for uncertainty	100.0%	100.0%	100.0%
		% of Total	88.6%	11.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.471[a]	9	.314
Likelihood Ratio	11.454	9	.246
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.25.

8.10.10.7 Crosstabulation Table by Company for Top Level 2 Traits "Strong interpersonal skills"

Crosstab

			Strong interpersonal skills		
			0	1	Total
Company	A	Count	15	3	18
		Expected Count	16.0	2.0	18.0
		% within Company	83.3%	16.7%	100.0%
		% within Strong interpersonal skills	8.3%	13.6%	8.9%
		% of Total	7.4%	1.5%	8.9%
	B	Count	16	1	17
		Expected Count	15.1	1.9	17.0
		% within Company	94.1%	5.9%	100.0%
		% within Strong interpersonal skills	8.9%	4.5%	8.4%
		% of Total	7.9%	.5%	8.4%
	C	Count	23	2	25
		Expected Count	22.3	2.7	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Strong interpersonal skills	12.8%	9.1%	12.4%
		% of Total	11.4%	1.0%	12.4%
	D	Count	20	1	21
		Expected Count	18.7	2.3	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Strong interpersonal skills	11.1%	4.5%	10.4%
		% of Total	9.9%	.5%	10.4%
	E	Count	18	2	20
		Expected Count	17.8	2.2	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Strong interpersonal skills	10.0%	9.1%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	20	3	23
		Expected Count	20.5	2.5	23.0
		% within Company	87.0%	13.0%	100.0%
		% within Strong interpersonal skills	11.1%	13.6%	11.4%
		% of Total	9.9%	1.5%	11.4%
	G	Count	9	2	11
		Expected Count	9.8	1.2	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Strong interpersonal skills	5.0%	9.1%	5.4%
		% of Total	4.5%	1.0%	5.4%
	H	Count	18	3	21
		Expected Count	18.7	2.3	21.0
		% within Company	85.7%	14.3%	100.0%
		% within Strong interpersonal skills	10.0%	13.6%	10.4%
		% of Total	8.9%	1.5%	10.4%
	I	Count	13	5	18
		Expected Count	16.0	2.0	18.0
		% within Company	72.2%	27.8%	100.0%
		% within Strong interpersonal skills	7.2%	22.7%	8.9%
		% of Total	6.4%	2.5%	8.9%
	J	Count	28	0	28
		Expected Count	25.0	3.0	28.0
		% within Company	100.0%	.0%	100.0%
		% within Strong interpersonal skills	15.6%	.0%	13.9%
		% of Total	13.9%	.0%	13.9%
Total		Count	180	22	202
		Expected Count	180.0	22.0	202.0
		% within Company	89.1%	10.9%	100.0%
		% within Strong interpersonal skills	100.0%	100.0%	100.0%
		% of Total	89.1%	10.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.775a	9	.226
Likelihood Ratio	13.523	9	.140
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.20.

8.10.10.8 Crosstabulation Table by Company

for Top Level 2 Traits "Cluster for think out-of-box"

Crosstab

			Cluster for think out-of-box		
			0	1	Total
Company	A	Count	17	1	18
		Expected Count	16.2	1.8	18.0
		% within Company	94.4%	5.6%	100.0%
		% within Cluster for think out-of-box	9.3%	5.0%	8.9%
		% of Total	8.4%	.5%	8.9%
	B	Count	15	2	17
		Expected Count	15.3	1.7	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Cluster for think out-of-box	8.2%	10.0%	8.4%
		% of Total	7.4%	1.0%	8.4%
	C	Count	24	1	25
		Expected Count	22.5	2.5	25.0
		% within Company	96.0%	4.0%	100.0%
		% within Cluster for think out-of-box	13.2%	5.0%	12.4%
		% of Total	11.9%	.5%	12.4%
	D	Count	20	1	21
		Expected Count	18.9	2.1	21.0
		% within Company	95.2%	4.8%	100.0%
		% within Cluster for think out-of-box	11.0%	5.0%	10.4%
		% of Total	9.9%	.5%	10.4%
	E	Count	20	0	20
		Expected Count	18.0	2.0	20.0
		% within Company	100.0%	.0%	100.0%
		% within Cluster for think out-of-box	11.0%	.0%	9.9%
		% of Total	9.9%	.0%	9.9%
	F	Count	22	1	23
		Expected Count	20.7	2.3	23.0
		% within Company	95.7%	4.3%	100.0%
		% within Cluster for think out-of-box	12.1%	5.0%	11.4%
		% of Total	10.9%	.5%	11.4%
	G	Count	11	0	11
		Expected Count	9.9	1.1	11.0
		% within Company	100.0%	.0%	100.0%
		% within Cluster for think out-of-box	6.0%	.0%	5.4%
		% of Total	5.4%	.0%	5.4%
	H	Count	19	2	21
		Expected Count	18.9	2.1	21.0
		% within Company	90.5%	9.5%	100.0%
		% within Cluster for think out-of-box	10.4%	10.0%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	14	4	18
		Expected Count	16.2	1.8	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Cluster for think out-of-box	7.7%	20.0%	8.9%
		% of Total	6.9%	2.0%	8.9%
	J	Count	20	8	28
		Expected Count	25.2	2.8	28.0
		% within Company	71.4%	28.6%	100.0%
		% within Cluster for think out-of-box	11.0%	40.0%	13.9%
		% of Total	9.9%	4.0%	13.9%
Total		Count	182	20	202
		Expected Count	182.0	20.0	202.0
		% within Company	90.1%	9.9%	100.0%
		% within Cluster for think out-of-box	100.0%	100.0%	100.0%
		% of Total	90.1%	9.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	20.254[a]	9	.016
Likelihood Ratio	19.967	9	.018
N of Valid Cases	202		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.09.

8.11 Barriers to Systems Thinking Development

8.11.1 Coding for Barriers to the Development of Systems Thinking

Barriers to the Development of Systems Thinking	Total
Work design	
- Problem spaces in engineering so large	1
- People working alone	1
- ST not explicitly in job description	1
- Can't identify with a physical component	1
- Narrow job	26
Schedule and cost constraints	42
Individual characteristics	
- Want to be told what to do	2
- Visionaries	1
- Lack of confidence	2
- Makes system too complex	2
- Lack of self-organizing	1
- Overwhelmed by problem	4
- Bias	2
- Pride and ego	5
- Doesn't understand interdependencies	3
- Lack of technical understanding	3
- Comfortable	24
- Inflexible	1
- More concerned w/career than program	1
- Lack of business acumen	1
- Can't communicate	1
- Translation of abstraction to something real	1
- Style	1
- Local thinking/myopia	41
- Thinking that everything can be quantified	1
- Not process oriented	1
- Engineering nature	1
- Get to detailed design too soon	1
- Hesitant to disclose expertise	1
- Introverted, work alone	1
- Many ST don't become engrs anyway	1
- Lack desire	1
- Dilemma b/n depth and breadth of knowledge	2
- Too late to change thinking	1

- How write specs	1
- Way of approaching a problem	1
SE	
- Need to develop SE skills	5
- SE arrogance	1
- SE don't understand they change how work is done	1
- Alternatives not considered	1
- SE pushed to focus on product	1
- Need for common tools	1
- SE not appreciated/marginalized	4
- SE esteem	2
- Not utilizing SE end-to-end	2
- No power sharing b/n SE of program and SE of product	1
- Setbacks of rigid SE process	5
- SE new to organization	2
- Confusion in ST/SA/SE	9
Ambiguity in English language	1
Interpersonal	13
Program, customer problems	9
System complexity	2
Sanity checking	1
Experience	
- Lack of opportunity to see system	2
- Lack of experience	7
- Lack of broad range of experience	7
Training/Education	
- Training issues	9
- Education issues	24
Organizations	
- Organization in general	3
- Kept in job if doing good job	5
- Organizational culture	7
- Process initiatives	4
- Managers	6
- Politics	3
- Organizational boundaries/structure	37
- Organizational incentives	11
Little girl vs. little boy	1
No structured approach	1
Physical space	1
Arbitrary system boundaries	1
Society as a whole specializes	1

Success	1
Desktop tools	1
Quality of output and true ingenuity	1

8.11.2 Level 1 Coding for Barriers to the Development of Systems Thinking

Level 1 Barriers to the Development of Systems Thinking	Total
Work design	30
Schedule and cost constraints	42
Individual characteristics	82
SE	29
Ambiguity in English language	1
Interpersonal	13
Program, customer problems	9
System complexity	2
Sanity checking	1
Experience	16
Training/Education	32
Organizations	63
Little girl vs. little boy	1
No structured approach	1
Physical space	1
Arbitrary system boundaries	1
Society as a whole specializes	1
Success	1
Desktop tools	1
Quality of output and true ingenuity	1

8.11.3 Top Level 1 Barriers to the Development of Systems Thinking

Top Level 1 Barriers to the Development of Systems Thinking for All Participants (N=192)

Rank	Node Category	Number	Percent
1	Individual characteristics	82	43%
2	Organizations	63	33%
3	Schedule and cost constraints	42	22%
4	Training/Education	32	17%
5	Work design	30	16%
6	SE	29	15%

Top Level 1 Barriers to the Development of Systems Thinking for Expert Panelists (N=36)

Rank	Node Category	Number	Percent
1	Organizations	13	36%
2	Schedule and cost constraints	12	33%
3	Individual characteristics	9	25%
4	Training/Education	5	14%
5	Work design	4	11%

Top Level 1 Barriers to the Development of Systems Thinking for Senior Systems Engineers (N=62)

Rank	Node Category	Number	Percent
1	Individual characteristics	24	39%
1	Organizations	24	39%
3	SE	13	21%
3	Training/Education	13	21%
5	Work design	10	16%
5	Schedule and cost constraints	10	16%

Top Level 1 Barriers to the Development of Systems Thinking for Senior Technical Specialists (N=46)

Rank	Node Category	Number	Percent
1	Individual characteristics	25	54%
2	Work design	8	17%
2	Schedule and cost constraints	8	17%
4	SE	7	15%
5	Experience	6	13%
5	Organizations	6	13%
7	Interpersonal	5	11%
7	Training/Education	5	11%

Top Level 1 Barriers to the Development of Systems Thinking for Junior Systems Engineers (N=48)

Rank	Node Category	Number	Percent
1	Individual characteristics	24	50%
2	Organizations	20	42%
3	Schedule and cost constraints	12	25%
4	Training/Education	9	19%
5	Work design	8	17%
6	SE	6	13%

8.11.4 Summary of Top Level 1 Barriers to the Development of Systems Thinking for All Classifications

Top Level 1 Barriers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=192)			Expert Panelists (N=36)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=46)			Junior Systems Engineers (N=48)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Individual characteristics	1	82	43%	3	9	25%	1	24	39%	1	25	54%	1	24	50%	8.609	0.035
Organizations	2	63	33%	1	13	36%	1	24	39%	5	6	13%	2	20	42%	11.017	0.012
Schedule and cost constraints	3	42	22%	2	12	33%	5	10	16%	2	8	17%	3	12	25%	4.779	0.189
Training/Education	4	32	17%	4	5	14%	3	13	21%	7	5	11%	4	9	19%	2.289	0.515
Work design	5	30	16%	5	4	11%	5	10	16%	2	8	17%	5	8	17%	0.717	0.869
SE	6	29	15%	6	3	8%	3	13	21%	4	7	15%	6	6	13%	3.204	0.361
Experience	7	16	8%	7	2	6%	7	4	6%	5	6	13%	7	4	8%	1.987	0.575
Interpersonal	8	13	7%	8	1	3%	7	4	6%	7	5	11%	8	3	6%	2.164	0.539

8.11.5 Crosstabulation Tables by Classification for Top Level 1 Barriers

8.11.5.1 Crosstabulation Table by Classification for Top Level 1 Barrier "Individual Characteristics"

Translated Classification * Individual characteristics Crosstabulation

			Individual characteristics		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	27	9	36
		Expected Count	20.6	15.4	36.0
		% within Translated Classification	75.0%	25.0%	100.0%
		% within Individual characteristics	24.5%	11.0%	18.8%
		% of Total	14.1%	4.7%	18.8%
	2_Senior Systems Engineer	Count	38	24	62
		Expected Count	35.5	26.5	62.0
		% within Translated Classification	61.3%	38.7%	100.0%
		% within Individual characteristics	34.5%	29.3%	32.3%
		% of Total	19.8%	12.5%	32.3%
	3_Senior Tech Specialist	Count	21	25	46
		Expected Count	26.4	19.6	46.0
		% within Translated Classification	45.7%	54.3%	100.0%
		% within Individual characteristics	19.1%	30.5%	24.0%
		% of Total	10.9%	13.0%	24.0%
	4_Junior Systems Engineer	Count	24	24	48
		Expected Count	27.5	20.5	48.0
		% within Translated Classification	50.0%	50.0%	100.0%
		% within Individual characteristics	21.8%	29.3%	25.0%
		% of Total	12.5%	12.5%	25.0%
Total		Count	110	82	192
		Expected Count	110.0	82.0	192.0
		% within Translated Classification	57.3%	42.7%	100.0%
		% within Individual characteristics	100.0%	100.0%	100.0%
		% of Total	57.3%	42.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.609[a]	3	.035
Likelihood Ratio	8.858	3	.031
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.38.

8.11.5.2 Crosstabulation Table by Classification for Top Level 1 Barrier "Organizations"

Translated Classification * Organizations Crosstabulation

			Organizations		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	23	13	36
		Expected Count	24.2	11.8	36.0
		% within Translated Classification	63.9%	36.1%	100.0%
		% within Organizations	17.8%	20.6%	18.8%
		% of Total	12.0%	6.8%	18.8%
	2_Senior Systems Engineer	Count	38	24	62
		Expected Count	41.7	20.3	62.0
		% within Translated Classification	61.3%	38.7%	100.0%
		% within Organizations	29.5%	38.1%	32.3%
		% of Total	19.8%	12.5%	32.3%
	3_Senior Tech Specialist	Count	40	6	46
		Expected Count	30.9	15.1	46.0
		% within Translated Classification	87.0%	13.0%	100.0%
		% within Organizations	31.0%	9.5%	24.0%
		% of Total	20.8%	3.1%	24.0%
	4_Junior Systems Engineer	Count	28	20	48
		Expected Count	32.3	15.8	48.0
		% within Translated Classification	58.3%	41.7%	100.0%
		% within Organizations	21.7%	31.7%	25.0%
		% of Total	14.6%	10.4%	25.0%
Total		Count	129	63	192
		Expected Count	129.0	63.0	192.0
		% within Translated Classification	67.2%	32.8%	100.0%
		% within Organizations	100.0%	100.0%	100.0%
		% of Total	67.2%	32.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.017[a]	3	.012
Likelihood Ratio	12.332	3	.006
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.81.

8.11.5.3 Crosstabulation Table by Classification for Top Level 1 Barrier "Schedule and Cost Constraints"

Translated Classification * Schedule and cost constraints Crosstabulation

			Schedule and cost constraints		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	24	12	36
		Expected Count	28.1	7.9	36.0
		% within Translated Classification	66.7%	33.3%	100.0%
		% within Schedule and cost constraints	16.0%	28.6%	18.8%
		% of Total	12.5%	6.3%	18.8%
	2_Senior Systems Engineer	Count	52	10	62
		Expected Count	48.4	13.6	62.0
		% within Translated Classification	83.9%	16.1%	100.0%
		% within Schedule and cost constraints	34.7%	23.8%	32.3%
		% of Total	27.1%	5.2%	32.3%
	3_Senior Tech Specialist	Count	38	8	46
		Expected Count	35.9	10.1	46.0
		% within Translated Classification	82.6%	17.4%	100.0%
		% within Schedule and cost constraints	25.3%	19.0%	24.0%
		% of Total	19.8%	4.2%	24.0%
	4_Junior Systems Engineer	Count	36	12	48
		Expected Count	37.5	10.5	48.0
		% within Translated Classification	75.0%	25.0%	100.0%
		% within Schedule and cost constraints	24.0%	28.6%	25.0%
		% of Total	18.8%	6.3%	25.0%
Total		Count	150	42	192
		Expected Count	150.0	42.0	192.0
		% within Translated Classification	78.1%	21.9%	100.0%
		% within Schedule and cost constraints	100.0%	100.0%	100.0%
		% of Total	78.1%	21.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.779[a]	3	.189
Likelihood Ratio	4.619	3	.202
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.88.

8.11.5.4 Crosstabulation Table by Classification for Top Level 1 Barrier "Training/Education"

Translated Classification * Training/Education Crosstabulation

			Training/Education		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	31	5	36
		Expected Count	30.0	6.0	36.0
		% within Translated Classification	86.1%	13.9%	100.0%
		% within Training/Education	19.4%	15.6%	18.8%
		% of Total	16.1%	2.6%	18.8%
	2_Senior Systems Engineer	Count	49	13	62
		Expected Count	51.7	10.3	62.0
		% within Translated Classification	79.0%	21.0%	100.0%
		% within Training/Education	30.6%	40.6%	32.3%
		% of Total	25.5%	6.8%	32.3%
	3_Senior Tech Specialist	Count	41	5	46
		Expected Count	38.3	7.7	46.0
		% within Translated Classification	89.1%	10.9%	100.0%
		% within Training/Education	25.6%	15.6%	24.0%
		% of Total	21.4%	2.6%	24.0%
	4_Junior Systems Engineer	Count	39	9	48
		Expected Count	40.0	8.0	48.0
		% within Translated Classification	81.3%	18.8%	100.0%
		% within Training/Education	24.4%	28.1%	25.0%
		% of Total	20.3%	4.7%	25.0%
Total		Count	160	32	192
		Expected Count	160.0	32.0	192.0
		% within Translated Classification	83.3%	16.7%	100.0%
		% within Training/Education	100.0%	100.0%	100.0%
		% of Total	83.3%	16.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.289[a]	3	.515
Likelihood Ratio	2.371	3	.499
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.00.

