Systems Engineering Knowledge Asset (SEKA) Management for Higher Performing Engineering Teams: People, Process and Technology toward Effective Knowledge-Workers

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Abstract of Dissertation

**Systems Engineering Knowledge Asset (SEKA) Management
for
Higher Performing Engineering Teams:
People, Process and Technology toward Effective Knowledge-Workers**

Systems engineering teams' value-creation for enterprises is slower than possible due to inefficiencies in communication, learning, common knowledge collaboration and leadership conduct. This dissertation outlines the surrounding people, process and technology dimensions for higher performing engineering teams. It describes a true experiment investigation of opportunities to improve communication, learning and common knowledge collaboration.

The art and practice of Systems Engineering contributes business value by orchestrating large numbers of knowledge-workers as engineering teams in the achievement of complex goals. During the creation of new systems, engineering team performance modulates business efficiencies to realize those complex goals. Higher performing engineering teams share a vision providing purpose, rely on personal knowledge convolved with collaborators knowledge to unleash potential, leverage common knowledge in their team mental models, and execute synergistically. Why do non-high performing teams exist? Culture change is hard. Humans prefer the familiar. Without Leadership and systematic enablement, teams usually do not naturally find the high performing team traits.

This research investigates a unique Information Technology based Systems Engineering Knowledge Asset (SEKA) management mechanism. The selected

mechanism integrates multiple techniques for improved collaboration efficacy. The research methodology was a modified true experiment with dual-posttest only, using an A and B group for comparative controls. Research findings reflect, with 99% confidence, that SEKA represented in 3-way Multiple Informational Representations Required of Referent (MIRRoR) knowledge constructs improves systems engineering teams' consumption of a common knowledge base.

Engineering teams can consume a set of information, which generates knowledge common with their collaborators, in a shorter period. More knowledge that is common facilitates increased ability to collaborate. Increased collaboration accelerates team learning, leading to shorter systems delivery schedules, lower cost to produce and earlier actionable intelligence. Shorter delivery times increase customer satisfaction; lower costs improve profit margin potential, and earlier actionable intelligence supports "left of boom" intervention.

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CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 Overview

Collaboration among systems engineers and project stakeholders is important for systems-creation learning-organizations to be competitive. Project communities of these systems engineers and stakeholders move toward high performance teams and deliver enterprise value sooner with efficient collaboration. Effectiveness of community knowledge exchange modulates innovation and creativity. Systems-creating enterprises remain competitive through their project communities' creativity, innovation and value delivery. Open knowledge systems help project communities create and exchange dynamic knowledge. Closed knowledge systems allow project communities to consume computer based training style static knowledge but do not support collaborator created knowledge assets. Psychology research has advanced static knowledge delivery techniques more than dynamic knowledge delivery techniques. This Information Technology (IT) based original experiment investigates delivering dynamic Systems Engineering Knowledge Assets (SEKA) in new information structures using closed knowledge systems' delivery techniques in open knowledge systems. The research problem is "effectively mobilizing tacit SEKA efficiently in project communities".

1.1.1 High Performance Engineering teams

Higher performing engineering teams enable better effectiveness, additional efficiencies and greater innovation for technical businesses. These are businesses practicing in the delivery of large complex systems' domain to meet unique, extensive or

intricate customer requirements. A method to raise the performance of engineering teams would enable these technical businesses to improve their competitive advantage posture. Such a method is the aim of this research. Technical businesses need to exhibit the qualities of a "Learning Organization" to adjust to advances in technology, attract the required human capital and remain competitive in the marketplace. (Senge P. , 2004) (Langan-Fox, Code, & Langfield-Smith, 2000) (DeFranco, Neill, & Clariana, 2010)

1.1.2 MIRROR SEKA approach explanation

The newly invented, IT friendly, information structure facilitates consistent knowledge asset creation. The new information structure called Multiple Informational Representations Required of Referent (MIRRoR) knowledge is this enabler. A 3-way MIRRoR knowledge construct, termed a Quality Knowledge Asset (QKA), implements a top-level representation in the bulleted style, a middle-level in synopsis summary style and a bottom-level in the verbose whitepaper style.

Recording of information with the intent to mobilize tacit knowledge has been an increasing goal since the invention of the printing press by Johannes Gutenberg around 1440. Linear, sequential assembly and consumption of material was a printing press friendly approach to knowledge capture in information form. Publishers have developed standards for manuscripts to facilitate printing. The result is familiar to readers who consume this Book Style Asset (BSA) to mobilize their tacit knowledge. Authors still tend to produce BSA when they are converting their knowledge to information for sharing over IT based open knowledge systems, e.g. collaborative environments.

The SEKA QKA method is designed to take advantage of IT collaborative environment capabilities to improve the knowledge transfer function. It allows consumers to understand the material more quickly.

1.2 Problem Statement

Systems engineering communities' value creation for enterprises is slower than possible due to inefficiencies in communication, learning, common knowledge collaboration and leadership conduct.

Free form BSA as collaborative environment content misses opportunities for improving knowledge transfer. Systems engineers and project stakeholders are typically professionals in fields other than writing and content development. They need to be able to share their knowledge in efficient consumption constructs immediately. Authors need help efficiently generating knowledge assets. The collaborative environment needs to elicit required information to populate a consistent structure. A collaborative environment application can efficiently present a common knowledge base when all assets are in consistent structures with consistent metadata.

People play multiple roles in project communities of knowledge-workers. Those with the knowledge author content. Collaborators learn dynamically created knowledge by consuming the information. Leaders influence the knowledge-worker productivity through their actions, directions and behaviors. (GAO, 2004)

Process design is required to enact culture change conducive to sharing and collaboration. Authors need training to populate and publish knowledge assets rather than working locally and hording knowledge. Consumers need to learn knowledge base

exploration processes to create knowledge in the Externalization, Internalization, Socialization and Combination dimensions. (Nonaka & Takeuchi, 1995)

Technology needs to enable people and their processes. Implementation of technological solutions needs to abstract collaboration application design away from specific content. Consistent constructs need designed for information structures that improve upon BSA. Collaboration environment architecture needs to be consumer centric. Content storage architecture needs optimization for content storage and abstracted away from presentation architecture. This allows flexible and multiple presentations of any given knowledge asset. (Lewis B. , 2002)

Collaborators need a technological enablement of processes to improve knowledge sharing and learning. Technology needs to make it easier for authors to share and consumers to learn common knowledge circulating in a project community. The speed of community knowledge development needs increased to drive enterprise value.