8.11.5.5 Crosstabulation Table by Classification for Top Level 1 Barrier "Work Design"

Translated Classification * Work design Crosstabulation

			Work design		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	32	4	36
		Expected Count	30.4	5.6	36.0
		% within Translated Classification	88.9%	11.1%	100.0%
		% within Work design	19.8%	13.3%	18.8%
		% of Total	16.7%	2.1%	18.8%
	2_Senior Systems Engineer	Count	52	10	62
		Expected Count	52.3	9.7	62.0
		% within Translated Classification	83.9%	16.1%	100.0%
		% within Work design	32.1%	33.3%	32.3%
		% of Total	27.1%	5.2%	32.3%
	3_Senior Tech Specialist	Count	38	8	46
		Expected Count	38.8	7.2	46.0
		% within Translated Classification	82.6%	17.4%	100.0%
		% within Work design	23.5%	26.7%	24.0%
		% of Total	19.8%	4.2%	24.0%
	4_Junior Systems Engineer	Count	40	8	48
		Expected Count	40.5	7.5	48.0
		% within Translated Classification	83.3%	16.7%	100.0%
		% within Work design	24.7%	26.7%	25.0%
		% of Total	20.8%	4.2%	25.0%
Total		Count	162	30	192
		Expected Count	162.0	30.0	192.0
		% within Translated Classification	84.4%	15.6%	100.0%
		% within Work design	100.0%	100.0%	100.0%
		% of Total	84.4%	15.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.717[a]	3	.869
Likelihood Ratio	.764	3	.858
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.63.

8.11.5.6 Crosstabulation Table by Classification for Top Level 1 Barrier "SE"

Translated Classification * SE Crosstabulation

			SE		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	33	3	36
		Expected Count	30.6	5.4	36.0
		% within Translated Classification	91.7%	8.3%	100.0%
		% within SE	20.2%	10.3%	18.8%
		% of Total	17.2%	1.6%	18.8%
	2_Senior Systems Engineer	Count	49	13	62
		Expected Count	52.6	9.4	62.0
		% within Translated Classification	79.0%	21.0%	100.0%
		% within SE	30.1%	44.8%	32.3%
		% of Total	25.5%	6.8%	32.3%
	3_Senior Tech Specialist	Count	39	7	46
		Expected Count	39.1	6.9	46.0
		% within Translated Classification	84.8%	15.2%	100.0%
		% within SE	23.9%	24.1%	24.0%
		% of Total	20.3%	3.6%	24.0%
	4_Junior Systems Engineer	Count	42	6	48
		Expected Count	40.8	7.3	48.0
		% within Translated Classification	87.5%	12.5%	100.0%
		% within SE	25.8%	20.7%	25.0%
		% of Total	21.9%	3.1%	25.0%
Total		Count	163	29	192
		Expected Count	163.0	29.0	192.0
		% within Translated Classification	84.9%	15.1%	100.0%
		% within SE	100.0%	100.0%	100.0%
		% of Total	84.9%	15.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.204[a]	3	.361
Likelihood Ratio	3.278	3	.351
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.44.

8.11.6 Crosstabulation Tables by Company for Top Level 1 Barriers

8.11.6.1 Crosstabulation Table by Company for Top Level 1 Barrier "Individual Characteristics"

Company * Individual characteristics Crosstabulation

			Individual characteristics		
			0	1	Total
Company	A	Count	11	5	16
		Expected Count	9.2	6.8	16.0
		% within Company	68.8%	31.3%	100.0%
		% within Individual characteristics	10.0%	6.1%	8.3%
		% of Total	5.7%	2.6%	8.3%
	B	Count	12	5	17
		Expected Count	9.7	7.3	17.0
		% within Company	70.6%	29.4%	100.0%
		% within Individual characteristics	10.9%	6.1%	8.9%
		% of Total	6.3%	2.6%	8.9%
	C	Count	16	9	25
		Expected Count	14.3	10.7	25.0
		% within Company	64.0%	36.0%	100.0%
		% within Individual characteristics	14.5%	11.0%	13.0%
		% of Total	8.3%	4.7%	13.0%
	D	Count	5	14	19
		Expected Count	10.9	8.1	19.0
		% within Company	26.3%	73.7%	100.0%
		% within Individual characteristics	4.5%	17.1%	9.9%
		% of Total	2.6%	7.3%	9.9%
	E	Count	13	6	19
		Expected Count	10.9	8.1	19.0
		% within Company	68.4%	31.6%	100.0%
		% within Individual characteristics	11.8%	7.3%	9.9%
		% of Total	6.8%	3.1%	9.9%
	F	Count	11	11	22
		Expected Count	12.6	9.4	22.0
		% within Company	50.0%	50.0%	100.0%
		% within Individual characteristics	10.0%	13.4%	11.5%
		% of Total	5.7%	5.7%	11.5%
	G	Count	7	4	11
		Expected Count	6.3	4.7	11.0
		% within Company	63.6%	36.4%	100.0%
		% within Individual characteristics	6.4%	4.9%	5.7%
		% of Total	3.6%	2.1%	5.7%
	H	Count	13	7	20
		Expected Count	11.5	8.5	20.0
		% within Company	65.0%	35.0%	100.0%
		% within Individual characteristics	11.8%	8.5%	10.4%
		% of Total	6.8%	3.6%	10.4%
	I	Count	9	9	18
		Expected Count	10.3	7.7	18.0
		% within Company	50.0%	50.0%	100.0%
		% within Individual characteristics	8.2%	11.0%	9.4%
		% of Total	4.7%	4.7%	9.4%
	J	Count	13	12	25
		Expected Count	14.3	10.7	25.0
		% within Company	52.0%	48.0%	100.0%
		% within Individual characteristics	11.8%	14.6%	13.0%
		% of Total	6.8%	6.3%	13.0%
Total		Count	110	82	192
		Expected Count	110.0	82.0	192.0
		% within Company	57.3%	42.7%	100.0%
		% within Individual characteristics	100.0%	100.0%	100.0%
		% of Total	57.3%	42.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.781[a]	9	.173
Likelihood Ratio	12.941	9	.165
N of Valid Cases	192		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 4.70.

8.11.6.2 Crosstabulation Table by Company for Top Level 1 Barrier "Organizations"

Company * Organizations Crosstabulation

			Organizations		
			0	1	Total
Company	A	Count	11	5	16
		Expected Count	10.8	5.3	16.0
		% within Company	68.8%	31.3%	100.0%
		% within Organizations	8.5%	7.9%	8.3%
		% of Total	5.7%	2.6%	8.3%
	B	Count	9	8	17
		Expected Count	11.4	5.6	17.0
		% within Company	52.9%	47.1%	100.0%
		% within Organizations	7.0%	12.7%	8.9%
		% of Total	4.7%	4.2%	8.9%
	C	Count	17	8	25
		Expected Count	16.8	8.2	25.0
		% within Company	68.0%	32.0%	100.0%
		% within Organizations	13.2%	12.7%	13.0%
		% of Total	8.9%	4.2%	13.0%
	D	Count	15	4	19
		Expected Count	12.8	6.2	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Organizations	11.6%	6.3%	9.9%
		% of Total	7.8%	2.1%	9.9%
	E	Count	9	10	19
		Expected Count	12.8	6.2	19.0
		% within Company	47.4%	52.6%	100.0%
		% within Organizations	7.0%	15.9%	9.9%
		% of Total	4.7%	5.2%	9.9%
	F	Count	10	12	22
		Expected Count	14.8	7.2	22.0
		% within Company	45.5%	54.5%	100.0%
		% within Organizations	7.8%	19.0%	11.5%
		% of Total	5.2%	6.3%	11.5%
	G	Count	9	2	11
		Expected Count	7.4	3.6	11.0
		% within Company	81.8%	18.2%	100.0%
		% within Organizations	7.0%	3.2%	5.7%
		% of Total	4.7%	1.0%	5.7%
	H	Count	18	2	20
		Expected Count	13.4	6.6	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Organizations	14.0%	3.2%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	14	4	18
		Expected Count	12.1	5.9	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Organizations	10.9%	6.3%	9.4%
		% of Total	7.3%	2.1%	9.4%
	J	Count	17	8	25
		Expected Count	16.8	8.2	25.0
		% within Company	68.0%	32.0%	100.0%
		% within Organizations	13.2%	12.7%	13.0%
		% of Total	8.9%	4.2%	13.0%
Total		Count	129	63	192
		Expected Count	129.0	63.0	192.0
		% within Company	67.2%	32.8%	100.0%
		% within Organizations	100.0%	100.0%	100.0%
		% of Total	67.2%	32.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.593[a]	9	.040
Likelihood Ratio	18.278	9	.032
N of Valid Cases	192		

a. 1 cells (5.0%) have expected count less than 5. The minimum expected count is 3.61.

8.11.6.3 Crosstabulation Table by Company for Top Level 1 Barrier "Schedule and Cost Constraints"

Company * Schedule and cost constraints Crosstabulation

			Schedule and cost constraints		Total
			0	1	
Company	A	Count	13	3	16
		Expected Count	12.5	3.5	16.0
		% within Company	81.3%	18.8%	100.0%
		% within Schedule and cost constraints	8.7%	7.1%	8.3%
		% of Total	6.8%	1.6%	8.3%
	B	Count	15	2	17
		Expected Count	13.3	3.7	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Schedule and cost constraints	10.0%	4.8%	8.9%
		% of Total	7.8%	1.0%	8.9%
	C	Count	18	7	25
		Expected Count	19.5	5.5	25.0
		% within Company	72.0%	28.0%	100.0%
		% within Schedule and cost constraints	12.0%	16.7%	13.0%
		% of Total	9.4%	3.6%	13.0%
	D	Count	17	2	19
		Expected Count	14.8	4.2	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Schedule and cost constraints	11.3%	4.8%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	16	3	19
		Expected Count	14.8	4.2	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Schedule and cost constraints	10.7%	7.1%	9.9%
		% of Total	8.3%	1.6%	9.9%
	F	Count	13	9	22
		Expected Count	17.2	4.8	22.0
		% within Company	59.1%	40.9%	100.0%
		% within Schedule and cost constraints	8.7%	21.4%	11.5%
		% of Total	6.8%	4.7%	11.5%
	G	Count	10	1	11
		Expected Count	8.6	2.4	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Schedule and cost constraints	6.7%	2.4%	5.7%
		% of Total	5.2%	.5%	5.7%
	H	Count	14	6	20
		Expected Count	15.6	4.4	20.0
		% within Company	70.0%	30.0%	100.0%
		% within Schedule and cost constraints	9.3%	14.3%	10.4%
		% of Total	7.3%	3.1%	10.4%
	I	Count	14	4	18
		Expected Count	14.1	3.9	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Schedule and cost constraints	9.3%	9.5%	9.4%
		% of Total	7.3%	2.1%	9.4%
	J	Count	20	5	25
		Expected Count	19.5	5.5	25.0
		% within Company	80.0%	20.0%	100.0%
		% within Schedule and cost constraints	13.3%	11.9%	13.0%
		% of Total	10.4%	2.6%	13.0%
Total		Count	150	42	192
		Expected Count	150.0	42.0	192.0
		% within Company	78.1%	21.9%	100.0%
		% within Schedule and cost constraints	100.0%	100.0%	100.0%
		% of Total	78.1%	21.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.042[a]	9	.347
Likelihood Ratio	9.964	9	.353
N of Valid Cases	192		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is 2.41.

8.11.6.4 Crosstabulation Table by Company for Top Level 1 Barrier "Training/Education"

Company * Training/Education Crosstabulation

			Training/Education		
			0	1	Total
Company	A	Count	14	2	16
		Expected Count	13.3	2.7	16.0
		% within Company	87.5%	12.5%	100.0%
		% within Training/Education	8.8%	6.3%	8.3%
		% of Total	7.3%	1.0%	8.3%
	B	Count	13	4	17
		Expected Count	14.2	2.8	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Training/Education	8.1%	12.5%	8.9%
		% of Total	6.8%	2.1%	8.9%
	C	Count	18	7	25
		Expected Count	20.8	4.2	25.0
		% within Company	72.0%	28.0%	100.0%
		% within Training/Education	11.3%	21.9%	13.0%
		% of Total	9.4%	3.6%	13.0%
	D	Count	17	2	19
		Expected Count	15.8	3.2	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Training/Education	10.6%	6.3%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	17	2	19
		Expected Count	15.8	3.2	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Training/Education	10.6%	6.3%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	20	2	22
		Expected Count	18.3	3.7	22.0
		% within Company	90.9%	9.1%	100.0%
		% within Training/Education	12.5%	6.3%	11.5%
		% of Total	10.4%	1.0%	11.5%
	G	Count	10	1	11
		Expected Count	9.2	1.8	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Training/Education	6.3%	3.1%	5.7%
		% of Total	5.2%	.5%	5.7%
	H	Count	16	4	20
		Expected Count	16.7	3.3	20.0
		% within Company	80.0%	20.0%	100.0%
		% within Training/Education	10.0%	12.5%	10.4%
		% of Total	8.3%	2.1%	10.4%
	I	Count	16	2	18
		Expected Count	15.0	3.0	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Training/Education	10.0%	6.3%	9.4%
		% of Total	8.3%	1.0%	9.4%
	J	Count	19	6	25
		Expected Count	20.8	4.2	25.0
		% within Company	76.0%	24.0%	100.0%
		% within Training/Education	11.9%	18.8%	13.0%
		% of Total	9.9%	3.1%	13.0%
Total		Count	160	32	192
		Expected Count	160.0	32.0	192.0
		% within Company	83.3%	16.7%	100.0%
		% within Training/Education	100.0%	100.0%	100.0%
		% of Total	83.3%	16.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.012[a]	9	.636
Likelihood Ratio	6.953	9	.642
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.83.

8.11.6.5 Crosstabulation Table by Company for Top Level 1 Barrier "Work Design"

Company * Work design Crosstabulation

			Work design		
			0	1	Total
Company	A	Count	16	0	16
		Expected Count	13.5	2.5	16.0
		% within Company	100.0%	.0%	100.0%
		% within Work design	9.9%	.0%	8.3%
		% of Total	8.3%	.0%	8.3%
	B	Count	14	3	17
		Expected Count	14.3	2.7	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Work design	8.6%	10.0%	8.9%
		% of Total	7.3%	1.6%	8.9%
	C	Count	21	4	25
		Expected Count	21.1	3.9	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Work design	13.0%	13.3%	13.0%
		% of Total	10.9%	2.1%	13.0%
	D	Count	17	2	19
		Expected Count	16.0	3.0	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Work design	10.5%	6.7%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	12	7	19
		Expected Count	16.0	3.0	19.0
		% within Company	63.2%	36.8%	100.0%
		% within Work design	7.4%	23.3%	9.9%
		% of Total	6.3%	3.6%	9.9%
	F	Count	17	5	22
		Expected Count	18.6	3.4	22.0
		% within Company	77.3%	22.7%	100.0%
		% within Work design	10.5%	16.7%	11.5%
		% of Total	8.9%	2.6%	11.5%
	G	Count	10	1	11
		Expected Count	9.3	1.7	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Work design	6.2%	3.3%	5.7%
		% of Total	5.2%	.5%	5.7%
	H	Count	19	1	20
		Expected Count	16.9	3.1	20.0
		% within Company	95.0%	5.0%	100.0%
		% within Work design	11.7%	3.3%	10.4%
		% of Total	9.9%	.5%	10.4%
	I	Count	16	2	18
		Expected Count	15.2	2.8	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Work design	9.9%	6.7%	9.4%
		% of Total	8.3%	1.0%	9.4%
	J	Count	20	5	25
		Expected Count	21.1	3.9	25.0
		% within Company	80.0%	20.0%	100.0%
		% within Work design	12.3%	16.7%	13.0%
		% of Total	10.4%	2.6%	13.0%
Total		Count	162	30	192
		Expected Count	162.0	30.0	192.0
		% within Company	84.4%	15.6%	100.0%
		% within Work design	100.0%	100.0%	100.0%
		% of Total	84.4%	15.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.432[a]	9	.144
Likelihood Ratio	15.000	9	.091
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.72.

8.11.6.6 Crosstabulation Table by Company for Top Level 1 Barrier "SE"

Company * SE Crosstabulation

			SE		
			0	1	Total
Company	A	Count	11	5	16
		Expected Count	13.6	2.4	16.0
		% within Company	68.8%	31.3%	100.0%
		% within SE	6.7%	17.2%	8.3%
		% of Total	5.7%	2.6%	8.3%
	B	Count	12	5	17
		Expected Count	14.4	2.6	17.0
		% within Company	70.6%	29.4%	100.0%
		% within SE	7.4%	17.2%	8.9%
		% of Total	6.3%	2.6%	8.9%
	C	Count	18	7	25
		Expected Count	21.2	3.8	25.0
		% within Company	72.0%	28.0%	100.0%
		% within SE	11.0%	24.1%	13.0%
		% of Total	9.4%	3.6%	13.0%
	D	Count	18	1	19
		Expected Count	16.1	2.9	19.0
		% within Company	94.7%	5.3%	100.0%
		% within SE	11.0%	3.4%	9.9%
		% of Total	9.4%	.5%	9.9%
	E	Count	19	0	19
		Expected Count	16.1	2.9	19.0
		% within Company	100.0%	.0%	100.0%
		% within SE	11.7%	.0%	9.9%
		% of Total	9.9%	.0%	9.9%
	F	Count	21	1	22
		Expected Count	18.7	3.3	22.0
		% within Company	95.5%	4.5%	100.0%
		% within SE	12.9%	3.4%	11.5%
		% of Total	10.9%	.5%	11.5%
	G	Count	7	4	11
		Expected Count	9.3	1.7	11.0
		% within Company	63.6%	36.4%	100.0%
		% within SE	4.3%	13.8%	5.7%
		% of Total	3.6%	2.1%	5.7%
	H	Count	18	2	20
		Expected Count	17.0	3.0	20.0
		% within Company	90.0%	10.0%	100.0%
		% within SE	11.0%	6.9%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	16	2	18
		Expected Count	15.3	2.7	18.0
		% within Company	88.9%	11.1%	100.0%
		% within SE	9.8%	6.9%	9.4%
		% of Total	8.3%	1.0%	9.4%
	J	Count	23	2	25
		Expected Count	21.2	3.8	25.0
		% within Company	92.0%	8.0%	100.0%
		% within SE	14.1%	6.9%	13.0%
		% of Total	12.0%	1.0%	13.0%
Total		Count	163	29	192
		Expected Count	163.0	29.0	192.0
		% within Company	84.9%	15.1%	100.0%
		% within SE	100.0%	100.0%	100.0%
		% of Total	84.9%	15.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.428[a]	9	.011
Likelihood Ratio	23.001	9	.006
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.66.

8.11.7 Top Level 2 Barriers to the Development of Systems Thinking

Top Level 2 Barriers to the Development of Systems Thinking for All Participants (N=192)

Rank	Node Category	Number	Percent
1	Schedule and cost constraints	42	22%
2	Local thinking/myopia	41	21%
3	Organizational boundaries/structure	37	19%
4	Narrow job	26	14%
5	Comfortable	24	13%
5	Education issues	24	13%

Top Level 2 Barriers to the Development of Systems Thinking for Expert Panelists (N=36)

Rank	Node Category	Number	Percent
1	Schedule and cost constraints	12	33%
2	Local thinking/myopia	6	17%
2	Organizational boundaries/structure	6	17%

Top Level 2 Barriers to the Development of Systems Thinking for Senior Systems Engineers (N=62)

Rank	Node Category	Number	Percent
1	Organizational boundaries/structure	14	23%
2	Education issues	12	19%
3	Schedule and cost constraints	10	16%
4	Narrow job	9	15%
4	Comfortable	9	15%
4	Local thinking/myopia	9	15%

Top Level 2 Barriers to the Development of Systems Thinking for Senior Technical Specialists (N=46)

Rank	Node Category	Number	Percent
1	Local thinking/myopia	15	33%
2	Narrow job	8	17%
2	Schedule and cost constraints	8	17%
4	Comfortable	7	15%
5	Interpersonal	5	11%
5	Organizational boundaries/structure	5	11%

Top Level 2 Barriers to the Development of Systems Thinking for Junior Systems Engineers (N=48)

Rank	Node Category	Number	Percent
1	Schedule and cost constraints	12	25%
1	Organizational boundaries/structure	12	25%
3	Local thinking/myopia	11	23%
4	Comfortable	8	17%
5	Narrow job	7	15%
6	Education issues	6	13%

8.11.8 Summary of Top Level 2 Barriers to the Development of Systems Thinking for All Classifications

Top Level 2 Barriers to the Development of Systems Thinking for All Classifications

(Node categories cited by 10% or more of the classification are shaded)

Node Category	All Participants (N=192)			Expert Panelists (N=36)			Senior Systems Engineers (N=62)			Senior Technical Specialists (N=46)			Junior Systems Engineers (N=48)			Chi-Square	Asymptotic Significance
	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent		
Schedule and cost constraints	1	42	22%	1	12	33%	3	10	16%	2	8	17%	1	12	25%	4.779	0.189
Local thinking/myopia	2	41	21%	2	6	17%	4	9	15%	1	15	33%	3	11	23%	5.736	0.125
Organizational boundaries/structure	3	37	19%	2	6	17%	1	14	23%	5	5	11%	1	12	25%	3.693	0.297
Narrow job	4	26	14%	7	2	6%	4	9	15%	2	8	17%	5	7	15%	2.638	0.451
Comfortable	5	24	13%	28	0	0%	4	9	15%	4	7	15%	4	8	17%	6.446	0.092
Education issues	5	24	13%	4	3	8%	2	12	19%	7	3	7%	6	6	13%	4.738	0.192
Interpersonal	7	13	7%	9	1	3%	7	4	6%	5	5	11%	9	3	6%	2.164	0.539

8.11.9 Crosstabulation Tables by Classification for Top Level 2 Barriers

8.11.9.1 Crosstabulation Table by Classification for Top Level 2 Barrier "Schedule and Cost Constraints"

Translated Classification * Schedule and cost constraints Crosstabulation

			Schedule and cost constraints		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	24	12	36
		Expected Count	28.1	7.9	36.0
		% within Translated Classification	66.7%	33.3%	100.0%
		% within Schedule and cost constraints	16.0%	28.6%	18.8%
		% of Total	12.5%	6.3%	18.8%
	2_Senior Systems Engineer	Count	52	10	62
		Expected Count	48.4	13.6	62.0
		% within Translated Classification	83.9%	16.1%	100.0%
		% within Schedule and cost constraints	34.7%	23.8%	32.3%
		% of Total	27.1%	5.2%	32.3%
	3_Senior Tech Specialist	Count	38	8	46
		Expected Count	35.9	10.1	46.0
		% within Translated Classification	82.6%	17.4%	100.0%
		% within Schedule and cost constraints	25.3%	19.0%	24.0%
		% of Total	19.8%	4.2%	24.0%
	4_Junior Systems Engineer	Count	36	12	48
		Expected Count	37.5	10.5	48.0
		% within Translated Classification	75.0%	25.0%	100.0%
		% within Schedule and cost constraints	24.0%	28.6%	25.0%
		% of Total	18.8%	6.3%	25.0%
Total		Count	150	42	192
		Expected Count	150.0	42.0	192.0
		% within Translated Classification	78.1%	21.9%	100.0%
		% within Schedule and cost constraints	100.0%	100.0%	100.0%
		% of Total	78.1%	21.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.779[a]	3	.189
Likelihood Ratio	4.619	3	.202
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.88.

8.11.9.2 Crosstabulation Table by Classification for Top Level 2 Barrier "Local Thinking/Myopia"

Translated Classification * Local thinking/myopia Crosstabulation

			Local thinking/myopia		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	30	6	36
		Expected Count	28.3	7.7	36.0
		% within Translated Classification	83.3%	16.7%	100.0%
		% within Local thinking/myopia	19.9%	14.6%	18.8%
		% of Total	15.6%	3.1%	18.8%
	2_Senior Systems Engineer	Count	53	9	62
		Expected Count	48.8	13.2	62.0
		% within Translated Classification	85.5%	14.5%	100.0%
		% within Local thinking/myopia	35.1%	22.0%	32.3%
		% of Total	27.6%	4.7%	32.3%
	3_Senior Tech Specialist	Count	31	15	46
		Expected Count	36.2	9.8	46.0
		% within Translated Classification	67.4%	32.6%	100.0%
		% within Local thinking/myopia	20.5%	36.6%	24.0%
		% of Total	16.1%	7.8%	24.0%
	4_Junior Systems Engineer	Count	37	11	48
		Expected Count	37.8	10.3	48.0
		% within Translated Classification	77.1%	22.9%	100.0%
		% within Local thinking/myopia	24.5%	26.8%	25.0%
		% of Total	19.3%	5.7%	25.0%
Total		Count	151	41	192
		Expected Count	151.0	41.0	192.0
		% within Translated Classification	78.6%	21.4%	100.0%
		% within Local thinking/myopia	100.0%	100.0%	100.0%
		% of Total	78.6%	21.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.736[a]	3	.125
Likelihood Ratio	5.583	3	.134
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.69.

8.11.9.3 Crosstabulation Table by Classification for Top Level 2 Barrier "Organizational Boundaries/Structure"

Translated Classification * Organizational boundaries/structure Crosstabulation

			Organizational boundaries/structure		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	30	6	36
		Expected Count	29.1	6.9	36.0
		% within Translated Classification	83.3%	16.7%	100.0%
		% within Organizational boundaries/structure	19.4%	16.2%	18.8%
		% of Total	15.6%	3.1%	18.8%
	2_Senior Systems Engineer	Count	48	14	62
		Expected Count	50.1	11.9	62.0
		% within Translated Classification	77.4%	22.6%	100.0%
		% within Organizational boundaries/structure	31.0%	37.8%	32.3%
		% of Total	25.0%	7.3%	32.3%
	3_Senior Tech Specialist	Count	41	5	46
		Expected Count	37.1	8.9	46.0
		% within Translated Classification	89.1%	10.9%	100.0%
		% within Organizational boundaries/structure	26.5%	13.5%	24.0%
		% of Total	21.4%	2.6%	24.0%
	4_Junior Systems Engineer	Count	36	12	48
		Expected Count	38.8	9.3	48.0
		% within Translated Classification	75.0%	25.0%	100.0%
		% within Organizational boundaries/structure	23.2%	32.4%	25.0%
		% of Total	18.8%	6.3%	25.0%
Total		Count	155	37	192
		Expected Count	155.0	37.0	192.0
		% within Translated Classification	80.7%	19.3%	100.0%
		% within Organizational boundaries/structure	100.0%	100.0%	100.0%
		% of Total	80.7%	19.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.693[a]	3	.297
Likelihood Ratio	3.920	3	.270
N of Valid Cases	192		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.94.

8.11.9.4 Crosstabulation Table by Classification for Top Level 2 Barrier "Narrow Job"

Translated Classification * Narrow job Crosstabulation

			Narrow job		
			0	1	Total
Translated Classification	1_Expert Panelist	Count	34	2	36
		Expected Count	31.1	4.9	36.0
		% within Translated Classification	94.4%	5.6%	100.0%
		% within Narrow job	20.5%	7.7%	18.8%
		% of Total	17.7%	1.0%	18.8%
	2_Senior Systems Engineer	Count	53	9	62
		Expected Count	53.6	8.4	62.0
		% within Translated Classification	85.5%	14.5%	100.0%
		% within Narrow job	31.9%	34.6%	32.3%
		% of Total	27.6%	4.7%	32.3%
	3_Senior Tech Specialist	Count	38	8	46
		Expected Count	39.8	6.2	46.0
		% within Translated Classification	82.6%	17.4%	100.0%
		% within Narrow job	22.9%	30.8%	24.0%
		% of Total	19.8%	4.2%	24.0%
	4_Junior Systems Engineer	Count	41	7	48
		Expected Count	41.5	6.5	48.0
		% within Translated Classification	85.4%	14.6%	100.0%
		% within Narrow job	24.7%	26.9%	25.0%
		% of Total	21.4%	3.6%	25.0%
Total		Count	166	26	192
		Expected Count	166.0	26.0	192.0
		% within Translated Classification	86.5%	13.5%	100.0%
		% within Narrow job	100.0%	100.0%	100.0%
		% of Total	86.5%	13.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.638[a]	3	.451
Likelihood Ratio	3.078	3	.380
N of Valid Cases	192		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.88.

8.11.9.5 Crosstabulation Table by Classification for Top Level 2 Barrier "Comfortable"

Translated Classification * Comfortable Crosstabulation

			Comfortable 0	Comfortable 1	Total
Translated Classification	1_Expert Panelist	Count	36	0	36
		Expected Count	31.5	4.5	36.0
		% within Translated Classification	100.0%	.0%	100.0%
		% within Comfortable	21.4%	.0%	18.8%
		% of Total	18.8%	.0%	18.8%
	2_Senior Systems Engineer	Count	53	9	62
		Expected Count	54.3	7.8	62.0
		% within Translated Classification	85.5%	14.5%	100.0%
		% within Comfortable	31.5%	37.5%	32.3%
		% of Total	27.6%	4.7%	32.3%
	3_Senior Tech Specialist	Count	39	7	46
		Expected Count	40.3	5.8	46.0
		% within Translated Classification	84.8%	15.2%	100.0%
		% within Comfortable	23.2%	29.2%	24.0%
		% of Total	20.3%	3.6%	24.0%
	4_Junior Systems Engineer	Count	40	8	48
		Expected Count	42.0	6.0	48.0
		% within Translated Classification	83.3%	16.7%	100.0%
		% within Comfortable	23.8%	33.3%	25.0%
		% of Total	20.8%	4.2%	25.0%
Total		Count	168	24	192
		Expected Count	168.0	24.0	192.0
		% within Translated Classification	87.5%	12.5%	100.0%
		% within Comfortable	100.0%	100.0%	100.0%
		% of Total	87.5%	12.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.446[a]	3	.092
Likelihood Ratio	10.828	3	.013
N of Valid Cases	192		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.50.

8.11.9.6 Crosstabulation Table by Classification for Top Level 2 Barrier "Education Issues"

Translated Classification * Education issues Crosstabulation

			Education issues		Total
			0	1	
Translated Classification	1_Expert Panelist	Count	33	3	36
		Expected Count	31.5	4.5	36.0
		% within Translated Classification	91.7%	8.3%	100.0%
		% within Education issues	19.6%	12.5%	18.8%
		% of Total	17.2%	1.6%	18.8%
	2_Senior Systems Engineer	Count	50	12	62
		Expected Count	54.3	7.8	62.0
		% within Translated Classification	80.6%	19.4%	100.0%
		% within Education issues	29.8%	50.0%	32.3%
		% of Total	26.0%	6.3%	32.3%
	3_Senior Tech Specialist	Count	43	3	46
		Expected Count	40.3	5.8	46.0
		% within Translated Classification	93.5%	6.5%	100.0%
		% within Education issues	25.6%	12.5%	24.0%
		% of Total	22.4%	1.6%	24.0%
	4_Junior Systems Engineer	Count	42	6	48
		Expected Count	42.0	6.0	48.0
		% within Translated Classification	87.5%	12.5%	100.0%
		% within Education issues	25.0%	25.0%	25.0%
		% of Total	21.9%	3.1%	25.0%
Total		Count	168	24	192
		Expected Count	168.0	24.0	192.0
		% within Translated Classification	87.5%	12.5%	100.0%
		% within Education issues	100.0%	100.0%	100.0%
		% of Total	87.5%	12.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.738[a]	3	.192
Likelihood Ratio	4.753	3	.191
N of Valid Cases	192		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.50.

8.11.10Crosstabulation Tables by Company for Top Level 2 Barriers

8.11.10.1 Crosstabulation Table by Company for Top Level 2 Barrier "Schedule and Cost Constraints"

Company * Schedule and cost constraints Crosstabulation

			Schedule and cost constraints		
			0	1	Total
Company	A	Count	13	3	16
		Expected Count	12.5	3.5	16.0
		% within Company	81.3%	18.8%	100.0%
		% within Schedule and cost constraints	8.7%	7.1%	8.3%
		% of Total	6.8%	1.6%	8.3%
	B	Count	15	2	17
		Expected Count	13.3	3.7	17.0
		% within Company	88.2%	11.8%	100.0%
		% within Schedule and cost constraints	10.0%	4.8%	8.9%
		% of Total	7.8%	1.0%	8.9%
	C	Count	18	7	25
		Expected Count	19.5	5.5	25.0
		% within Company	72.0%	28.0%	100.0%
		% within Schedule and cost constraints	12.0%	16.7%	13.0%
		% of Total	9.4%	3.6%	13.0%
	D	Count	17	2	19
		Expected Count	14.8	4.2	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Schedule and cost constraints	11.3%	4.8%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	16	3	19
		Expected Count	14.8	4.2	19.0
		% within Company	84.2%	15.8%	100.0%
		% within Schedule and cost constraints	10.7%	7.1%	9.9%
		% of Total	8.3%	1.6%	9.9%
	F	Count	13	9	22
		Expected Count	17.2	4.8	22.0
		% within Company	59.1%	40.9%	100.0%
		% within Schedule and cost constraints	8.7%	21.4%	11.5%
		% of Total	6.8%	4.7%	11.5%
	G	Count	10	1	11
		Expected Count	8.6	2.4	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Schedule and cost constraints	6.7%	2.4%	5.7%
		% of Total	5.2%	.5%	5.7%
	H	Count	14	6	20
		Expected Count	15.6	4.4	20.0
		% within Company	70.0%	30.0%	100.0%
		% within Schedule and cost constraints	9.3%	14.3%	10.4%
		% of Total	7.3%	3.1%	10.4%
	I	Count	14	4	18
		Expected Count	14.1	3.9	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Schedule and cost constraints	9.3%	9.5%	9.4%
		% of Total	7.3%	2.1%	9.4%
	J	Count	20	5	25
		Expected Count	19.5	5.5	25.0
		% within Company	80.0%	20.0%	100.0%
		% within Schedule and cost constraints	13.3%	11.9%	13.0%
		% of Total	10.4%	2.6%	13.0%
Total		Count	150	42	192
		Expected Count	150.0	42.0	192.0
		% within Company	78.1%	21.9%	100.0%
		% within Schedule and cost constraints	100.0%	100.0%	100.0%
		% of Total	78.1%	21.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.042[a]	9	.347
Likelihood Ratio	9.964	9	.353
N of Valid Cases	192		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is 2.41.

8.11.10.2 Crosstabulation Table by Company for Top Level 2 Barrier "Local Thinking/Myopia"

Company * Local thinking/myopia Crosstabulation

			Local thinking/myopia 0	Local thinking/myopia 1	Total
Company	A	Count	14	2	16
		Expected Count	12.6	3.4	16.0
		% within Company	87.5%	12.5%	100.0%
		% within Local thinking/myopia	9.3%	4.9%	8.3%
		% of Total	7.3%	1.0%	8.3%
	B	Count	13	4	17
		Expected Count	13.4	3.6	17.0
		% within Company	76.5%	23.5%	100.0%
		% within Local thinking/myopia	8.6%	9.8%	8.9%
		% of Total	6.8%	2.1%	8.9%
	C	Count	20	5	25
		Expected Count	19.7	5.3	25.0
		% within Company	80.0%	20.0%	100.0%
		% within Local thinking/myopia	13.2%	12.2%	13.0%
		% of Total	10.4%	2.6%	13.0%
	D	Count	14	5	19
		Expected Count	14.9	4.1	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Local thinking/myopia	9.3%	12.2%	9.9%
		% of Total	7.3%	2.6%	9.9%
	E	Count	14	5	19
		Expected Count	14.9	4.1	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Local thinking/myopia	9.3%	12.2%	9.9%
		% of Total	7.3%	2.6%	9.9%
	F	Count	20	2	22
		Expected Count	17.3	4.7	22.0
		% within Company	90.9%	9.1%	100.0%
		% within Local thinking/myopia	13.2%	4.9%	11.5%
		% of Total	10.4%	1.0%	11.5%
	G	Count	8	3	11
		Expected Count	8.7	2.3	11.0
		% within Company	72.7%	27.3%	100.0%
		% within Local thinking/myopia	5.3%	7.3%	5.7%
		% of Total	4.2%	1.6%	5.7%
	H	Count	15	5	20
		Expected Count	15.7	4.3	20.0
		% within Company	75.0%	25.0%	100.0%
		% within Local thinking/myopia	9.9%	12.2%	10.4%
		% of Total	7.8%	2.6%	10.4%
	I	Count	14	4	18
		Expected Count	14.2	3.8	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Local thinking/myopia	9.3%	9.8%	9.4%
		% of Total	7.3%	2.1%	9.4%
	J	Count	19	6	25
		Expected Count	19.7	5.3	25.0
		% within Company	76.0%	24.0%	100.0%
		% within Local thinking/myopia	12.6%	14.6%	13.0%
		% of Total	9.9%	3.1%	13.0%
Total		Count	151	41	192
		Expected Count	151.0	41.0	192.0
		% within Company	78.6%	21.4%	100.0%
		% within Local thinking/myopia	100.0%	100.0%	100.0%
		% of Total	78.6%	21.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.849[a]	9	.921
Likelihood Ratio	4.307	9	.890
N of Valid Cases	192		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is 2.35.