1.3 People, Process and Technology

1.3.1 Peoples' Role

1.3.1.1 Leadership's role

Leaders' conduct including actions, behaviors and directions, affect knowledge-workers positively and negatively. The effect on knowledge-workers affects problem solving abilities, responsible dedication, whole body commitment, superior results delivery, and retention. The resulting effect can enhance or degrade a workforce's agility and ability to create business value. Literature review contents were used to relate leader

conduct to Knowledge-worker productivity. This review produced an observation of five negatively correlated and seven positively correlated leader conducts with respect to Knowledge-worker productivity. (Taylor, 1911) (Burns, 1967) (Wren & Greenwood, 1998) (Senge P. , 1990) (Covey S. R., The 8th Habit, 2004) (Covey S. R., 1989) (Keirsey & Bates, 1978) (GAO, 2004)

Leadership conducts producing negative effects on knowledge-worker productivity:

1. Directing methods
2. Micro management
3. Linear thinking
4. Individual isolation
5. Controlling actions

Leadership conducts producing positive effects on knowledge-worker productivity:

1. Shared vision
2. Results focus
3. Systems thinking
4. Empowering trust
5. Enabled learning
6. Flexible treatment
7. Collaborative synergy

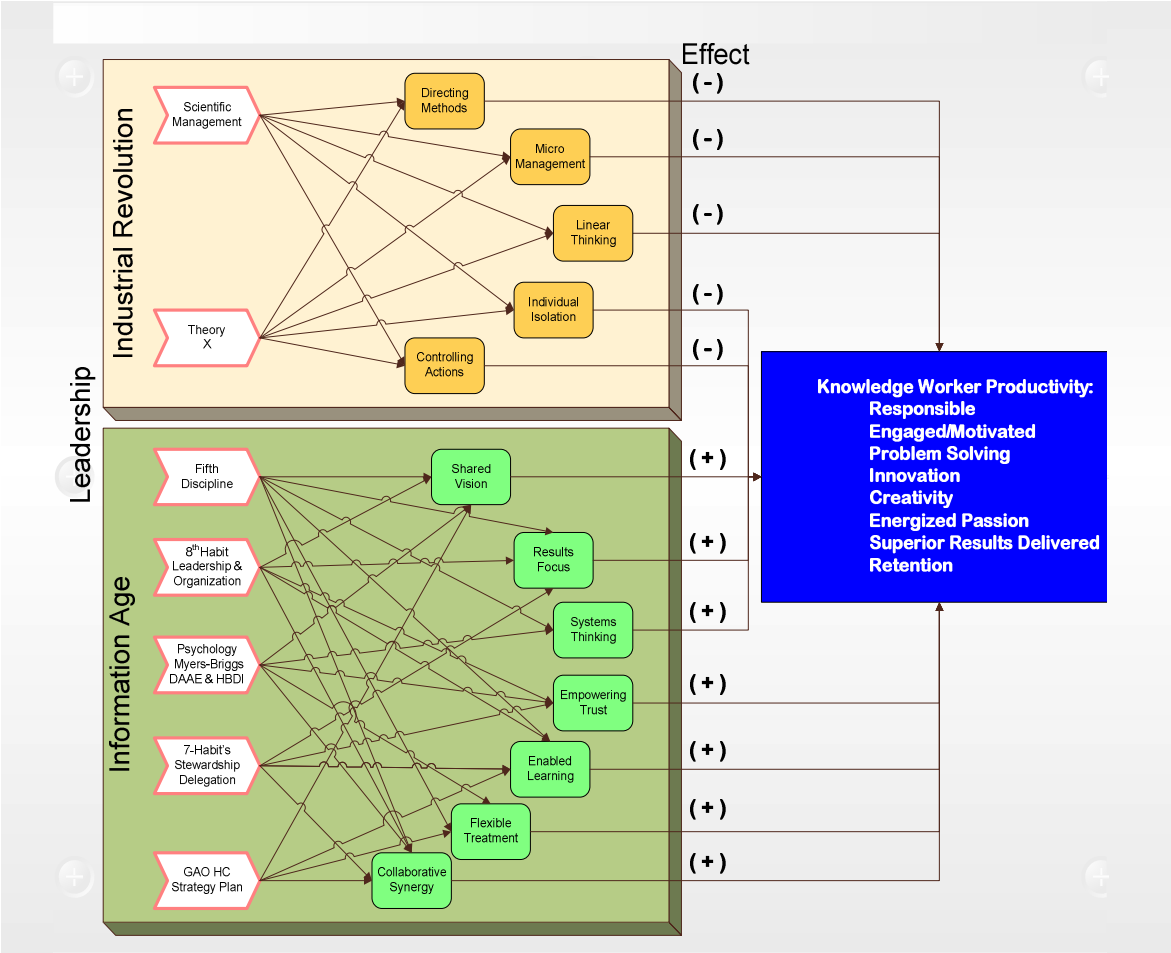

Figure 2: Graphical Representation of Leadership's Role

The compare and contrast looks at the Industrial Revolution and Information Age, see Figure 2. The predominant management theories employed during the Industrial Revolution were Scientific Management (Taylor, 1911) and Theory X (Burns, 1967) (Wren & Greenwood, 1998).

Industrial revolution: Scientific Management, referred to as Taylorism, observed inefficiencies in rule-of-thumb execution of mechanical systems by manual workers. Scientific review led to significant physical performance improvements. Knowledge-workers and mental fatigue were not part of Taylor's investigation. Implications from implementation and extended submersion in these more efficient environments often had

effectiveness defects on the whole-person employees and long-term enterprises. Theory X amplified beliefs that workers were mentally incapable. Leaders used this belief to justify the management styles' position that it was right to control workers actions and direct methods through micromanagement. Since workers' ability to understand their work and its impact on the whole-system was limited, Theory X supported breaking the work down into parts and having workers think linearly about their isolated segment.