8.11.10.3 Crosstabulation Table by Company for Top Level 2 Barrier "Organizational Boundaries/Structure"

Company * Organizational boundaries/structure Crosstabulation

			Organizational boundaries/structure		Total
			0	1	
Company	A	Count	12	4	16
		Expected Count	12.9	3.1	16.0
		% within Company	75.0%	25.0%	100.0%
		% within Organizational boundaries/structure	7.7%	10.8%	8.3%
		% of Total	6.3%	2.1%	8.3%
	B	Count	11	6	17
		Expected Count	13.7	3.3	17.0
		% within Company	64.7%	35.3%	100.0%
		% within Organizational boundaries/structure	7.1%	16.2%	8.9%
		% of Total	5.7%	3.1%	8.9%
	C	Count	21	4	25
		Expected Count	20.2	4.8	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Organizational boundaries/structure	13.5%	10.8%	13.0%
		% of Total	10.9%	2.1%	13.0%
	D	Count	17	2	19
		Expected Count	15.3	3.7	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Organizational boundaries/structure	11.0%	5.4%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	14	5	19
		Expected Count	15.3	3.7	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Organizational boundaries/structure	9.0%	13.5%	9.9%
		% of Total	7.3%	2.6%	9.9%
	F	Count	13	9	22
		Expected Count	17.8	4.2	22.0
		% within Company	59.1%	40.9%	100.0%
		% within Organizational boundaries/structure	8.4%	24.3%	11.5%
		% of Total	6.8%	4.7%	11.5%
	G	Count	11	0	11
		Expected Count	8.9	2.1	11.0
		% within Company	100.0%	.0%	100.0%
		% within Organizational boundaries/structure	7.1%	.0%	5.7%
		% of Total	5.7%	.0%	5.7%
	H	Count	19	1	20
		Expected Count	16.1	3.9	20.0
		% within Company	95.0%	5.0%	100.0%
		% within Organizational boundaries/structure	12.3%	2.7%	10.4%
		% of Total	9.9%	.5%	10.4%
	I	Count	16	2	18
		Expected Count	14.5	3.5	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Organizational boundaries/structure	10.3%	5.4%	9.4%
		% of Total	8.3%	1.0%	9.4%
	J	Count	21	4	25
		Expected Count	20.2	4.8	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Organizational boundaries/structure	13.5%	10.8%	13.0%
		% of Total	10.9%	2.1%	13.0%
Total		Count	155	37	192
		Expected Count	155.0	37.0	192.0
		% within Company	80.7%	19.3%	100.0%
		% within Organizational boundaries/structure	100.0%	100.0%	100.0%
		% of Total	80.7%	19.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.663[a]	9	.039
Likelihood Ratio	19.219	9	.023
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 2.12.

8.11.10.4 Crosstabulation Table by Company for Top Level 2 Barrier "Narrow Job"

Company * Narrow job Crosstabulation

			Narrow job		
			0	1	Total
Company	A	Count	16	0	16
		Expected Count	13.8	2.2	16.0
		% within Company	100.0%	.0%	100.0%
		% within Narrow job	9.6%	.0%	8.3%
		% of Total	8.3%	.0%	8.3%
	B	Count	14	3	17
		Expected Count	14.7	2.3	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Narrow job	8.4%	11.5%	8.9%
		% of Total	7.3%	1.6%	8.9%
	C	Count	21	4	25
		Expected Count	21.6	3.4	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Narrow job	12.7%	15.4%	13.0%
		% of Total	10.9%	2.1%	13.0%
	D	Count	17	2	19
		Expected Count	16.4	2.6	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Narrow job	10.2%	7.7%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	14	5	19
		Expected Count	16.4	2.6	19.0
		% within Company	73.7%	26.3%	100.0%
		% within Narrow job	8.4%	19.2%	9.9%
		% of Total	7.3%	2.6%	9.9%
	F	Count	18	4	22
		Expected Count	19.0	3.0	22.0
		% within Company	81.8%	18.2%	100.0%
		% within Narrow job	10.8%	15.4%	11.5%
		% of Total	9.4%	2.1%	11.5%
	G	Count	10	1	11
		Expected Count	9.5	1.5	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Narrow job	6.0%	3.8%	5.7%
		% of Total	5.2%	.5%	5.7%
	H	Count	19	1	20
		Expected Count	17.3	2.7	20.0
		% within Company	95.0%	5.0%	100.0%
		% within Narrow job	11.4%	3.8%	10.4%
		% of Total	9.9%	.5%	10.4%
	I	Count	16	2	18
		Expected Count	15.6	2.4	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Narrow job	9.6%	7.7%	9.4%
		% of Total	8.3%	1.0%	9.4%
	J	Count	21	4	25
		Expected Count	21.6	3.4	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Narrow job	12.7%	15.4%	13.0%
		% of Total	10.9%	2.1%	13.0%
Total		Count	166	26	192
		Expected Count	166.0	26.0	192.0
		% within Company	86.5%	13.5%	100.0%
		% within Narrow job	100.0%	100.0%	100.0%
		% of Total	86.5%	13.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.732[a]	9	.561
Likelihood Ratio	9.716	9	.374
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.49.

8.11.10.5 Crosstabulation Table by Company for Top Level 2 Barrier "Comfortable"

Company * Comfortable Crosstabulation

			Comfortable		Total
			0	1	
Company	A	Count	15	1	16
		Expected Count	14.0	2.0	16.0
		% within Company	93.8%	6.3%	100.0%
		% within Comfortable	8.9%	4.2%	8.3%
		% of Total	7.8%	.5%	8.3%
	B	Count	17	0	17
		Expected Count	14.9	2.1	17.0
		% within Company	100.0%	.0%	100.0%
		% within Comfortable	10.1%	.0%	8.9%
		% of Total	8.9%	.0%	8.9%
	C	Count	21	4	25
		Expected Count	21.9	3.1	25.0
		% within Company	84.0%	16.0%	100.0%
		% within Comfortable	12.5%	16.7%	13.0%
		% of Total	10.9%	2.1%	13.0%
	D	Count	15	4	19
		Expected Count	16.6	2.4	19.0
		% within Company	78.9%	21.1%	100.0%
		% within Comfortable	8.9%	16.7%	9.9%
		% of Total	7.8%	2.1%	9.9%
	E	Count	18	1	19
		Expected Count	16.6	2.4	19.0
		% within Company	94.7%	5.3%	100.0%
		% within Comfortable	10.7%	4.2%	9.9%
		% of Total	9.4%	.5%	9.9%
	F	Count	17	5	22
		Expected Count	19.3	2.8	22.0
		% within Company	77.3%	22.7%	100.0%
		% within Comfortable	10.1%	20.8%	11.5%
		% of Total	8.9%	2.6%	11.5%
	G	Count	10	1	11
		Expected Count	9.6	1.4	11.0
		% within Company	90.9%	9.1%	100.0%
		% within Comfortable	6.0%	4.2%	5.7%
		% of Total	5.2%	.5%	5.7%
	H	Count	18	2	20
		Expected Count	17.5	2.5	20.0
		% within Company	90.0%	10.0%	100.0%
		% within Comfortable	10.7%	8.3%	10.4%
		% of Total	9.4%	1.0%	10.4%
	I	Count	14	4	18
		Expected Count	15.8	2.3	18.0
		% within Company	77.8%	22.2%	100.0%
		% within Comfortable	8.3%	16.7%	9.4%
		% of Total	7.3%	2.1%	9.4%
	J	Count	23	2	25
		Expected Count	21.9	3.1	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Comfortable	13.7%	8.3%	13.0%
		% of Total	12.0%	1.0%	13.0%
Total		Count	168	24	192
		Expected Count	168.0	24.0	192.0
		% within Company	87.5%	12.5%	100.0%
		% within Comfortable	100.0%	100.0%	100.0%
		% of Total	87.5%	12.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.814[a]	9	.366
Likelihood Ratio	11.527	9	.241
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.38.

8.11.10.6 Crosstabulation Table by Company for Top Level 2 Barrier "Education Issues"

Company * Education issues Crosstabulation

			Education issues 0	Education issues 1	Total
Company	A	Count	14	2	16
		Expected Count	14.0	2.0	16.0
		% within Company	87.5%	12.5%	100.0%
		% within Education issues	8.3%	8.3%	8.3%
		% of Total	7.3%	1.0%	8.3%
	B	Count	14	3	17
		Expected Count	14.9	2.1	17.0
		% within Company	82.4%	17.6%	100.0%
		% within Education issues	8.3%	12.5%	8.9%
		% of Total	7.3%	1.6%	8.9%
	C	Count	23	2	25
		Expected Count	21.9	3.1	25.0
		% within Company	92.0%	8.0%	100.0%
		% within Education issues	13.7%	8.3%	13.0%
		% of Total	12.0%	1.0%	13.0%
	D	Count	17	2	19
		Expected Count	16.6	2.4	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Education issues	10.1%	8.3%	9.9%
		% of Total	8.9%	1.0%	9.9%
	E	Count	17	2	19
		Expected Count	16.6	2.4	19.0
		% within Company	89.5%	10.5%	100.0%
		% within Education issues	10.1%	8.3%	9.9%
		% of Total	8.9%	1.0%	9.9%
	F	Count	20	2	22
		Expected Count	19.3	2.8	22.0
		% within Company	90.9%	9.1%	100.0%
		% within Education issues	11.9%	8.3%	11.5%
		% of Total	10.4%	1.0%	11.5%
	G	Count	11	0	11
		Expected Count	9.6	1.4	11.0
		% within Company	100.0%	.0%	100.0%
		% within Education issues	6.5%	.0%	5.7%
		% of Total	5.7%	.0%	5.7%
	H	Count	17	3	20
		Expected Count	17.5	2.5	20.0
		% within Company	85.0%	15.0%	100.0%
		% within Education issues	10.1%	12.5%	10.4%
		% of Total	8.9%	1.6%	10.4%
	I	Count	16	2	18
		Expected Count	15.8	2.3	18.0
		% within Company	88.9%	11.1%	100.0%
		% within Education issues	9.5%	8.3%	9.4%
		% of Total	8.3%	1.0%	9.4%
	J	Count	19	6	25
		Expected Count	21.9	3.1	25.0
		% within Company	76.0%	24.0%	100.0%
		% within Education issues	11.3%	25.0%	13.0%
		% of Total	9.9%	3.1%	13.0%
Total		Count	168	24	192
		Expected Count	168.0	24.0	192.0
		% within Company	87.5%	12.5%	100.0%
		% within Education issues	100.0%	100.0%	100.0%
		% of Total	87.5%	12.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.984[a]	9	.742
Likelihood Ratio	6.843	9	.653
N of Valid Cases	192		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is 1.38.

8.12 Statistical Tests

8.12.1 Summary of Comparisons Between All Classifications

All the classifications were compared to each other for each of the top-ranked node categories. Once again, the classifications were Expert Panelists, Senior Systems Engineers, Senior Technical Specialists, and Junior Systems Engineers. The results of the tests are shown here.

Summary of All Classifications Chi-Square Results

Level 1 Determination of Strength Top-Ranked Node Category	Chi - Square	Asymptotic Significance
Difficulty with this	6.659	0.036
Experience and observation	3.788	0.150
Look for certain characteristics	2.277	0.320
Formal methods	3.648	0.161

Level 2 Determination of Strength Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Do not know	5.757	0.056
Experience/demonstrate ability	0.790	0.674
Not formal method in company	0.035	0.983
Observation	3.001	0.223
Look for certain characteristics	2.277	0.320
Management identifies/evaluates	3.557	0.169

Level 1 Key Steps Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Work Experiences	17.625	0.001
Education	6.076	0.108
Individual characteristics	7.605	0.055
Life experiences outside work	10.402	0.015
Interpersonal	1.515	0.679

Level 2 Key Steps Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Work on diverse things	3.028	0.387
Systems jobs/experiences	4.384	0.223
Family	6.129	0.105
Early life experiences	3.452	0.327
Hobbies	12.582	0.006

Level 1 Enablers Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Experience	4.134	0.247
Individual Skills & Traits	1.677	0.642
Interpersonal	9.129	0.028
Organization	3.424	0.331
Interventions	3.791	0.285
Tools & Methodology	4.573	0.206

Level 2 Enablers Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Broad experience base	10.434	0.015
Job/opportunity to see systems view	1.181	0.757
Training	4.417	0.220
Experience in general	4.828	0.185
Education	1.824	0.610
Innate	3.987	0.263
Broad perspective	2.686	0.443

Level 1 Individual Traits Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Personality	7.510	0.057
Thinking	4.202	0.240
Problem Solving/Style	2.018	0.569
Interpersonal	4.255	0.235
Experience	1.939	0.585
Communication	2.594	0.459

Level 2 Individual Traits Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Cluster for thinking broadly	2.352	0.503
Cluster for curiosity	7.378	0.061
Cluster for questioning	2.324	0.508
Open-minded	5.620	0.132
Communication	2.594	0.459
Cluster for tolerance for uncertainty	5.096	0.165
Strong interpersonal skills	0.442	0.931
Cluster for think out-of-box	4.380	0.223

Level 1 Barrier Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Individual characteristics	8.609	0.035
Organizations	11.017	0.012
Schedule and cost constraints	4.779	0.189
Training/Education	2.289	0.515
Work design	0.717	0.869
SE	3.204	0.361

Level 2 Barrier Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Schedule and cost constraints	4.779	0.189
Local thinking/myopia	5.736	0.125
Organizational boundaries/structure	3.693	0.297
Narrow job	2.638	0.451
Comfortable	6.446	0.092
Education issues	4.738	0.192

8.12.2 Paired Differences Between Senior Systems Engineers and Other Classifications

One of the key aspects of the research design was to compare the Senior Systems Engineers to two control groups, Senior Technical Specialists and Junior Systems Engineers. The results of the tests are shown here, along with the results of comparing the Senior Systems Engineers to the Expert Panelists. The values listed are the Pearson chi-square value and the corresponding asymptotic significance. The detailed numbers are provided here for thoroughness.

Summary of Dyad Chi-Square Comparisons

	Senior Systems Engineers vs. Senior Technical Specialists (N=113)		Senior Systems Engineers vs. Junior Systems Engineers (N=114)	
Level 1 Determination of Strong Systems Thinking	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Difficulty with this	3.021	0.082	6.050	0.014
Experience and observation	1.019	0.313	3.781	0.052
Look for certain characteristics	1.502	0.220	0.026	0.872
Formal methods	2.207	0.137	0.084	0.772

	Senior Systems Engineers vs. Senior Technical Specialists (N=113)		Senior Systems Engineers vs. Junior Systems Engineers (N=114)	
Level 2 Determination of Strong Systems Thinking	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Do not know	0.212	0.646	5.187	0.023
Experience/demonstrate ability	0.514	0.473	0.599	0.439
Not formal method in company	0.017	0.897	0.004	0.950
Observation	0.342	0.559	3.014	0.083
Look for certain characteristics	1.502	0.220	0.026	0.872
Management identifies/evaluates	0.205	0.651	2.297	0.130

	Senior Systems Engineers vs. Expert Panelists (N=98)		Senior Systems Engineers vs. Senior Technical Specialists (N=113)		Senior Systems Engineers vs. Junior Systems Engineers (N=113)	
Level 1 Key Steps	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Work Experiences	14.605	0.000	2.455	0.117	0.020	0.887
Education	0.009	0.926	0.141	0.707	3.597	0.058
Individual characteristics	3.032	0.082	0.398	0.528	2.554	0.110
Life experiences outside work	9.902	0.002	0.694	0.405	0.173	0.678
Interpersonal	0.934	0.334	0.000	0.984	0.652	0.420

	Senior Systems Engineers vs. Expert Panelists (N=98)		Senior Systems Engineers vs. Senior Technical Specialists (N=113)		Senior Systems Engineers vs. Junior Systems Engineers (N=113)	
Level 2 Key Steps	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Work on diverse things	1.810	0.179	0.141	0.708	0.174	0.676
Systems jobs/experiences	3.729	0.053	0.796	0.372	0.086	0.770
Family	3.650	0.056	0.402	0.526	0.683	0.409
Early life experiences	0.084	0.773	2.304	0.129	2.304	0.129
Hobbies	6.513	0.011	7.438	0.006	2.867	0.090

	Senior Systems Engineers vs. Expert Panelists (N=87)		Senior Systems Engineers vs. Senior Technical Specialists (N=95)		Senior Systems Engineers vs. Junior Systems Engineers (N=99)	
Level 1 Enablers	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Experience	0.553	0.457	0.236	0.627	3.921	0.048
Individual Skills & Traits	1.107	0.313	0.023	0.879	0.961	0.327
Interpersonal	0.061	0.805	1.553	0.213	6.358	0.012
Organization	1.472	0.225	0.219	0.640	0.192	0.661
Interventions	3.104	0.078	1.175	0.278	1.766	0.184
Tools & Methodology	1.343	0.247	3.683	0.055	1.675	0.196

	Senior Systems Engineers vs. Expert Panelists (N=87)		Senior Systems Engineers vs. Senior Technical Specialists (N=95)		Senior Systems Engineers vs. Junior Systems Engineers (N=99)	
Level 2 Enablers	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Broad experience base	2.182	0.140	3.035	0.081	9.733	0.002
Job/opportunity to see systems view	0.778	0.378	0.950	0.330	0.246	0.620
Training	2.453	0.117	2.486	0.115	2.015	0.156
Experience in general	2.131	0.144	0.448	0.503	0.794	0.373
Education	0.127	0.721	0.980	0.322	0.259	0.611
Innate	1.354	0.245	0.005	0.945	2.532	0.112
Broad perspective	0.492	0.483	0.072	0.789	2.532	0.112

	Senior Systems Engineers vs. Expert Panelists (N=98)		Senior Systems Engineers vs. Senior Technical Specialists (N=113)		Senior Systems Engineers vs. Junior Systems Engineers (N=113)	
Level 1 Individual Traits	Chi-Square	Asymptotic Significance	Chi-Square	Asymptotic Significance	Chi-Square	Asymptotic Significance
Personality	2.262	0.133	0.069	0.793	2.231	0.135
Thinking	1.345	0.246	0.000	0.997	2.857	0.091
Problem Solving/Style	0.014	0.907	0.872	0.351	0.269	0.604
Interpersonal	3.403	0.065	0.155	0.694	1.861	0.173
Experience	0.114	0.736	0.784	0.376	0.784	0.376
Communication	0.344	0.557	2.607	0.106	0.438	0.508

	Senior Systems Engineers vs. Expert Panelists (N=98)		Senior Systems Engineers vs. Senior Technical Specialists (N=113)		Senior Systems Engineers vs. Junior Systems Engineers (N=113)	
Level 2 Individual Traits	Chi-Square	Asymptotic Significance	Chi-Square	Asymptotic Significance	Chi-Square	Asymptotic Significance
Cluster for thinking broadly	1.255	0.263	1.365	0.243	1.905	0.168
Cluster for curiosity	2.898	0.089	0.195	0.659	1.387	0.239
Cluster for questioning	1.220	0.269	1.297	0.255	0.003	0.957
Open-minded	2.939	0.086	4.074	0.044	0.652	0.420
Communication	0.344	0.557	2.607	0.106	0.438	0.508
Cluster for tolerance for uncertainty	0.292	0.589	2.387	0.122	1.375	0.241
Strong interpersonal skills	0.313	0.576	0.086	0.770	0.002	0.969
Cluster for think out-of-box	0.084	0.773	3.186	0.074	0.055	0.815

	Senior Systems Engineers vs. Expert Panelists (N=98)		Senior Systems Engineers vs. Senior Technical Specialists (N=108)		Senior Systems Engineers vs. Junior Systems Engineers (N=110)	
Level 1 Barrier	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Individual characteristics	1.917	0.166	2.606	0.106	1.402	0.236
Organizations	0.065	0.798	8.671	0.003	0.099	0.754
Schedule and cost constraints	3.872	0.049	0.030	0.862	1.331	0.249
Training/Education	0.761	0.383	1.939	0.164	1.570	0.456
Work design	0.468	0.494	0.030	0.862	0.006	0.940
SE	2.661	0.103	0.579	0.447	2.040	0.564

	Senior Systems Engineers vs. Expert Panelists (N=98)		Senior Systems Engineers vs. Senior Technical Specialists (N=108)		Senior Systems Engineers vs. Junior Systems Engineers (N=110)	
Level 2 Barrier	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**	**Chi-Square**	**Asymptotic Significance**
Schedule and cost constraints	3.872	0.049	0.030	0.862	1.331	0.249
Local thinking/myopia	0.081	0.776	5.001	0.025	1.283	0.257
Organizational boundaries/structure	0.490	0.484	2.498	0.114	0.088	0.767
Narrow job	1.835	0.176	0.165	0.685	0.000	0.992
Comfortable	5.754	0.016	0.010	0.919	0.096	0.757
Education issues	2.134	0.144	3.636	0.057	0.929	0.335

8.12.3 Summary of Chi-Square Comparisons of All Companies

To compare the responses between the companies, Pearson chi-square tests were run for each of the top-ranked node categories. The results were shown previously with the company crosstabulation tables. A summary of the chi-square values and the asymptotic significance values is given below to show the trend on how often responses between companies differed. Highlighted are the node categories where the chi-square asymptotic significance value is less than 0.050, which is considered significant. The crosstabulation tables show the actual counts versus the expected counts for each company.

Summary of Company Chi-Square Results

Level 1 Determination of Strength Top-Ranked Node Category	Chi - Square	Asymptotic Significance
Difficulty with this	15.115	0.088
Experience and observation	6.376	0.702
Look for certain characteristics	2.153	0.989
Formal methods	10.037	0.348

Level 2 Determination of Strength Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Do not know	12.461	0.189
Experience/demonstrate ability	11.024	0.274
Not formal method in company	4.493	0.876
Observation	9.167	0.422
Look for certain characteristics	2.153	0.989
Management identifies/evaluates	10.611	0.303

Level 1 Key Steps Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Work Experiences	11.072	0.271
Education	3.804	0.924
Individual characteristics	15.192	0.086
Life experiences outside work	9.709	0.375
Interpersonal	5.215	0.815

Level 2 Key Steps Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Work on diverse things	12.215	0.201
Systems jobs/experiences	8.157	0.518
Family	3.895	0.918
Early life experiences	9.935	0.356
Hobbies	6.375	0.702

Level 1 Enablers Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Experience	17.165	0.046
Individual Skills & Traits	3.467	0.943
Interpersonal	7.731	0.561
Organization	12.174	0.204
Interventions	7.538	0.581
Tools & Methodology	15.780	0.072

Level 2 Enablers Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Broad experience base	5.807	0.759
Job/opportunity to see systems view	16.357	0.060
Training	4.897	0.843
Experience in general	7.815	0.553
Education	12.133	0.206
Innate	11.202	0.262
Broad perspective	18.438	0.030

Level 1 Individual Traits Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Personality	4.476	0.877
Thinking	12.935	0.166
Problem Solving/Style	4.836	0.848
Interpersonal	11.445	0.246
Experience	13.126	0.157
Communication	17.070	0.048

Level 2 Individual Traits Top-Ranked Node Category	Chi-Square	Asymptotic Significance
Cluster for thinking broadly	10.314	0.326
Cluster for curiosity	5.847	0.755
Cluster for questioning	4.613	0.867
Open-minded	14.729	0.099
Communication	17.070	0.048
Cluster for tolerance for uncertainty	10.471	0.314
Strong interpersonal skills	11.775	0.226
Cluster for think out-of-box	20.254	0.016

Level 1 Barrier Top-Ranked Node Category	**Chi-Square**	**Asymptotic Significance**
Individual characteristics	12.781	0.173
Organizations	17.593	0.040
Schedule and cost constraints	10.042	0.347
Training/Education	7.012	0.636
Work design	13.432	0.144
SE	21.428	0.011

Level 2 Barrier Top-Ranked Node Category	**Chi-Square**	**Asymptotic Significance**
Schedule and cost constraints	10.042	0.347
Local thinking/myopia	3.849	0.921
Organizational boundaries/structure	17.663	0.039
Narrow job	7.732	0.561
Comfortable	9.814	0.366
Education issues	5.984	0.742

8.12.4 Summary of Chi-Square Comparisons for Two Companies

Below are the details of the comparison of two companies, Company B and Company J. One has a product-centric systems focus, while the other deals more with systems-of-systems issues. The summary is shown in the text of the document.

Summary of Paired Company Comparison Chi-Square Results Between Company B and Company J

Level 1 Determination of Strength Top-Ranked Node Category (N=37)	Chi-Square	Asymptotic Significance
Difficulty with this	2.588	0.108
Experience and observation	0.833	0.362
Look for certain characteristics	0.202	0.653
Formal methods	0.226	0.635

Level 2 Determination of Strength Top-Ranked Node Category (N=37)	Chi-Square	Asymptotic Significance
Do not know	0.800	0.371
Experience/demonstrate ability	5.188	0.023
Not formal method in company	0.159	0.690
Observation	0.202	0.653
Look for certain characteristics	0.202	0.653
Management identifies/evaluates	0.005	0.946

Level 1 Key Steps Top-Ranked Node Category (N=46)	Chi-Square	Asymptotic Significance
Work Experiences	0.007	0.933
Education	0.047	0.828
Individual characteristics	4.070	0.044
Life experiences outside work	0.044	0.834
Interpersonal	0.158	0.691

Level 2 Key Steps Top-Ranked Node Category (N=46)	Chi-Square	Asymptotic Significance
Work on diverse things	1.442	0.230
Systems jobs/experiences	0.342	0.559
Family	0.217	0.641
Early life experiences	0.104	0.747
Hobbies	0.217	0.641

Level 1 Enablers Top-Ranked Node Category (N=42)	Chi-Square	Asymptotic Significance
Experience	2.471	0.116
Individual Skills & Traits	0.667	0.414
Interpersonal	0.002	0.963
Organization	0.002	0.963
Interventions	1.224	0.268
Tools & Methodology	0.068	0.794

Level 2 Enablers Top-Ranked Node Category (N=42)	Chi-Square	Asymptotic Significance
Broad experience base	0.105	0.746
Job/opportunity to see systems view	7.135	0.008
Training	1.993	0.158
Experience in general	0.068	0.794
Education	0.148	0.700
Innate	0.166	0.683
Broad perspective	0.920	0.338

Level 1 Individual Traits Top-Ranked Node Category (N=45)	Chi-Square	Asymptotic Significance
Personality	0.001	0.977
Thinking	0.001	0.977
Problem Solving/Style	0.189	0.664
Interpersonal	0.440	0.507
Experience	0.618	0.432
Communication	2.645	0.104

Level 2 Individual Traits Top-Ranked Node Category (N=45)	Chi-Square	Asymptotic Significance
Cluster for thinking broadly	2.316	0.128
Cluster for curiosity	0.382	0.537
Cluster for questioning	0.000	0.986
Open-minded	1.141	0.285
Communication	2.645	0.104
Cluster for tolerance for uncertainty	4.203	0.040
Strong interpersonal skills	1.684	0.194
Cluster for think out-of-box	1.729	0.189

Level 1 Barrier Top-Ranked Node Category (N=42)	Chi-Square	Asymptotic Significance
Individual characteristics	1.451	0.228
Organizations	0.973	0.324
Schedule and cost constraints	0.494	0.482
Training/Education	0.001	0.972
Work design	0.036	0.849
SE	3.340	0.068

Level 2 Barrier Top-Ranked Node Category (N=42)	Chi-Square	Asymptotic Significance
Schedule and cost constraints	0.494	0.482
Local thinking/myopia	0.001	0.972
Organizational boundaries/structure	2.077	0.150
Narrow job	0.020	0.888
Comfortable	1.428	0.232
Education issues	0.243	0.622

8.13 Examples of Coding – Curiosity

To give an example of the coding procedure, here are the 39 items that were coded in the category "curiosity" for the question, "Are there certain individual characteristics or innate traits that seem to predict the development of systems thinking? If so, what are they?" Each item comes from a separate interview, though the names of the respondents have been removed to keep the responses anonymous.

- "Curiosity and acting on that curiosity, satisfy that curiosity"
- "curiosity"
- "curiosity"
- "CURIOSITY TO know about other disciplines"
- "Have to want to seek out these things, have to pursue on their own initiative, even if not directly relevant to task at hand; curiosity"
- "CURIOSITY is major factor"
- "Creativity, one of the biggest things, creative intellect, curiosity, creative about how to solve problems, you can nurture it but they are born with it, definitely in demand here, hard to find these
- "the ability to ask the right questions – one of the highest; comes together with curiosity; curiosity is an important item
- "curiosity too; characteristic = desire to grow and expand and get training"
- "thinking would include rationality, skepticism, curiosity, intelligence"
- "Curiosity, wants to understand why something works the way it does, why does a car run or not"
- "questioning, curious"
- "Always looking for bigger picture, CURIOUS people, good ST are curious"
- "Trait – folks w/broad interest, want to know what other folks in project working on; how their part fits in; curiosity, interest"
- "CURIOUS"
- "Well-versed in alternate domains and alternate technologies, CURIOUS OUTSIDE YOUR DOMAIN, natural curiosity that folks have"
- "CURIOSITY to see & look at new things, not squashed w/child"
- "Insanely curious"
- "Curiosity, can go into details and ask questions, but know details and want to make it better; distinguish between scientist/researcher and the SE; inquisitive, curious, but not where his curiosity goes too deep"
- "curiosity"

- "curiosity, jack-of-all-trades – interested & capable in a lot of areas; why test engrs. good (deals with controls, cost, schedule, good lead test engr.)"
- "curious"
- "curiosity"
- "Curiosity, risk taking, wanting to know connections…"
- "curiosity, seeing what people around them doing"
- "Curiosity, inquisitive, thinkers, insight (from whatever background"
- "Desire to figure out how things work, take things apart from their youngest days; if love working with cars, take it apart, know how works, helps you to build one; certain amount of personality, I was always interested in understanding how things worked; curiosity? curiosity into how the system works; interested in "how" system does what it does
- "CURIOUS, never satisfied w/1st answer, digs deeper & deeper"
- "curiosity & drive for better soln, not accepting status quo"
- "Curiosity. I'm just naturally curious, ask lots of questions, wonder what's on the other side, ask what's in the box, what makes the output come out as it does, interested in interdependencies"
- "CURIOUS"
- "People who are looking beyond what they are working on to see what others are doing (not working at desk and not looking elsewhere); inherently curious on what others are doing"
- "curious"
- "curiosity to be assigned to new tasks"
- "CURIOUS"
- "curiosity; hard to know; disc. choose to go into – like reliability"
- "curiosity of how things work together, holistic view of org/product"
- "ASKS QUESTIONS, curious"
- "open mind, social person, communication, natural curiosity (things, people, processes) how works"

8.14 Descriptive Statistics of Sampled Systems Engineers

This section shows the analysis of the surveys that were collected. The surveys were given to each of the four classifications of Expert Panelists, Senior Systems Engineers, Senior Technical Specialists, and Junior Systems Engineers. Shown here are the results for the questions addressing interview company, interview classification, highest level of education, Bachelor's degree major, number of years at current employer, number of years listed in the job history, job rotations, systems engineering training, and process improvement training. Key results are given in the text, and this section shows a more complete analysis of the data.

The significance of this section is that throughout the execution of this study, various people expressed heuristics and opinions on the demographics of Senior Systems Engineers. Here, data show the actual demographics to better inform these arguments and opinions. The usefulness to practitioners is that this section begins to collect the hiring patterns and development strategies for various companies.

8.14.1 Interview Company

To show the basis for the survey data, Table 8.14.1 is a frequency analysis to show the number and percent of survey respondents from each company. The 10 interview companies are coded from A to J. Company J had the most survey respondents, with 26 respondents or 13.8% of the total survey respondents. For all but one company, there were at least 15 responses to the survey.

Table 8.14.1: Number of Survey Participants in Each of the Companies

Number of Participants in Each of the Companies - Frequency Analysis (S4)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	17	9.0	9.0	9.0
	B	15	8.0	8.0	17.0
	C	22	11.7	11.7	28.7
	D	19	10.1	10.1	38.8
	E	18	9.6	9.6	48.4
	F	23	12.2	12.2	60.6
	G	10	5.3	5.3	66.0
	H	21	11.2	11.2	77.1
	I	17	9.0	9.0	86.2
	J	26	13.8	13.8	100.0
	Total	188	100.0	100.0	

Table 8.14.2 shows the number of participants by company and classification, with the classifications being Expert Panelist, Senior Systems Engineer, Senior Technical Specialist, and Junior Systems Engineer as shown in the columns. The rows are once again the 10 interview companies coded from A to J. Company J had the most Senior Systems Engineers participating, with 12.