Information age: The Fifth Discipline is a systems thinking paradigm that advocates advanced productivity achievement is more probable when workers are trusted with knowledge of the big picture. Illiterate workers building engines to support warplanes in the industrial revolution demonstrated they delivered superior results when they rotated through all the jobs. Without reading, the workers understood the causality loops involved in their work and became a learning organization (Senge P. , 1990, 2006). Psychology literature supports the theory that humans do better work when they understand whom they are depending on and who is depending on them and why. Personality preferences indicate they are more productive when allowed flexibility in the ways they achieve goals. Effective teams require a cross section of preferences on a team to optimize productivity (Herrmann, 1996) (Keirsey & Bates, Please Understand Me, 1978) (Keirsey, Please Understand Me II, 1998). Stewardship delegation, from the 7-Habits of Highly Effective People, takes this productivity a step further by injecting empowered trust. Delegation of responsibility takes the form of focusing on results instead of directing methods (Covey S. R., 1989). The 8th habit, voice, amplifies the 7-Habits with added motivation and energized passion in workers' work. (Covey S. R., The 8th Habit, 2004) The GAO Human Capital Strategy Plan acknowledges the

ineffectiveness of leadership who were holding on to Industrial Revolution techniques. These leaders are holding the United States government back in terms of knowledge-worker productivity. The new plan for 2004 – 2006 was to treat knowledge-workers with flexibility, giving them latitude to generate collaborative synergy in support of shared visions. The synergy allows focus on, and delivery of, superior results. (GAO, 2004)

1.3.1.2 Author and Consumer Collaborators' Role

Authors need to share their knowledge in multiple forms as the collaborative environments elicit. They should perform their daily work in the collaborative environment rather than working offline with the intent to publish later. Overcome by other events, the publish-later concept may not support free knowledge circulation. In addition to overt structured knowledge asset creation in the collaborative environment, non-structured deliverable artifacts including concept of operation documents, systems requirements documents, design drawings, and test plans need published in the collaborative environment. Search indexing non-structured knowledge assets combined with structured knowledge assets enable wider semantic and keyword content discovery. In the information age, common knowledge shared among project communities supports greater knowledge-worker productivity.

Consumers have a responsibility to stay plugged-in to the knowledge flow circulating in the community. They should perform their daily duties in the collaborative environment where they have ready access to all dynamically created and published knowledge assets. When consumers mix their knowledge with new knowledge discovered in the collaborative environment, they should assume the role of author by creating their new knowledge dynamically in the system.

1.3.1.3 Pre-Retiree and Mentee Collaborators' Role

The collaborative environment facilitates conversion of intellectual property ownership from individuals who develop it, to the enterprise who funded its development. This is especially important at attrition time. A specific form of attrition is retirement. When an employee has had a long and successful career, they reach the pre-retiree stage about a decade before they leave the enterprise. This is the time to start overtly passing the baton through aggressive mentoring of multiple mentee. The collaborative environment is a resource for these relationships. (Powers, 2002) (Liebowitz, 2004)

Enterprises have had trouble influencing pre-retirees to write down everything they know that might be useful in the future. A collaborative environment would allow the mentee to author dynamic knowledge assets as soon as they learned it. This learning comes from the Socialization mode of new knowledge creation, a reflection of knowledge the pre-retiree passed on to the mentee. After dynamic knowledge publication, the pre-retiree reviews the mentee's reflection and validates it as essentially correct – or suggests alterations. This codified and captured knowledge in the collaborative environment is essentially conveying ownership to the enterprise. The cycle perpetuates with the mentee as the recorded author. This is good for his/her career and supports successful collaboration. (Hu, 2010) (Powers, 2002) (Nonaka & Takeuchi, 1995)

1.3.2 Processes' Role

1.3.2.1 Elicitation Process

The consistent elicitation of SEKA from authors and their willingness to prepare the multiple representations of their knowledge is key. When a collaborator dynamically creates new knowledge to share, the Externalization process needs to make it easy for them to author in new instantiations of the information structure. Interactive technology wizards need to walk the author through filling out the form that becomes the new knowledge asset. Upon satisfying the form's requirements, the final step publishes the content for indexing, browsing and general discovery.

1.3.2.2 Storage Process

Storing the information structures that represent elicited knowledge needs to use an efficient structure to optimize retrieval. Stored content organization does not relate to the organization of the presentation layer. Presentation layer (theming and display rendering) dynamically accesses the stored content and constructs screens of information at invocation time. This decoupling allows results to be a combination of content, theme template and metadata. (Lewis B. , 2002)

1.3.2.3 Indexing and Search Process

Discovery of relevant knowledge representations support knowledge circulation throughout the project community. Indexing published content for both keyword search and semantic search allows consumers to find and consume content. Natural Language Processing (NLP) enables semantic search. SaffronOne, by Saffron Technologies inc., is an example of an NLP engine focused on efficient storage of metadata. SaffonOne's

Saffron Memory Base allows big data search for meaning rather than keyword match. (Aparicio IV, 2010)

1.3.2.4 Expertise Location Process

Who knows what? Reference data for expertise locating capabilities captures knowledge assets about people, their skills, interests and responsibilities. A common method uses three sets of metadata: Declaration metadata, Designation metadata and Derivation metadata. Declaration is a process for the collaborative environment to capture and index skills self-reported, or declared, by employees. The Designation process records metadata based on associating employees with their responsibilities. Derivation is capturing expertise metadata based on an employee's actions, content trails, and authored knowledge assets. (Lewis, B., 2002).

Reverse search: content finds people. Using the metadata about people, content fed into a reverse search engine returns people who have knowledge relevant to the content. In addition to names, the results list contact information to facilitate tacit-to-tacit knowledge collaboration. (Maybury, 2006) (Lewis B. , 2010)

1.3.2.5 Consumer-Centric Architecture and Organization Process

Organization of the user interface includes freedom from the storage organization. This decoupling facilitates flexible theming and supports portal technology for views into the collaborative environment. The Collaborative environment links access to the single central copy of knowledge assets, avoiding duplication and enabling reuse in multiple portals. Portal displays are focused views from the consumers' perspective, combining knowledge asset access in logical groupings. Roles within the team are a good place to start defining logical groupings. Align to organizations by finding the organization chart

functions, e.g. engineering / finance, etc., and design portals with the knowledge assets they use in their roles. Cross-functional groups, e.g. Integrated Product Teams (IPT), are common Group Focused portal opportunities. IPTs view their group information in their IPT Group Focused portal. A given IPT should have concurrent assignments on multiple iterations of a product or even multiple products at any given time. To simplify their Group Focused portal, the knowledge assets displayed are limited to items of general interest, announcements, awareness topic and teaming support. IPT members have access to product specific knowledge asset displays e.g. portal view for serial number 001, would have knowledge assets allocated to just serial number 001; similarly, serial number 002 knowledge assets would be filtered for view in serial number 002's portal. (Shelby Jr., Sarkani, & Mazzuchi, 2012)