Table 8.14.2: Number of Survey Participants by Coded Company and Classification

Company * S5 Crosstabulation

			S5				
			1_Expert Panelist	2_Senior Systems Engineer	3_Senior Tech Specialist	4_Junior Systems Engineer	Total
Company	A	Count	4	5	4	4	17
		Expected Count	3.1	5.0	4.3	4.7	17.0
		% within Company	23.5%	29.4%	23.5%	23.5%	100.0%
		% within S5	11.8%	9.1%	8.5%	7.7%	9.0%
		% of Total	2.1%	2.7%	2.1%	2.1%	9.0%
	B	Count	4	2	4	5	15
		Expected Count	2.7	4.4	3.8	4.1	15.0
		% within Company	26.7%	13.3%	26.7%	33.3%	100.0%
		% within S5	11.8%	3.6%	8.5%	9.6%	8.0%
		% of Total	2.1%	1.1%	2.1%	2.7%	8.0%
	C	Count	3	9	5	5	22
		Expected Count	4.0	6.4	5.5	6.1	22.0
		% within Company	13.6%	40.9%	22.7%	22.7%	100.0%
		% within S5	8.8%	16.4%	10.6%	9.6%	11.7%
		% of Total	1.6%	4.8%	2.7%	2.7%	11.7%
	D	Count	6	3	2	8	19
		Expected Count	3.4	5.6	4.8	5.3	19.0
		% within Company	31.6%	15.8%	10.5%	42.1%	100.0%
		% within S5	17.6%	5.5%	4.3%	15.4%	10.1%
		% of Total	3.2%	1.6%	1.1%	4.3%	10.1%
	E	Count	4	4	4	6	18
		Expected Count	3.3	5.3	4.5	5.0	18.0
		% within Company	22.2%	22.2%	22.2%	33.3%	100.0%
		% within S5	11.8%	7.3%	8.5%	11.5%	9.6%
		% of Total	2.1%	2.1%	2.1%	3.2%	9.6%
	F	Count	5	5	7	6	23
		Expected Count	4.2	6.7	5.8	6.4	23.0
		% within Company	21.7%	21.7%	30.4%	26.1%	100.0%
		% within S5	14.7%	9.1%	14.9%	11.5%	12.2%
		% of Total	2.7%	2.7%	3.7%	3.2%	12.2%
	G	Count	0	3	4	3	10
		Expected Count	1.8	2.9	2.5	2.8	10.0
		% within Company	.0%	30.0%	40.0%	30.0%	100.0%
		% within S5	.0%	5.5%	8.5%	5.8%	5.3%
		% of Total	.0%	1.6%	2.1%	1.6%	5.3%
	H	Count	3	6	6	6	21
		Expected Count	3.8	6.1	5.3	5.8	21.0
		% within Company	14.3%	28.6%	28.6%	28.6%	100.0%
		% within S5	8.8%	10.9%	12.8%	11.5%	11.2%
		% of Total	1.6%	3.2%	3.2%	3.2%	11.2%
	I	Count	3	6	5	3	17
		Expected Count	3.1	5.0	4.3	4.7	17.0
		% within Company	17.6%	35.3%	29.4%	17.6%	100.0%
		% within S5	8.8%	10.9%	10.6%	5.8%	9.0%
		% of Total	1.6%	3.2%	2.7%	1.6%	9.0%
	J	Count	2	12	6	6	26
		Expected Count	4.7	7.6	6.5	7.2	26.0
		% within Company	7.7%	46.2%	23.1%	23.1%	100.0%
		% within S5	5.9%	21.8%	12.8%	11.5%	13.8%
		% of Total	1.1%	6.4%	3.2%	3.2%	13.8%
Total		Count	34	55	47	52	188
		Expected Count	34.0	55.0	47.0	52.0	188.0
		% within Company	18.1%	29.3%	25.0%	27.7%	100.0%
		% within S5	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	18.1%	29.3%	25.0%	27.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	20.067[a]	27	.828
Likelihood Ratio	22.181	27	.728
N of Valid Cases	188		

a. 25 cells (62.5%) have expected count less than 5. The minimum expected count is 1.81.

8.14.2 Interview Classification

Table 8.14.3 is a frequency analysis showing the number of survey participants for each of the interview classifications of Expert Panelist, Senior Systems Engineer, Senior Technical Specialist, and Junior Systems Engineer. Senior Systems Engineers had the highest participation, with 55 participants yielding 29.3% of the surveys collected. The two control groups of Senior Technical Specialists and Junior Systems Engineers each had at least 25% of the participants.

Table 8.14.3: Number of Survey Participants by Classification

S5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1_Expert Panelist	34	18.1	18.1	18.1
	2_Senior Systems Engineer	55	29.3	29.3	47.3
	3_Senior Tech Specialist	47	25.0	25.0	72.3
	4_Junior Systems Engineer	52	27.7	27.7	100.0
	Total	188	100.0	100.0	

8.14.3 Highest Level of Education

Table 8.14.4 shows the frequency analysis for the highest level of education for all survey participants. The Master's degree was the most common highest level of education, with over 50% of survey participants indicating this level.

Table 8.14.4: Frequency Analysis for Highest Level of Education

Highest Level of Education for All Survey Participants (N_S11)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High school graduation or GED equivalent (1)	2	1.1	1.1	1.1
	Two-year post-secondary or technical certificate (2)	3	1.6	1.6	2.7
	Bachelor's degree or equivalent (3)	56	29.8	29.8	32.4
	Master's degree (4)	95	50.5	50.5	83.0
	Doctoral degree (5)	32	17.0	17.0	100.0
	Total	188	100.0	100.0	

Table 8.14.5 shows the highest level of education for each classification. There were more Junior Systems Engineers with Master's degrees than there were participants with Master's degrees from the other classifications. This is most likely due to current trends in education where more students are seeking Master's degrees, and the Junior Systems Engineers are closer to leaving the current educational system. As can be seen from the chi-square test results, with an asymptotic significance value of 0.001, the null hypothesis of no differences between classifications can be confidently rejected. This means there is a statistically significant difference between the classifications.

Table 8.14.5: Crosstabulation of Classification and Highest Level of Education

S5 * Level of Education Crosstabulation

			Level of Education					
			1_High school graduation or GED equivalent	2_Two-year post-secondary or technical certificate	3_Bachelor's degree or equivalent	4_Master's degree	5_Doctoral degree	Total
S5	1_Expert Panelist	Count	0	0	6	18	10	34
		Expected Count	.4	.5	10.1	17.2	5.8	34.0
		% within S5	.0%	.0%	17.6%	52.9%	29.4%	100.0%
		% within Level of Education	.0%	.0%	10.7%	18.9%	31.3%	18.1%
		% of Total	.0%	.0%	3.2%	9.6%	5.3%	18.1%
	2_Senior Systems Engineer	Count	0	0	20	28	7	55
		Expected Count	.6	.9	16.4	27.8	9.4	55.0
		% within S5	.0%	.0%	36.4%	50.9%	12.7%	100.0%
		% within Level of Education	.0%	.0%	35.7%	29.5%	21.9%	29.3%
		% of Total	.0%	.0%	10.6%	14.9%	3.7%	29.3%
	3_Senior Tech Specialist	Count	2	3	15	15	12	47
		Expected Count	.5	.8	14.0	23.8	8.0	47.0
		% within S5	4.3%	6.4%	31.9%	31.9%	25.5%	100.0%
		% within Level of Education	100.0%	100.0%	26.8%	15.8%	37.5%	25.0%
		% of Total	1.1%	1.6%	8.0%	8.0%	6.4%	25.0%
	4_Junior Systems Engineer	Count	0	0	15	34	3	52
		Expected Count	.6	.8	15.5	26.3	8.9	52.0
		% within S5	.0%	.0%	28.8%	65.4%	5.8%	100.0%
		% within Level of Education	.0%	.0%	26.8%	35.8%	9.4%	27.7%
		% of Total	.0%	.0%	8.0%	18.1%	1.6%	27.7%
Total		Count	2	3	56	95	32	188
		Expected Count	2.0	3.0	56.0	95.0	32.0	188.0
		% within S5	1.1%	1.6%	29.8%	50.5%	17.0%	100.0%
		% within Level of Education	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	1.1%	1.6%	29.8%	50.5%	17.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	32.632[a]	12	.001
Likelihood Ratio	32.605	12	.001
N of Valid Cases	188		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is .36.

Table 8.14.6 shows the highest level of education by company. Company F has the highest number of participants with Bachelor's degrees as the highest level of education, with 17 participants indicating this. This is 73.9% of the participants from this company. The greatest convergence in one cell is for Company A where 82.4% of the participants have a Master's degree as their highest level of education. Company J has the most participants with a Doctoral degree as the highest level of education, with 8 participants or 30.8% of the company's participants indicating this. The asymptotic significance value of 0.000 shows the null hypothesis of no differences between companies can be very confidently rejected. This means there is a statistically significant difference between the companies.

Table 8.14.6: Crosstabulation of Company and Highest Level of Education

Company * Level of Education Crosstabulation

			Level of Education					
			1_High school graduation or GED equivalent	2_Two-year post-secondary or technical certificate	3_Bachelor's degree or equivalent	4_Master's degree	5_Doctoral degree	Total
Company	A	Count	0	0	3	14	0	17
		Expected Count	.2	.3	5.1	8.6	2.9	17.0
		% within Company	.0%	.0%	17.6%	82.4%	.0%	100.0%
		% within Level of Education	.0%	.0%	5.4%	14.7%	.0%	9.0%
		% of Total	.0%	.0%	1.6%	7.4%	.0%	9.0%
	B	Count	0	0	2	10	3	15
		Expected Count	.2	.2	4.5	7.6	2.6	15.0
		% within Company	.0%	.0%	13.3%	66.7%	20.0%	100.0%
		% within Level of Education	.0%	.0%	3.6%	10.5%	9.4%	8.0%
		% of Total	.0%	.0%	1.1%	5.3%	1.6%	8.0%
	C	Count	0	0	10	9	3	22
		Expected Count	.2	.4	6.6	11.1	3.7	22.0
		% within Company	.0%	.0%	45.5%	40.9%	13.6%	100.0%
		% within Level of Education	.0%	.0%	17.9%	9.5%	9.4%	11.7%
		% of Total	.0%	.0%	5.3%	4.8%	1.6%	11.7%
	D	Count	0	0	1	12	6	19
		Expected Count	.2	.3	5.7	9.6	3.2	19.0
		% within Company	.0%	.0%	5.3%	63.2%	31.6%	100.0%
		% within Level of Education	.0%	.0%	1.8%	12.6%	18.8%	10.1%
		% of Total	.0%	.0%	.5%	6.4%	3.2%	10.1%
	E	Count	0	0	3	9	6	18
		Expected Count	.2	.3	5.4	9.1	3.1	18.0
		% within Company	.0%	.0%	16.7%	50.0%	33.3%	100.0%
		% within Level of Education	.0%	.0%	5.4%	9.5%	18.8%	9.6%
		% of Total	.0%	.0%	1.6%	4.8%	3.2%	9.6%
	F	Count	0	1	17	5	0	23
		Expected Count	.2	.4	6.9	11.6	3.9	23.0
		% within Company	.0%	4.3%	73.9%	21.7%	.0%	100.0%
		% within Level of Education	.0%	33.3%	30.4%	5.3%	.0%	12.2%
		% of Total	.0%	.5%	9.0%	2.7%	.0%	12.2%
	G	Count	0	0	1	6	3	10
		Expected Count	.1	.2	3.0	5.1	1.7	10.0
		% within Company	.0%	.0%	10.0%	60.0%	30.0%	100.0%
		% within Level of Education	.0%	.0%	1.8%	6.3%	9.4%	5.3%
		% of Total	.0%	.0%	.5%	3.2%	1.6%	5.3%
	H	Count	2	2	7	10	0	21
		Expected Count	.2	.3	6.3	10.6	3.6	21.0
		% within Company	9.5%	9.5%	33.3%	47.6%	.0%	100.0%
		% within Level of Education	100.0%	66.7%	12.5%	10.5%	.0%	11.2%
		% of Total	1.1%	1.1%	3.7%	5.3%	.0%	11.2%
	I	Count	0	0	8	6	3	17
		Expected Count	.2	.3	5.1	8.6	2.9	17.0
		% within Company	.0%	.0%	47.1%	35.3%	17.6%	100.0%
		% within Level of Education	.0%	.0%	14.3%	6.3%	9.4%	9.0%
		% of Total	.0%	.0%	4.3%	3.2%	1.6%	9.0%
	J	Count	0	0	4	14	8	26
		Expected Count	.3	.4	7.7	13.1	4.4	26.0
		% within Company	.0%	.0%	15.4%	53.8%	30.8%	100.0%
		% within Level of Education	.0%	.0%	7.1%	14.7%	25.0%	13.8%
		% of Total	.0%	.0%	2.1%	7.4%	4.3%	13.8%
Total		Count	2	3	56	95	32	188
		Expected Count	2.0	3.0	56.0	95.0	32.0	188.0
		% within Company	1.1%	1.6%	29.8%	50.5%	17.0%	100.0%
		% within Level of Education	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	1.1%	1.6%	29.8%	50.5%	17.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	86.086[a]	36	.000
Likelihood Ratio	84.083	36	.000
N of Valid Cases	188		

a. 32 cells (64.0%) have expected count less than 5. The minimum expected count is .11.

8.14.4 Bachelor's Degree Major

On the survey, participants were asked to note their Bachelor's degree major. The reason for this is that in the pilot interviews, some respondents felt that certain undergraduate majors were better systems engineers. As an example, a couple early respondents noted that physicists were the best systems engineers. To address these opinions, undergraduate major was included in the survey. The comparison between Bachelor's degree major and coded company is shown in Table 8.14.7, and the comparison between Bachelor's degree major and interview classification is shown in Table 8.14.8. Note that the Bachelor's degree majors were grouped into categories to simplify analysis.

As the table shows, Electrical Engineering/Computer Science is the most frequent Bachelor's degree major with 33.5%, with Mechanical Engineering at 17.0% as the next most frequent major. For some companies, one Bachelor's degree major tends to dominate in the survey responses. For Company J, 65.4% of the participants are Electrical Engineering/Computer Science. For Company B, 73.3% of the participants have Mechanical Engineering for their Bachelor's degree major. The asymptotic significance value of 0.000 shows the null hypothesis of no differences between companies can be very confidently rejected. This means there is a statistically significant difference between the responses from different companies.

Table 8.14.7: Crosstabulation of Bachelor's Degree Major and Coded Company

S13' * Company Crosstabulation

			Company										
			A	B	C	D	E	F	G	H	I	J	Total
S13'	-	Count	0	0	0	0	16	2	0	4	1	0	23
		Expected Count	2.1	1.8	2.7	2.3	2.2	2.8	1.2	2.6	2.1	3.2	23.0
		% within S13'	.0%	.0%	.0%	.0%	69.6%	8.7%	.0%	17.4%	4.3%	.0%	100.0%
		% within Company	.0%	.0%	.0%	.0%	88.9%	8.7%	.0%	19.0%	5.9%	.0%	12.2%
		% of Total	.0%	.0%	.0%	.0%	8.5%	1.1%	.0%	2.1%	.5%	.0%	12.2%
	Aerospace Engineering	Count	1	1	7	2	0	3	0	0	0	0	14
		Expected Count	1.3	1.1	1.6	1.4	1.3	1.7	.7	1.6	1.3	1.9	14.0
		% within S13'	7.1%	7.1%	50.0%	14.3%	.0%	21.4%	.0%	.0%	.0%	.0%	100.0%
		% within Company	5.9%	6.7%	31.8%	10.5%	.0%	13.0%	.0%	.0%	.0%	.0%	7.4%
		% of Total	.5%	.5%	3.7%	1.1%	.0%	1.6%	.0%	.0%	.0%	.0%	7.4%
	Civil Engineering	Count	1	0	1	0	0	2	0	0	0	0	4
		Expected Count	.4	.3	.5	.4	.4	.5	.2	.4	.4	.6	4.0
		% within S13'	25.0%	.0%	25.0%	.0%	.0%	50.0%	.0%	.0%	.0%	.0%	100.0%
		% within Company	5.9%	.0%	4.5%	.0%	.0%	8.7%	.0%	.0%	.0%	.0%	2.1%
		% of Total	.5%	.0%	.5%	.0%	.0%	1.1%	.0%	.0%	.0%	.0%	2.1%
	Electrical Engineering/Computer Science	Count	8	0	7	3	1	1	4	13	9	17	63
		Expected Count	5.7	5.0	7.4	6.4	6.0	7.7	3.4	7.0	5.7	8.7	63.0
		% within S13'	12.7%	.0%	11.1%	4.8%	1.6%	1.6%	6.3%	20.6%	14.3%	27.0%	100.0%
		% within Company	47.1%	.0%	31.8%	15.8%	5.6%	4.3%	40.0%	61.9%	52.9%	65.4%	33.5%
		% of Total	4.3%	.0%	3.7%	1.6%	.5%	.5%	2.1%	6.9%	4.8%	9.0%	33.5%
	Mathematics	Count	1	0	1	3	0	0	0	1	0	0	6
		Expected Count	.5	.5	.7	.6	.6	.7	.3	.7	.5	.8	6.0
		% within S13'	16.7%	.0%	16.7%	50.0%	.0%	.0%	.0%	16.7%	.0%	.0%	100.0%
		% within Company	5.9%	.0%	4.5%	15.8%	.0%	.0%	.0%	4.8%	.0%	.0%	3.2%
		% of Total	.5%	.0%	.5%	1.6%	.0%	.0%	.0%	.5%	.0%	.0%	3.2%
	Mechanical Engineering	Count	2	11	3	1	0	13	1	1	0	0	32
		Expected Count	2.9	2.6	3.7	3.2	3.1	3.9	1.7	3.6	2.9	4.4	32.0
		% within S13'	6.3%	34.4%	9.4%	3.1%	.0%	40.6%	3.1%	3.1%	.0%	.0%	100.0%
		% within Company	11.8%	73.3%	13.6%	5.3%	.0%	56.5%	10.0%	4.8%	.0%	.0%	17.0%
		% of Total	1.1%	5.9%	1.6%	.5%	.0%	6.9%	.5%	.5%	.0%	.0%	17.0%
	Multiple Majors	Count	1	1	1	1	0	1	2	1	2	3	13
		Expected Count	1.2	1.0	1.5	1.3	1.2	1.6	.7	1.5	1.2	1.8	13.0
		% within S13'	7.7%	7.7%	7.7%	7.7%	.0%	7.7%	15.4%	7.7%	15.4%	23.1%	100.0%
		% within Company	5.9%	6.7%	4.5%	5.3%	.0%	4.3%	20.0%	4.8%	11.8%	11.5%	6.9%
		% of Total	.5%	.5%	.5%	.5%	.0%	.5%	1.1%	.5%	1.1%	1.6%	6.9%
	Other	Count	3	1	2	2	1	1	0	1	2	4	17
		Expected Count	1.5	1.4	2.0	1.7	1.6	2.1	.9	1.9	1.5	2.4	17.0
		% within S13'	17.6%	5.9%	11.8%	11.8%	5.9%	5.9%	.0%	5.9%	11.8%	23.5%	100.0%
		% within Company	17.6%	6.7%	9.1%	10.5%	5.6%	4.3%	.0%	4.8%	11.8%	15.4%	9.0%
		% of Total	1.6%	.5%	1.1%	1.1%	.5%	.5%	.0%	.5%	1.1%	2.1%	9.0%
	Other Engineering	Count	0	1	0	2	0	0	2	0	1	0	6
		Expected Count	.5	.5	.7	.6	.6	.7	.3	.7	.5	.8	6.0
		% within S13'	.0%	16.7%	.0%	33.3%	.0%	.0%	33.3%	.0%	16.7%	.0%	100.0%
		% within Company	.0%	6.7%	.0%	10.5%	.0%	.0%	20.0%	.0%	5.9%	.0%	3.2%
		% of Total	.0%	.5%	.0%	1.1%	.0%	.0%	1.1%	.0%	.5%	.0%	3.2%
	Science	Count	0	0	0	2	0	0	0	0	2	2	6
		Expected Count	.5	.5	.7	.6	.6	.7	.3	.7	.5	.8	6.0
		% within S13'	.0%	.0%	.0%	33.3%	.0%	.0%	.0%	.0%	33.3%	33.3%	100.0%
		% within Company	.0%	.0%	.0%	10.5%	.0%	.0%	.0%	.0%	11.8%	7.7%	3.2%
		% of Total	.0%	.0%	.0%	1.1%	.0%	.0%	.0%	.0%	1.1%	1.1%	3.2%
	Systems	Count	0	0	0	3	0	0	1	0	0	0	4
		Expected Count	.4	.3	.5	.4	.4	.5	.2	.4	.4	.6	4.0
		% within S13'	.0%	.0%	.0%	75.0%	.0%	.0%	25.0%	.0%	.0%	.0%	100.0%
		% within Company	.0%	.0%	.0%	15.8%	.0%	.0%	10.0%	.0%	.0%	.0%	2.1%
		% of Total	.0%	.0%	.0%	1.6%	.0%	.0%	.5%	.0%	.0%	.0%	2.1%
Total		Count	17	15	22	19	18	23	10	21	17	26	188
		Expected Count	17.0	15.0	22.0	19.0	18.0	23.0	10.0	21.0	17.0	26.0	188.0
		% within S13'	9.0%	8.0%	11.7%	10.1%	9.6%	12.2%	5.3%	11.2%	9.0%	13.8%	100.0%
		% within Company	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	9.0%	8.0%	11.7%	10.1%	9.6%	12.2%	5.3%	11.2%	9.0%	13.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	309.543[a]	90	.000
Likelihood Ratio	260.527	90	.000
N of Valid Cases	188		

a. 101 cells (91.8%) have expected count less than 5. The minimum expected count is .21.