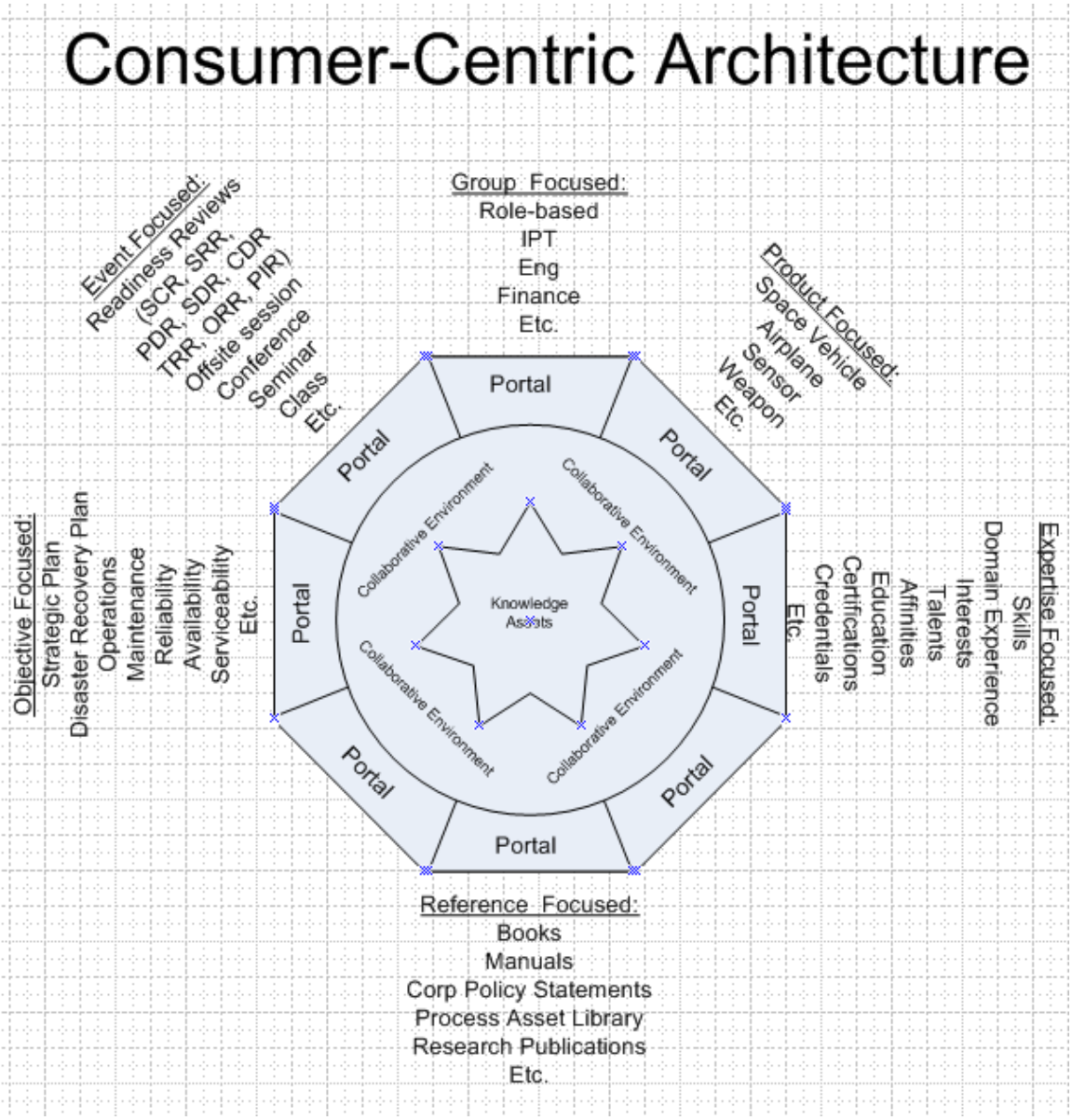

Figure 3: Consumer Centric Architecture

Beyond Group Focused and Product Focused, candidate focuses include Event Focused, Objective Focused, Expertise Focused and Reference Focused - see Figure 3. Enterprises should evaluate their specific requirements and implement portals best suited to their knowledge-workers and goals.

1.3.3 Technology's Role

1.3.3.1 Open Knowledge Systems: Collaborative Environment and Cloud

Open knowledge systems are compatible with the evolving IT concept of cloud computing. The IT marketplace is experiencing significant product hype related to cloud computing enablers. The concept decouples specific IT components, e.g. applications, databases, computer hosts, disk storage, and network connectivity, from the service models they provide, e.g. Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). A collaborative environment can install on an IaaS or leverage compatible middleware for installation on PaaS. Entrepreneurs could develop a collaborative environment service and deliver as SaaS. (Mell & Grace, 2011) (Sienkiewicz, 2009) (Wayner, 2008) (Chang, Sanford, & Hosame, 2010)

1.3.3.2 Capture of Externalization

Information Technology enacts the elicitation process when interacting with cognoscente authors to ensure consistent information structures represent the knowledge they are sharing. This technology-enabled elicitation is one of Nonaka and Takeuchi's four knowledge creation modes. Their knowledge creation model is Socialization, Externalization, Combination and Internalization (SECI). It considers tacit and explicit knowledge in a 2x2 matrix, giving the four modes - see Figure 4. The four interactions: 1) Socialization is tacit to tacit, 2) Externalization is tacit to explicit, 3) Combination is explicit to explicit and 4) Internalization is explicit to tacit.

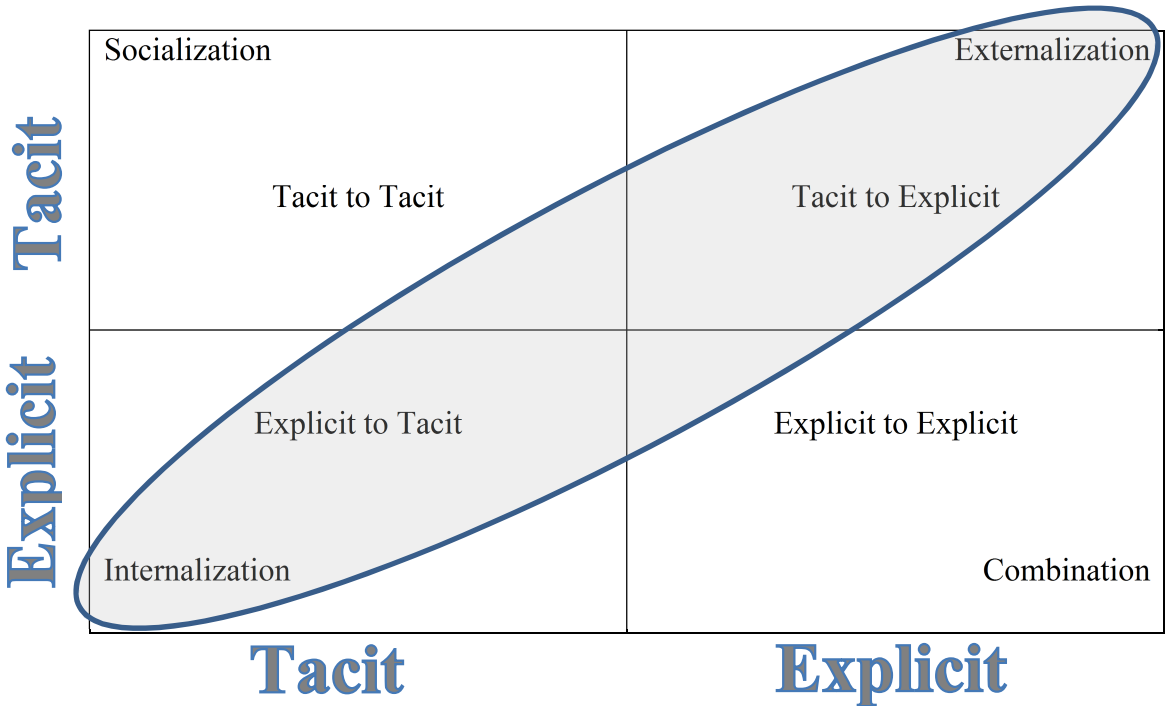

Figure 4: Adaption of Nonaka and Takeuchi's Knowledge Creation Model

Capture of Externalization is a method for an information knowledge system to aid authors in the creation of information structures. (Mustapha, 2012) (Nonaka, 1991) (Nonaka, 1994)

1.3.3.3 Presentation for Internalization

Consumers read or otherwise explore collaborative environment content for the purpose of Internalization, explicit to tacit knowledge conversion, i.e. learning. The collaborative environment aids the consumer's express exploration with non-linear navigation, allowing them to go as swiftly through the content as their education and experience allows. Their awareness is deepened by meta-cognition metadata in scaffolding surrounding the prime dual-coded content. This simultaneously display content and metadata reduces cognitive loading with reduced representational holding

required. When the consumer is required to hold less representational content in active memory, it widens the audience who can effectively consume the material.

Color highlighting can provide meta-cognition clues to associate content to metadata. There is a threshold to color highlighting's enhancement. Research indicates color-highlighting needs to be kept under four or five colors for most consumers (Hershberger & Terry, 1965).

1.4 Purpose of Research

The purpose of this research is to investigate an Information Technology friendly and Cloud Computing compatible, unique Systems Engineering Knowledge Asset (SEKA) management method of integrated techniques for improved collaboration efficacy. Systems engineers and stakeholders as knowledge-workers could use such techniques to improve engineering team SEKA consumption. A common SEKA infused "team mental model", and synergistic team application of SEKA can produce better business and intelligence results.

1.4.1 Novelty of this contribution

Self-Regulated Learning (SRL) environments' research for Computer-Based Training (CBT) has developed superior techniques for Nonaka and Takeuchi's Internalization mode. These techniques improve delivery of pre-developed and codified static content. Professional authors prepare Signal Available Relevant Accessible (SARA) theory of signaling and Dual-Coding Theory (DCT) content. These authors are removed from the actual delivery and use of the CBT. They typically do not interact with, or learn from, consumers. The presentation layer with scaffolding panels and

navigational controls are custom developed for the content. Integrators combine the content with the presentation software and package the system for e-learning. Contents in closed knowledge systems are similar to contents of a book or training material with holistic content contained. Readers/consumers are not expected to develop a new piece of knowledge and write the next chapter.

In contrast to closed knowledge systems, collaborators' open knowledge systems anticipate a consumer learning, making unique connections and writing the next knowledge asset. In addition to knowledge assets learned from the open knowledge system, the consumer can use the system to locate expertise outside of the system. It is not anticipated that holistic content is contained in the open knowledge system but rather the system depends on external sources of knowledge to grow and advance collaboration.

A segment of knowledge management literature addresses collaborative environments and open knowledge systems. Closed knowledge management systems are a primary focus for a segment of educational psychology literature. The combination of systems engineering, psychology, human factors and knowledge management literature contributes to this SEKA consumption study but do not fulfill the whole intent. An identified gap is in open knowledge systems employed as collaborative environments. Systems engineers and project stakeholders, who are typically professionals in domains other than writing, are asked to codify their knowledge for sharing. This study investigated an IT system to effectively elicit collaboration environment dynamic content that can be displayed like computer based training static content. This newly published content leverages consistent information structures and closed knowledge system techniques to improve consumers' ability to learn.

Posit systems engineers and project stakeholders as a learning organization that shares knowledge assets quicker and collaborates about common knowledge sooner. This study contributes open knowledge system improvement recommendations and experimentally verifies positive effects on project communities of systems engineers and stakeholders. These improvement techniques were mocked up to simulate the proposed IT system. The investigator executed the author role for Externalization and the test-subjects participated in the consumer role for Internalization. Knowledge creation transfer from Externalization mode to Internalization mode is highlighted by an oval in Figure 4.

1.5 Research Investigation

The Research Questions: Do project communities learn more efficiently and effectively with a knowledge base constructed in a 3-way MIRRoR knowledge QKA scheme? Do the new information structures work better for only systems engineers, only stakeholders, both or neither? Related to a knowledge-worker gender gap, does the new method work better for men, women, neither or both?