Table 8.14.8 shows the number of occurrences for each Bachelor's degree major by classification. For the participants in the study, Electrical Engineering/Computer Science was the most frequent Bachelor's degree for Senior Systems Engineers. 50.9% of the Senior Systems Engineers participating in this study, or 28 participants, were Electrical Engineering/Computer Science.

Table 8.14.8: Crosstabulation of Bachelor's Degree and Classification

S13' * S5 Crosstabulation

			S5				
			1_Expert Panelist	2_Senior Systems Engineer	3_Senior Tech Specialist	4_Junior Systems Engineer	Total
S13'	-	Count	4	3	10	6	23
		Expected Count	4.2	6.7	5.8	6.4	23.0
		% within S13'	17.4%	13.0%	43.5%	26.1%	100.0%
		% within S5	11.8%	5.5%	21.3%	11.5%	12.2%
		% of Total	2.1%	1.6%	5.3%	3.2%	12.2%
	Aerospace Engineering	Count	3	4	2	5	14
		Expected Count	2.5	4.1	3.5	3.9	14.0
		% within S13'	21.4%	28.6%	14.3%	35.7%	100.0%
		% within S5	8.8%	7.3%	4.3%	9.6%	7.4%
		% of Total	1.6%	2.1%	1.1%	2.7%	7.4%
	Civil Engineering	Count	0	0	1	3	4
		Expected Count	.7	1.2	1.0	1.1	4.0
		% within S13'	.0%	.0%	25.0%	75.0%	100.0%
		% within S5	.0%	.0%	2.1%	5.8%	2.1%
		% of Total	.0%	.0%	.5%	1.6%	2.1%
	Electrical Engineering/Computer Science	Count	9	28	13	13	63
		Expected Count	11.4	18.4	15.8	17.4	63.0
		% within S13'	14.3%	44.4%	20.6%	20.6%	100.0%
		% within S5	26.5%	50.9%	27.7%	25.0%	33.5%
		% of Total	4.8%	14.9%	6.9%	6.9%	33.5%
	Mathematics	Count	3	2	1	0	6
		Expected Count	1.1	1.8	1.5	1.7	6.0
		% within S13'	50.0%	33.3%	16.7%	.0%	100.0%
		% within S5	8.8%	3.6%	2.1%	.0%	3.2%
		% of Total	1.6%	1.1%	.5%	.0%	3.2%
	Mechanical Engineering	Count	7	7	8	10	32
		Expected Count	5.8	9.4	8.0	8.9	32.0
		% within S13'	21.9%	21.9%	25.0%	31.3%	100.0%
		% within S5	20.6%	12.7%	17.0%	19.2%	17.0%
		% of Total	3.7%	3.7%	4.3%	5.3%	17.0%
	Multiple Majors	Count	2	2	5	4	13
		Expected Count	2.4	3.8	3.3	3.6	13.0
		% within S13'	15.4%	15.4%	38.5%	30.8%	100.0%
		% within S5	5.9%	3.6%	10.6%	7.7%	6.9%
		% of Total	1.1%	1.1%	2.7%	2.1%	6.9%
	Other	Count	2	6	3	6	17
		Expected Count	3.1	5.0	4.3	4.7	17.0
		% within S13'	11.8%	35.3%	17.6%	35.3%	100.0%
		% within S5	5.9%	10.9%	6.4%	11.5%	9.0%
		% of Total	1.1%	3.2%	1.6%	3.2%	9.0%
	Other Engineering	Count	2	0	2	2	6
		Expected Count	1.1	1.8	1.5	1.7	6.0
		% within S13'	33.3%	.0%	33.3%	33.3%	100.0%
		% within S5	5.9%	.0%	4.3%	3.8%	3.2%
		% of Total	1.1%	.0%	1.1%	1.1%	3.2%
	Science	Count	2	2	2	0	6
		Expected Count	1.1	1.8	1.5	1.7	6.0
		% within S13'	33.3%	33.3%	33.3%	.0%	100.0%
		% within S5	5.9%	3.6%	4.3%	.0%	3.2%
		% of Total	1.1%	1.1%	1.1%	.0%	3.2%
	Systems	Count	0	1	0	3	4
		Expected Count	.7	1.2	1.0	1.1	4.0
		% within S13'	.0%	25.0%	.0%	75.0%	100.0%
		% within S5	.0%	1.8%	.0%	5.8%	2.1%
		% of Total	.0%	.5%	.0%	1.6%	2.1%
Total		Count	34	55	47	52	188
		Expected Count	34.0	55.0	47.0	52.0	188.0
		% within S13'	18.1%	29.3%	25.0%	27.7%	100.0%
		% within S5	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	18.1%	29.3%	25.0%	27.7%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	38.335[a]	30	.141
Likelihood Ratio	43.192	30	.056
N of Valid Cases	188		

a. 33 cells (75.0%) have expected count less than 5. The minimum expected count is .72.

8.14.5 Number of Years at Current Employer

The number of years a person has worked in a certain systems context may affect that person's quality of systems thinking in that context. In the survey, participants were asked for the number of years they have worked for their current employer. Though this measure does not fully address the issue of systems familiarity, it is a beginning indicator. In addition, it also shows practioners the strategies which other companies are employing.

For each of the interview classifications, the mean number of years at the current company is shown in Table 8.14.9. In this chart, "1" is for the Expert Panelists, "2" is for the Senior Systems Engineers, "3" is for the Senior Technical Specialists, and "4" is for the Junior Systems Engineers. As one might expect, the mean number of years at the current company is highest for the Expert Panelists, with a mean of 19.18 years. Likewise, the mean number of years at the current company is lowest for the Junior Systems Engineers, with the mean of 7.87 years.

Table 8.14.9: Mean Number of Years at Current Company by Classification

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
S22' * N_S5	185	98.4%	3	1.6%	188	100.0%

Report

S22'

N_S5	Mean	N	Std. Deviation	Median	Minimum	Maximum	% of Total N
1.00	19.18	33	9.541	20.00	1	37	17.8%
2.00	15.41	54	8.304	17.00	1	32	29.2%
3.00	15.47	47	10.537	17.00	1	38	25.4%
4.00	7.87	51	7.897	5.00	1	31	27.6%
Total	14.02	185	9.836	15.00	1	38	100.0%

Table 8.14.10 compares the mean number of years at the current employer for each of the companies. In this table, the designation is that "1.00" is for Company A, "2.00" is for Company B, etc. Note that for Company G ("7.00"), the mean number of years at the company is 7.00 years, and for Company I ("9.00"), the mean number of years at the company is 7.07 years. At the other end of the spectrum, the mean number of years at the company is 17.67 years for Company F ("6.00"). For all participants in total, the maximum number of years at the current employer is 38 years, and the mean number of years at the current employer is 14 years.

Table 8.14.10: Mean Number of Years at Current Company by Company

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
S22' * N_S3	185	98.4%	3	1.6%	188	100.0%

Report

S22'

N_S3	Mean	N	Std. Deviation	Median	Minimum	Maximum	% of Total N
1.00	14.65	17	7.729	16.00	1	27	9.2%
2.00	15.43	14	10.689	14.00	3	31	7.6%
3.00	15.86	22	12.376	16.50	1	38	11.9%
4.00	11.84	19	11.582	6.00	1	32	10.3%
5.00	15.44	18	7.883	17.00	1	26	9.7%
6.00	17.67	23	5.736	18.00	6	31	12.4%
7.00	7.00	10	5.981	4.50	2	18	5.4%
8.00	15.95	21	11.707	19.00	2	36	11.4%
9.00	7.07	15	6.995	4.00	1	21	8.1%
10.00	13.81	26	9.720	16.00	1	37	14.1%
Total	14.02	185	9.836	15.00	1	38	100.0%

The crosstabulation comparing the company to the mean number of years at the current company is shown in Table 8.14.11. Similarly, Table 8.14.12 shows the crosstabulation comparing the interview classification to the mean number of years at the current company. For both of these tables, the chi-square test gives a very low expected count. Since the smaller the expected count, the less valid the results of the chi-square test, the extremely high chi-square values are not reliable. Nonetheless, they are shown for completeness. The full display of expected counts, percentages, and totals are not given in these tables for the sake of space. Only the actual counts are shown.

Table 8.14.11: Mean Number of Years at Current Company by Company

S22' * Company Crosstabulation

Count

		Company										
		A	B	C	D	E	F	G	H	I	J	Total
S22'	1	2	0	1	5	1	0	0	0	3	3	15
	2	1	0	1	2	0	0	3	2	4	1	14
	3	0	2	2	0	0	0	1	1	0	1	7
	4	0	0	4	0	0	0	1	1	1	1	8
	5	0	2	0	1	0	0	1	3	1	2	10
	6	0	0	1	2	0	2	0	1	0	1	7
	7	0	2	0	0	3	0	1	1	0	0	7
	8	1	1	0	1	3	0	0	0	1	1	8
	9	0	0	0	0	0	0	0	1	0	0	1
	10	0	0	0	1	0	0	0	0	1	1	3
	11	0	0	0	0	0	0	1	0	0	0	1
	12	2	0	0	0	0	0	0	0	1	0	3
	14	0	0	0	0	0	3	0	0	0	1	4
	15	1	0	1	0	0	2	0	0	1	1	6
	16	2	0	1	0	0	2	1	0	0	0	6
	17	1	0	1	0	3	2	0	0	0	2	9
	18	0	0	0	0	1	3	1	0	0	3	8
	19	0	0	0	0	0	1	0	0	0	0	1
	19	1	0	1	0	0	2	0	1	0	1	6
	20	4	1	2	1	1	1	0	1	1	1	13
	21	0	0	0	1	0	2	0	1	1	2	7
	22	0	0	2	0	1	0	0	2	0	0	5
	23	1	0	1	0	2	1	0	0	0	1	6
	24	0	0	0	0	1	0	0	0	0	0	1
	25	0	3	0	2	1	0	0	0	0	1	7
	26	0	2	0	0	1	0	0	1	0	0	4
	27	1	0	0	1	0	0	0	0	0	0	2
	28	0	0	0	0	0	0	0	1	0	0	1
	30	0	0	0	0	0	1	0	1	0	1	3
	31	0	1	0	1	0	1	0	1	0	0	4
	32	0	0	0	1	0	0	0	1	0	0	2
	33	0	0	1	0	0	0	0	0	0	0	1
	35	0	0	1	0	0	0	0	0	0	0	1
	36	0	0	0	0	0	0	0	1	0	0	1
	37	0	0	0	0	0	0	0	0	0	1	1
	38	0	0	2	0	0	0	0	0	0	0	2
Total		17	14	22	19	18	23	10	21	15	26	185

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	372.364[a]	315	.014
Likelihood Ratio	327.590	315	.301
N of Valid Cases	185		

a. 360 cells (100.0%) have expected count less than 5. The minimum expected count is .05.

Table 8.14.12: Mean Number of Years at Current Company by Classification

S22' * S5 Crosstabulation

Count

		S5				
		1_Expert Panelist	2_Senior Systems Engineer	3_Senior Tech Specialist	4_Junior Systems Engineer	Total
S22'	1	2	1	3	9	15
	2	0	4	3	7	14
	3	1	0	2	4	7
	4	0	3	3	2	8
	5	0	2	2	6	10
	6	1	3	1	2	7
	7	2	0	1	4	7
	8	1	3	1	3	8
	9	0	0	0	1	1
	10	0	1	0	2	3
	11	0	0	1	0	1
	12	1	1	1	0	3
	14	0	3	0	1	4
	15	2	1	3	0	6
	16	1	3	1	1	6
	17	2	3	4	0	9
	18	1	3	3	1	8
	19	0	0	0	1	1
	19	0	3	3	0	6
	20	4	5	3	1	13
	21	2	2	2	1	7
	22	0	4	1	0	5
	23	1	2	1	2	6
	24	0	0	0	1	1
	25	3	3	1	0	7
	26	2	1	1	0	4
	27	1	0	0	1	2
	28	1	0	0	0	1
	30	1	1	1	0	3
	31	1	1	1	1	4
	32	1	1	0	0	2
	33	1	0	0	0	1
	35	0	0	1	0	1
	36	0	0	1	0	1
	37	1	0	0	0	1
	38	0	0	2	0	2
Total		33	54	47	51	185

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	121.211[a]	105	.133
Likelihood Ratio	136.791	105	.020
N of Valid Cases	185		

a. 144 cells (100.0%) have expected count less than 5. The minimum expected count is .18.

8.14.6 Number of Years Listed in the Job History

In the survey, participants were asked to list information about their last job positions. The survey asked for job position, company, and length of time. Six spaces were listed, though multiple respondents added additional assignments. For consistency, seven job positions were allowed in SPSS. Unfortunately, the survey did not ask for the total number of years worked. To get an indication of this, a sum was taken of the number of years listed in last seven job positions. This section gives the results of analyzing this sum. Since some respondents did run out of space, this is an underestimate of the total number of years of work experience for participants.

Table 8.14.13 shows the descriptive statistics comparing the company to the number of years listed in the job positions. As before, the designation is that "1.00" is for Company A, "2.00" is for Company B, etc. For all participants, the maximum number of years listed in the job positions is 42 years, and the mean is 18.7 years. As expected, these are both higher than the number of years worked in the current company, as shown previously. With a mean of only 15.64 years, Company G has a much smaller mean number of years than Company J; however, this is skewed by the differences in the number of participants from each company.

The descriptive statistics comparing the interview classification to the number of years listed in the job positions are shown in Table 8.14.14. As before, "1" is for the Expert Panelists, "2" is for the Senior Systems Engineers, "3" is for the Senior Technical Specialists, and "4" is for the Junior Systems Engineers. For the Senior Systems Engineers, the mean is 20.27 years of experience. As intended, the Junior Systems Engineers have much less experience than the Senior Technical Specialists or the Senior Systems Engineers. The Junior Systems Engineers' mean of 11.91 years is much smaller than the mean of 20.27 years for the Senior Systems Engineers or the mean of 21.83 for the Senior Technical Specialists. The crosstabulations are too lengthy to present here, and as in the last section, the expected counts are so small that the chi-square test results are less valid.

Table 8.14.13: Descriptive Statistics for the Number of Years Listed in the Job Positions by Company

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
N_S26+N_S29+N_S32+N_S35+N_S38+N_S41+N_S44 * N_S3	186	98.9%	2	1.1%	188	100.0%

Report

N_S26+N_S29+N_S32+N_S35+N_S38+N_S41+N_S44

N_S3	Mean	N	Std. Deviation	Median	Minimum	Maximum	% of Total N
1.00	17.9950	16	10.15793	19.5000	.00	37.00	8.6%
2.00	17.1613	15	9.42550	16.0000	.00	31.00	8.1%
3.00	20.7738	21	13.12819	21.5000	.00	41.00	11.3%
4.00	18.6016	19	11.72457	22.0000	.00	34.00	10.2%
5.00	18.9722	18	8.32514	23.0000	.00	29.50	9.7%
6.00	18.9274	23	9.10097	18.0000	.00	42.00	12.4%
7.00	15.6420	10	7.93035	14.0000	7.50	34.50	5.4%
8.00	16.7300	21	9.98318	20.0000	.00	32.00	11.3%
9.00	17.8335	17	7.17730	19.0000	7.50	34.50	9.1%
10.00	21.3846	26	11.30206	23.0000	.83	41.00	14.0%
Total	18.7031	186	10.08126	19.7500	.00	42.00	100.0%

Table 8.14.14: Descriptive Statistics for the Number of Years Listed in the Job Positions by Classification

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
N_S26+N_S29+N_ S32+N_S35+N_S38+N_ S41+N_S44 * N_S5	186	98.9%	2	1.1%	188	100.0%

Report

N_S26+N_S29+N_S32+N_S35+N_S38+N_S41+N_S44

N_S5	Mean	N	Std. Deviation	Median	Minimum	Maximum	% of Total N
1.00	22.3815	33	10.17135	25.0000	.00	42.00	17.7%
2.00	20.2700	54	8.20239	19.7500	.00	41.00	29.0%
3.00	21.8334	47	10.55607	23.0000	.00	41.00	25.3%
4.00	11.9121	52	8.11914	9.2500	.00	30.00	28.0%
Total	18.7031	186	10.08126	19.7500	.00	42.00	100.0%

8.14.7 Job Rotations

The survey also included questions about typical interventions that are used to develop systems thinking. One of these questions asked participants if have participated in a training program that used job rotations. Table 8.14.15 shows the crosstabulation comparing interview classification to the response on whether the respondent has participated in a formal training program with job rotations. There is not much difference between the classifications, as the low chi-square value shows.