Goals and Objectives: The research investigation aimed toward identification of dynamic knowledge creation techniques for improving the explicit to tacit knowledge transfer function. The investigator created unique investigational instruments based on the investigation objective to discover an information structure and presentation style capable of making Internalization faster in learning dynamic knowledge.

Scope of Study: Thirty project community test-subjects explored a systems engineering knowledge base using an investigational instrument containing more than three-hundred pages of content.

Assumptions and Constraints: The experimental treatment used the investigator's knowledge and interpretation of a Systems Engineering Handbook as the knowledge base. This content is often considered difficult material to understand and apply. The assumption is that an effect detected with difficult subject matter would support a similar effect on easier and varied domains of subject matter.

1.6 Conceptual Framework

The investigational analysis of 3-way MIRRoR knowledge consumption used the framework graphically illustrated in Figure 5.

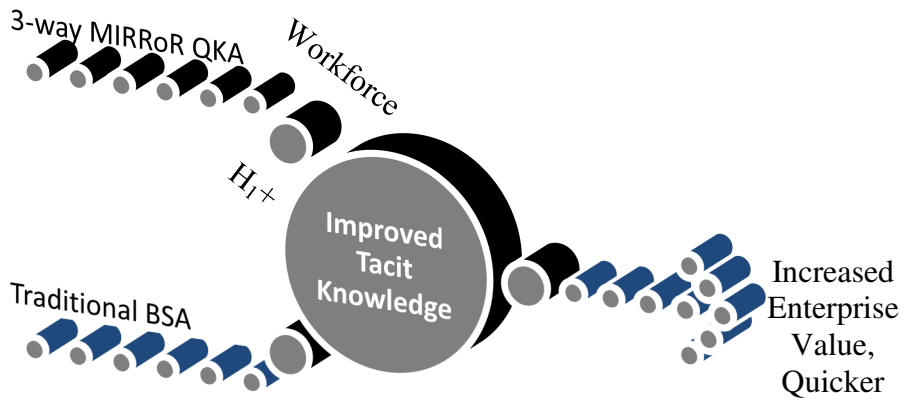

Figure 5: Conceptual Framework Represented Graphically

The 3-way MIRRoR knowledge, QKA, presented by an IT collaborative environment system exhibits the qualities of user-driven exploration and fast meaning transmission. This approach does not bias toward sequential progression through

content. Consumers may leverage their education and background more effectively for accelerated consumption of the material. Traditional BSAs bias the consumer toward sequential progress through the material, which may consume more time than a domain knowledgeable consumer requires to understand the material.

Traditional BSAs and 3-way MIRRoR QKAs are both capable of sparking human thought and leaving measurable residue in the form of tacit knowledge. This framework is used to investigate the magnitude of the residue.

1.7 Integrating the Elements

Knowledge-workers who make up the subject project communities include systems engineers and stakeholders. Collaboration and SEKA management modulates effectiveness, varying progress toward achieving complex goals. The art of enabling high performance engineering teams includes alchemy of people, process and technology. Such alchemy, based on literature review and experimentation, assembles into this study. A true experiment tests a technology implementation of an open knowledge system process to enable improved knowledge transfer between people. High performance engineering teams depend on leadership fostering a productive environment where they leverage knowledge transfer for creativity, innovation and value creation. Productive knowledge-workers are key to enterprises remaining competitive.

1.8 Organization of Research

1.8.1 Overview of the Literature Review

Enterprise value creation may have opportunities for efficiency gains. This literature review focuses on the enterprise environment where systems engineers and stakeholders execute new systems creation projects. Literature is searched for human-in-the-loop improvement opportunities, technology enablement, systemic solutions, recommended cultural paradigm shifts, energizing leadership conduct and executable business strategy plans. The primary literature domains reviewed include systems engineering, psychology, knowledge management, Information Technology and business leadership.

1.8.2 Overview of the Research Methodology

A modified "True Experiment" with dual-posttest only approach was used to avoid pre-test confounding. The dual-posttest approach supports analysis to ensure the content does not bias results. Each test-subject supplies data points for the treatment (QKA) and non-treatment (BSA) methods. Their prior knowledge of the material is carried into both segments of the experiment. The analysis focuses on the difference between the data sets, not the absolute values. Therefore, a given test-subject's prior knowledge is taken out of the equation and the treatment effect, given their knowledge, is evaluated.

Randomly selected test-subjects were assigned to groups A and B using the unbiased ping-pong approach. This approach allows the groups to be considered equivalent from a capabilities perspective. Experimentation using these types of groups

with thirty treatment and thirty non-treatment data points will commonly exhibit t-distributions that closely mirror the normal distribution curve, allowing valid claims of causality.

1.8.3 Overview of Data Results, Analysis and Findings

Thirty participants answered twenty posttest questions, ten on 3-way MIRROR knowledge QKA (treatment) content and ten on BSA (non-treatment) content. Analysis was performed to compare systems engineers versus stakeholders and men versus women. The analysis performed was single factor ANOVA capabilities in Microsoft Excel 2010. The findings indicate, with 99% confidence, that QKA method improves learning over the BSA method.

1.8.4 Overview of Conclusions

Multiple divisions of the data consistently demonstrate, with 99% confidence, that knowledge-workers, men and women, Systems Engineers and project stakeholders, generate more tacit knowledge when content is presented in 3-way MIRROR knowledge QKA construct.

CHAPTER 2. LITERATURE REVIEW AND EVALUATION

The research used in this dissertation project spans over one-hundred years. The two literature maps break up the literature by journal articles, see Figure 6, and books, see Figure 7. Literature domains include systems engineering, psychology, knowledge management, human factors, cognitive science, information technology, management and leadership. This set of literature supported a conference proceeding publication at the International Council on Systems Engineering's International Symposium, "SE in a Cloud: Retiree Knowledge Capture and Consumption Optimization" (Shelby Jr., Sarkani, & Mazzuchi, 2012). The author presented the paper in Rome, Italy, in July of 2012. The research produced two journal articles: "Tacit Knowledge Mobilization Effect Due To Information Structure" in the *Information Knowledge Systems Management* journal (Shelby Jr., Mazzuchi, & Sarkani, 2014) and "Systems Engineering Knowledge Management (SEKA) Consumption Investigation" in the INCOSE *Systems Engineering* journal (Shelby Jr., Mazzuchi, & Sarkani, 2014).

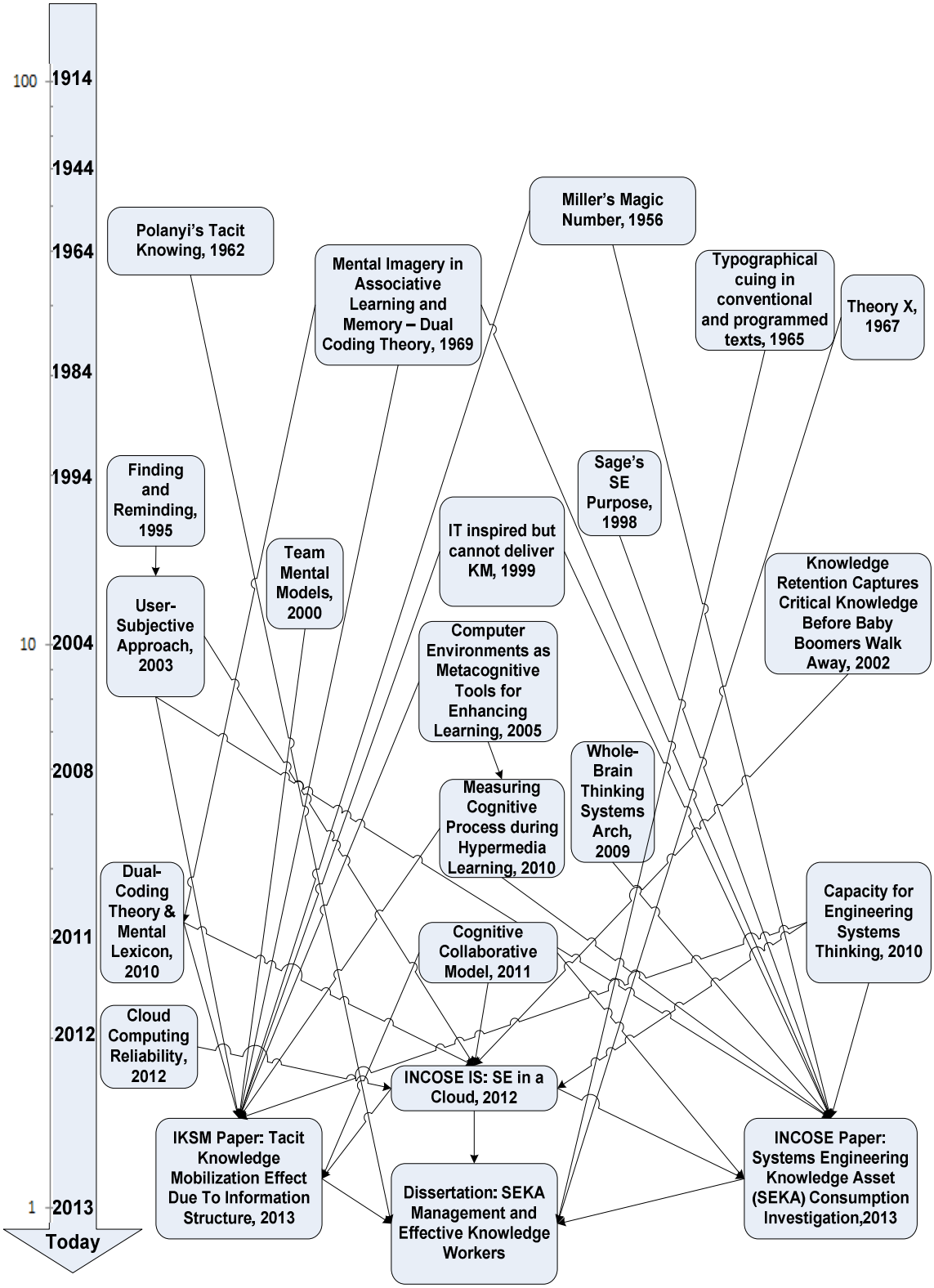

Figure 6: Timeline of Key Research Journal Articles

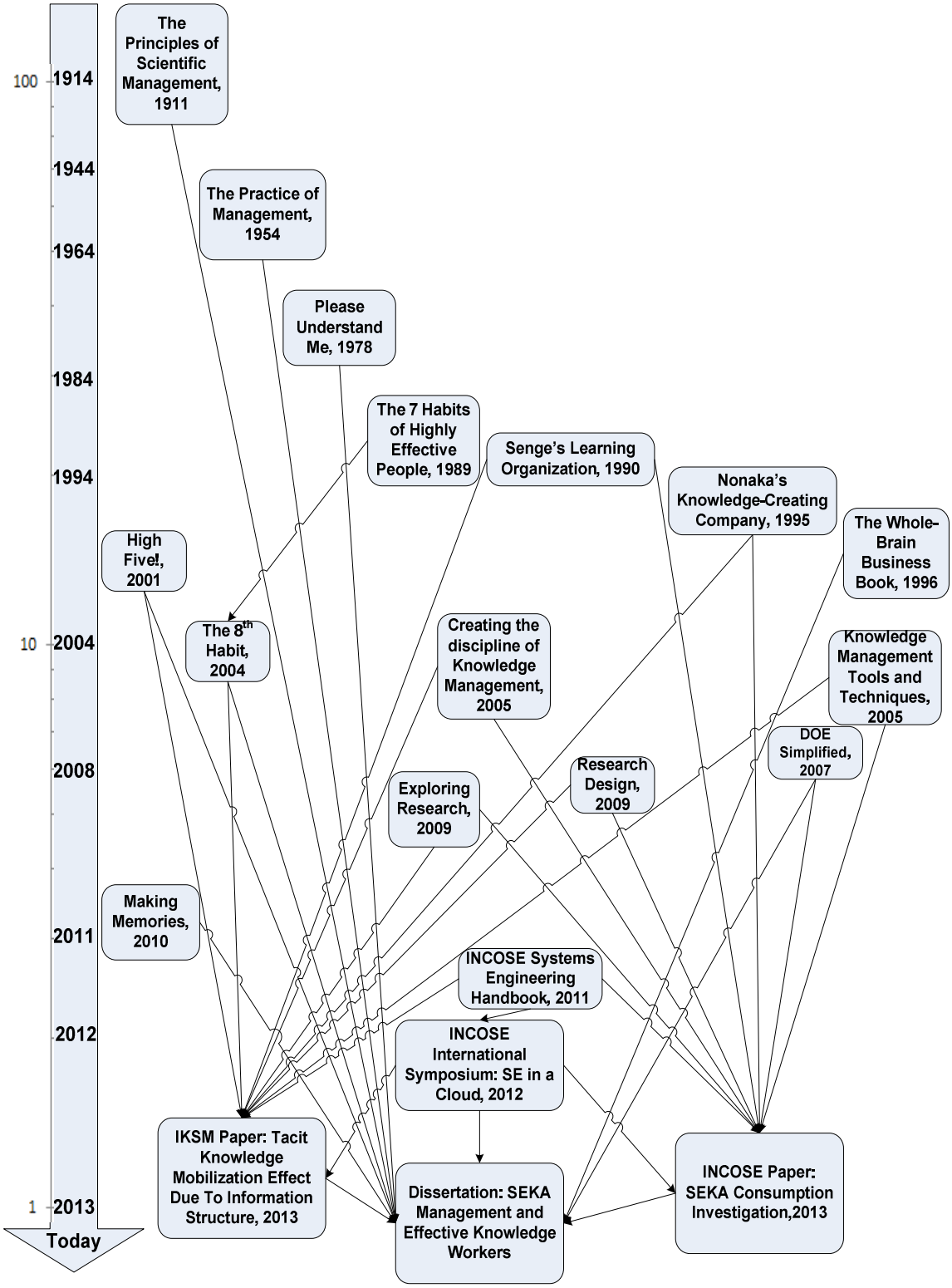

Figure 7: Literature Map of Books with Significant Contributions

2.1 Systems Engineering Literature

Andrew Sage sets the stage for systems engineering's dependence on information and knowledge. He says, "The *Systems Engineering* journal will pay particular attention to the knowledge principles, knowledge practices, and knowledge perspectives which are needed to bring about trustworthy and high quality systems that are cost-effective.' (Sage, 1998) His 7th of 8 ingredients to enable systems engineering design methodologies is knowledge management. Incorporation of innovative Information Technology advances is needed to ensure efficient enterprise integration (Sage, 1998). Enterprise integration is increasing critical to dispersed systems engineering teams. Systems engineering is a socio-technical activity where common knowledge is critical to project communities. Historical systems engineering leadership's mantra is that co-location is the right way to get teams to work together. This injects significant cost into the project and may limit access to the best resources. In the name of cost efficient systems, prime contractors require a secure collaborative environment to work with sub-contractors, as well as their internal teams from multiple locations. The more efficient these collaborative environments are in the human communication channel, the more the system under development can be cost-effective. (Harris, 2001) (Fagerstrom & Olsson, 2002)

Collaborative environments can, and should, host a variety of systems engineering tools. A common environment hosting common tools helps develop common skills for the use of those tools. This expands the collaboration ability of the team. An agile ConOps development process tool is needed to allow participants separated by time and space to visualize the new system and work from a shared mental model. The quality of requirements could be improved if expert systems tools aid the elicitation of knowledge

assets like requirements. The First Requirements Elucidator Demonstration (FRED) tool, could improve the knowledge assets' coarse quality of requirements before humans refine them. (Mostashari, McComb, Kennedy, Cloutier, & Korfiatis, 2012) (Kasser, 2004)

Additional tools and capabilities recommended in a cloud collaborative environments include web 2.0 blogs, wikis, streams, yellow pages, document reading rooms, multi-media repositories, document libraries, virtual meeting spaces for desktop/application sharing, instant messaging (texting), email, video teleconferencing, semantic and keyword search / reverse search and expertise location (Maybury, 2006) (Marwick, 2001). A Systems LIfecycle Management (SLIM) set of standards include a variety of systems engineering tools. A candidate list of systems engineering tools for inclusion in cloud collaborative environment tool suites (Bajaj, et al., 2011) (Khuzadi, 2011):