Table 8.14.15: Crosstabulation of Classification and Participation in Training Program with Job Rotations

S5 * S45 Crosstabulation

			S45			Total
			-	N	Y	
S5	1_Expert Panelist	Count	0	25	9	34
		Expected Count	.9	23.1	9.9	34.0
		% within S5	.0%	73.5%	26.5%	100.0%
		% within S45	.0%	19.5%	16.4%	18.1%
		% of Total	.0%	13.3%	4.8%	18.1%
	2_Senior Systems Engineer	Count	1	37	17	55
		Expected Count	1.5	37.4	16.1	55.0
		% within S5	1.8%	67.3%	30.9%	100.0%
		% within S45	20.0%	28.9%	30.9%	29.3%
		% of Total	.5%	19.7%	9.0%	29.3%
	3_Senior Tech Specialist	Count	2	33	12	47
		Expected Count	1.3	32.0	13.8	47.0
		% within S5	4.3%	70.2%	25.5%	100.0%
		% within S45	40.0%	25.8%	21.8%	25.0%
		% of Total	1.1%	17.6%	6.4%	25.0%
	4_Junior Systems Engineer	Count	2	33	17	52
		Expected Count	1.4	35.4	15.2	52.0
		% within S5	3.8%	63.5%	32.7%	100.0%
		% within S45	40.0%	25.8%	30.9%	27.7%
		% of Total	1.1%	17.6%	9.0%	27.7%
Total		Count	5	128	55	188
		Expected Count	5.0	128.0	55.0	188.0
		% within S5	2.7%	68.1%	29.3%	100.0%
		% within S45	100.0%	100.0%	100.0%	100.0%
		% of Total	2.7%	68.1%	29.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.698[a]	6	.846
Likelihood Ratio	3.521	6	.741
N of Valid Cases	188		

a. 4 cells (33.3%) have expected count less than 5. The minimum expected count is .90.

Table 8.14.16 shows the crosstabulation comparing company to the response on whether the respondent has participated in a formal training program with job rotations. Unlike the crosstabulation by interview classification, there is a difference between the companies. The high Chi-Square value is offset by the fact that 14 cells (46.7%) have expected count less than 5. This decreases the validity of the chi-square test.

Nonetheless, it is notable that in Company F and Company H, a majority of survey respondents have participated in these programs, with 87.0% and 57.1% respectively participating. This is expected, since the expert panelists in both of these companies cited a formal, company job rotation program as one of the strategies for developing senior systems personnel. On the contrary, in Company I, no respondents have participated in job rotation programs.

Table 8.14.16: Crosstabulation of Company and Participation in Training Program with Job Rotations

Company * S45 Crosstabulation

			S45			
			-	N	Y	Total
Company	A	Count	0	13	4	17
		Expected Count	.5	11.6	5.0	17.0
		% within Company	.0%	76.5%	23.5%	100.0%
		% within S45	.0%	10.2%	7.3%	9.0%
		% of Total	.0%	6.9%	2.1%	9.0%
	B	Count	0	8	7	15
		Expected Count	.4	10.2	4.4	15.0
		% within Company	.0%	53.3%	46.7%	100.0%
		% within S45	.0%	6.3%	12.7%	8.0%
		% of Total	.0%	4.3%	3.7%	8.0%
	C	Count	0	21	1	22
		Expected Count	.6	15.0	6.4	22.0
		% within Company	.0%	95.5%	4.5%	100.0%
		% within S45	.0%	16.4%	1.8%	11.7%
		% of Total	.0%	11.2%	.5%	11.7%
	D	Count	1	16	2	19
		Expected Count	.5	12.9	5.6	19.0
		% within Company	5.3%	84.2%	10.5%	100.0%
		% within S45	20.0%	12.5%	3.6%	10.1%
		% of Total	.5%	8.5%	1.1%	10.1%
	E	Count	1	16	1	18
		Expected Count	.5	12.3	5.3	18.0
		% within Company	5.6%	88.9%	5.6%	100.0%
		% within S45	20.0%	12.5%	1.8%	9.6%
		% of Total	.5%	8.5%	.5%	9.6%
	F	Count	1	2	20	23
		Expected Count	.6	15.7	6.7	23.0
		% within Company	4.3%	8.7%	87.0%	100.0%
		% within S45	20.0%	1.6%	36.4%	12.2%
		% of Total	.5%	1.1%	10.6%	12.2%
	G	Count	0	9	1	10
		Expected Count	.3	6.8	2.9	10.0
		% within Company	.0%	90.0%	10.0%	100.0%
		% within S45	.0%	7.0%	1.8%	5.3%
		% of Total	.0%	4.8%	.5%	5.3%
	H	Count	2	7	12	21
		Expected Count	.6	14.3	6.1	21.0
		% within Company	9.5%	33.3%	57.1%	100.0%
		% within S45	40.0%	5.5%	21.8%	11.2%
		% of Total	1.1%	3.7%	6.4%	11.2%
	I	Count	0	17	0	17
		Expected Count	.5	11.6	5.0	17.0
		% within Company	.0%	100.0%	.0%	100.0%
		% within S45	.0%	13.3%	.0%	9.0%
		% of Total	.0%	9.0%	.0%	9.0%
	J	Count	0	19	7	26
		Expected Count	.7	17.7	7.6	26.0
		% within Company	.0%	73.1%	26.9%	100.0%
		% within S45	.0%	14.8%	12.7%	13.8%
		% of Total	.0%	10.1%	3.7%	13.8%
Total		Count	5	128	55	188
		Expected Count	5.0	128.0	55.0	188.0
		% within Company	2.7%	68.1%	29.3%	100.0%
		% within S45	100.0%	100.0%	100.0%	100.0%
		% of Total	2.7%	68.1%	29.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	81.911[a]	18	.000
Likelihood Ratio	90.105	18	.000
N of Valid Cases	188		

a. 14 cells (46.7%) have expected count less than 5. The minimum expected count is .27.

8.14.8 Systems Engineering Training

Another typical intervention is the use of systems engineering training. Table 8.14.17 shows the crosstabulation of classification and participation in systems engineering training. A higher percentage of Junior Systems Engineers than Senior Systems Engineers have participated in systems engineering training, with 57.7% and 54.5% respectively. Of all survey participants, 50% have participated in systems engineering training programs.

Table 8.14.17: Crosstabulation of Classification and Participation in Systems Engineering Training

S5 * S47 Crosstabulation

			S47			
			-	N	Y	Total
S5	1_Expert Panelist	Count	0	18	16	34
		Expected Count	.9	16.1	17.0	34.0
		% within S5	.0%	52.9%	47.1%	100.0%
		% within S47	.0%	20.2%	17.0%	18.1%
		% of Total	.0%	9.6%	8.5%	18.1%
	2_Senior Systems Engineer	Count	1	24	30	55
		Expected Count	1.5	26.0	27.5	55.0
		% within S5	1.8%	43.6%	54.5%	100.0%
		% within S47	20.0%	27.0%	31.9%	29.3%
		% of Total	.5%	12.8%	16.0%	29.3%
	3_Senior Tech Specialist	Count	2	27	18	47
		Expected Count	1.3	22.3	23.5	47.0
		% within S5	4.3%	57.4%	38.3%	100.0%
		% within S47	40.0%	30.3%	19.1%	25.0%
		% of Total	1.1%	14.4%	9.6%	25.0%
	4_Junior Systems Engineer	Count	2	20	30	52
		Expected Count	1.4	24.6	26.0	52.0
		% within S5	3.8%	38.5%	57.7%	100.0%
		% within S47	40.0%	22.5%	31.9%	27.7%
		% of Total	1.1%	10.6%	16.0%	27.7%
Total		Count	5	89	94	188
		Expected Count	5.0	89.0	94.0	188.0
		% within S5	2.7%	47.3%	50.0%	100.0%
		% within S47	100.0%	100.0%	100.0%	100.0%
		% of Total	2.7%	47.3%	50.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.229[a]	6	.398
Likelihood Ratio	7.118	6	.310
N of Valid Cases	188		

a. 4 cells (33.3%) have expected count less than 5. The minimum expected count is .90.

Table 8.14.18 shows the crosstabulation of company and participation in systems engineering training. Some companies are utilizing this intervention more than others. As an example, 78.9% of participants from Company D have had systems engineering training, whereas only 20.0% of participants from Company G have had this training. Note that some respondents may have had systems engineering training at a previous employer. The low asymptotic significance value of 0.006 shows the null hypothesis of no differences between companies can be confidently rejected.

Table 8.14.18: Crosstabulation of Company and Participation in Systems Engineering Training Program

Company * S47 Crosstabulation

			S47			
			-	N	Y	Total
Company	A	Count	0	4	13	17
		Expected Count	.5	8.0	8.5	17.0
		% within Company	.0%	23.5%	76.5%	100.0%
		% within S47	.0%	4.5%	13.8%	9.0%
		% of Total	.0%	2.1%	6.9%	9.0%
	B	Count	0	11	4	15
		Expected Count	.4	7.1	7.5	15.0
		% within Company	.0%	73.3%	26.7%	100.0%
		% within S47	.0%	12.4%	4.3%	8.0%
		% of Total	.0%	5.9%	2.1%	8.0%
	C	Count	0	7	15	22
		Expected Count	.6	10.4	11.0	22.0
		% within Company	.0%	31.8%	68.2%	100.0%
		% within S47	.0%	7.9%	16.0%	11.7%
		% of Total	.0%	3.7%	8.0%	11.7%
	D	Count	1	3	15	19
		Expected Count	.5	9.0	9.5	19.0
		% within Company	5.3%	15.8%	78.9%	100.0%
		% within S47	20.0%	3.4%	16.0%	10.1%
		% of Total	.5%	1.6%	8.0%	10.1%
	E	Count	1	13	4	18
		Expected Count	.5	8.5	9.0	18.0
		% within Company	5.6%	72.2%	22.2%	100.0%
		% within S47	20.0%	14.6%	4.3%	9.6%
		% of Total	.5%	6.9%	2.1%	9.6%
	F	Count	1	13	9	23
		Expected Count	.6	10.9	11.5	23.0
		% within Company	4.3%	56.5%	39.1%	100.0%
		% within S47	20.0%	14.6%	9.6%	12.2%
		% of Total	.5%	6.9%	4.8%	12.2%
	G	Count	0	8	2	10
		Expected Count	.3	4.7	5.0	10.0
		% within Company	.0%	80.0%	20.0%	100.0%
		% within S47	.0%	9.0%	2.1%	5.3%
		% of Total	.0%	4.3%	1.1%	5.3%
	H	Count	2	9	10	21
		Expected Count	.6	9.9	10.5	21.0
		% within Company	9.5%	42.9%	47.6%	100.0%
		% within S47	40.0%	10.1%	10.6%	11.2%
		% of Total	1.1%	4.8%	5.3%	11.2%
	I	Count	0	9	8	17
		Expected Count	.5	8.0	8.5	17.0
		% within Company	.0%	52.9%	47.1%	100.0%
		% within S47	.0%	10.1%	8.5%	9.0%
		% of Total	.0%	4.8%	4.3%	9.0%
	J	Count	0	12	14	26
		Expected Count	.7	12.3	13.0	26.0
		% within Company	.0%	46.2%	53.8%	100.0%
		% within S47	.0%	13.5%	14.9%	13.8%
		% of Total	.0%	6.4%	7.4%	13.8%
Total		Count	5	89	94	188
		Expected Count	5.0	89.0	94.0	188.0
		% within Company	2.7%	47.3%	50.0%	100.0%
		% within S47	100.0%	100.0%	100.0%	100.0%
		% of Total	2.7%	47.3%	50.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.288[a]	18	.006
Likelihood Ratio	38.997	18	.003
N of Valid Cases	188		

a. 11 cells (36.7%) have expected count less than 5. The minimum expected count is .27.

8.14.9 Process Improvement Training

Another typical intervention that might affect the level of one's systems thinking is participation in process improvement training. Table 8.14.19 shows the crosstabulation of classification and participation in process improvement training. Overall, 58.5% of survey participants have participated in process improvement training. The high asymptotic significance value shows that the results are consistent with the expectation of no differences between classifications.

Table 8.14.19: Crosstabulation of Classification and Participation in Process Improvement Training

S5 * S49 Crosstabulation

			S49			
			-	N	Y	Total
S5	1_Expert Panelist	Count	1	10	23	34
		Expected Count	1.1	13.0	19.9	34.0
		% within S5	2.9%	29.4%	67.6%	100.0%
		% within S49	16.7%	13.9%	20.9%	18.1%
		% of Total	.5%	5.3%	12.2%	18.1%
	2_Senior Systems Engineer	Count	1	24	30	55
		Expected Count	1.8	21.1	32.2	55.0
		% within S5	1.8%	43.6%	54.5%	100.0%
		% within S49	16.7%	33.3%	27.3%	29.3%
		% of Total	.5%	12.8%	16.0%	29.3%
	3_Senior Tech Specialist	Count	2	18	27	47
		Expected Count	1.5	18.0	27.5	47.0
		% within S5	4.3%	38.3%	57.4%	100.0%
		% within S49	33.3%	25.0%	24.5%	25.0%
		% of Total	1.1%	9.6%	14.4%	25.0%
	4_Junior Systems Engineer	Count	2	20	30	52
		Expected Count	1.7	19.9	30.4	52.0
		% within S5	3.8%	38.5%	57.7%	100.0%
		% within S49	33.3%	27.8%	27.3%	27.7%
		% of Total	1.1%	10.6%	16.0%	27.7%
Total		Count	6	72	110	188
		Expected Count	6.0	72.0	110.0	188.0
		% within S5	3.2%	38.3%	58.5%	100.0%
		% within S49	100.0%	100.0%	100.0%	100.0%
		% of Total	3.2%	38.3%	58.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.327[a]	6	.887
Likelihood Ratio	2.391	6	.880
N of Valid Cases	188		

a. 4 cells (33.3%) have expected count less than 5. The minimum expected count is 1.09.

Table 8.14.20 shows the crosstabulation of company and participation in process improvement training. Here, the very low asymptotic significance value of 0.000 shows the null hypothesis of no differences between companies can be very confidently rejected. This shows that there are statistically significant differences between companies. In Company F, 87% of the survey respondents have had process improvement training. In Company E, only 5.6% of the survey respondents have had this training.

Table 8.14.20: Crosstabulation of Company and Participation in Process Improvement Training

Company * S49 Crosstabulation

			S49			
			-	N	Y	Total
Company	A	Count	0	5	12	17
		Expected Count	.5	6.5	9.9	17.0
		% within Company	.0%	29.4%	70.6%	100.0%
		% within S49	.0%	6.9%	10.9%	9.0%
		% of Total	.0%	2.7%	6.4%	9.0%
	B	Count	1	4	10	15
		Expected Count	.5	5.7	8.8	15.0
		% within Company	6.7%	26.7%	66.7%	100.0%
		% within S49	16.7%	5.6%	9.1%	8.0%
		% of Total	.5%	2.1%	5.3%	8.0%
	C	Count	0	8	14	22
		Expected Count	.7	8.4	12.9	22.0
		% within Company	.0%	36.4%	63.6%	100.0%
		% within S49	.0%	11.1%	12.7%	11.7%
		% of Total	.0%	4.3%	7.4%	11.7%
	D	Count	1	8	10	19
		Expected Count	.6	7.3	11.1	19.0
		% within Company	5.3%	42.1%	52.6%	100.0%
		% within S49	16.7%	11.1%	9.1%	10.1%
		% of Total	.5%	4.3%	5.3%	10.1%
	E	Count	1	16	1	18
		Expected Count	.6	6.9	10.5	18.0
		% within Company	5.6%	88.9%	5.6%	100.0%
		% within S49	16.7%	22.2%	.9%	9.6%
		% of Total	.5%	8.5%	.5%	9.6%
	F	Count	1	2	20	23
		Expected Count	.7	8.8	13.5	23.0
		% within Company	4.3%	8.7%	87.0%	100.0%
		% within S49	16.7%	2.8%	18.2%	12.2%
		% of Total	.5%	1.1%	10.6%	12.2%
	G	Count	0	6	4	10
		Expected Count	.3	3.8	5.9	10.0
		% within Company	.0%	60.0%	40.0%	100.0%
		% within S49	.0%	8.3%	3.6%	5.3%
		% of Total	.0%	3.2%	2.1%	5.3%
	H	Count	2	3	16	21
		Expected Count	.7	8.0	12.3	21.0
		% within Company	9.5%	14.3%	76.2%	100.0%
		% within S49	33.3%	4.2%	14.5%	11.2%
		% of Total	1.1%	1.6%	8.5%	11.2%
	I	Count	0	3	14	17
		Expected Count	.5	6.5	9.9	17.0
		% within Company	.0%	17.6%	82.4%	100.0%
		% within S49	.0%	4.2%	12.7%	9.0%
		% of Total	.0%	1.6%	7.4%	9.0%
	J	Count	0	17	9	26
		Expected Count	.8	10.0	15.2	26.0
		% within Company	.0%	65.4%	34.6%	100.0%
		% within S49	.0%	23.6%	8.2%	13.8%
		% of Total	.0%	9.0%	4.8%	13.8%
Total		Count	6	72	110	188
		Expected Count	6.0	72.0	110.0	188.0
		% within Company	3.2%	38.3%	58.5%	100.0%
		% within S49	100.0%	100.0%	100.0%	100.0%
		% of Total	3.2%	38.3%	58.5%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	54.850[a]	18	.000
Likelihood Ratio	61.762	18	.000
N of Valid Cases	188		

a. 11 cells (36.7%) have expected count less than 5. The minimum expected count is .32.