- Product Lifecycle Management (PLM) e.g. Teamcenter & Windchill,
- Manufacturing-Supply Chain e.g. Tecnomatix & SAP
- Libraries/Databases e.g. CAD models, cost models, material DBs, & supplier DBs
- Simulation/CAE e.g. MatLab, Simulink, ABAQUS, pSPICE, & Mathematica
- Requirements e.g. DOORS & RequisitePro
- Project Management (PM) e.g. Microsoft Project & Primavera
- Computer Aided Design (CAD) e.g. NX, Pro/E & CATIA
- Optimization e.g. ModelCenter & Isight.

Moti Frank analyzed the attributes considered important to successful Systems Engineers. He calls his overall assessment Capacity for Engineering Systems Thinking (CEST). CEST identifies and describes fourteen "General Cognitive Characteristics of Successful Systems Professional" of which a subset is understanding: the Whole System, Interconnectedness, Creativity, Ambiguity Tolerance, Implications of change, non-engineering considerations (externalities), and Analytics. (Frank, 2010)

Ambidextrous thinking, using both the left-brain for analytical work and the right-brain for holistic work, is a common trait for systems architects. Systems engineering tools tend to focus on analytical, linear thinking. Architects augment this left-brain thinking in words and numbers with right-brain understanding in images and drawings. This right-brain activity is where systems thinking derive causality loops for holistic understanding. (Di Carlo, Khoshnevis, & Udwadia, 2009)

John Colombi, et. al. describe the predictive mental workload and Human Systems Integration (HSI) considerations that are commonly performed by Systems Engineers and stakeholders. (Colombi, et al., 2012) Often, Systems Engineers think of their end users more than they consider the environments they use for systems creation.

The Cognitive Collaborative Model (CCM) journal article demonstrated the importance of managing knowledge for better engineering team performance. Good-shared mental models are highly correlated with high performance engineering teams (DeFranco, Neill, & Clariana, 2010).

2.1.1 Capacity for Engineering Systems Thinking and the Retiree

In a mentor/mentee relationship, the Journeyman should probe for the cognitive characteristics of systems engineers. Journeyman should incorporate knowledge assets

with an understanding of the whole system, inter-connective considerations, simplicity on the far-side of complexity (Covey 2004), avoidance of analysis paralysis with a tolerance for ambiguity, the promotion of creativity, change implications, structural or pattern recurrence, boundaries and the need to acknowledge externalities like funding, business value, and politics, see Figure 8. (Frank 2010)

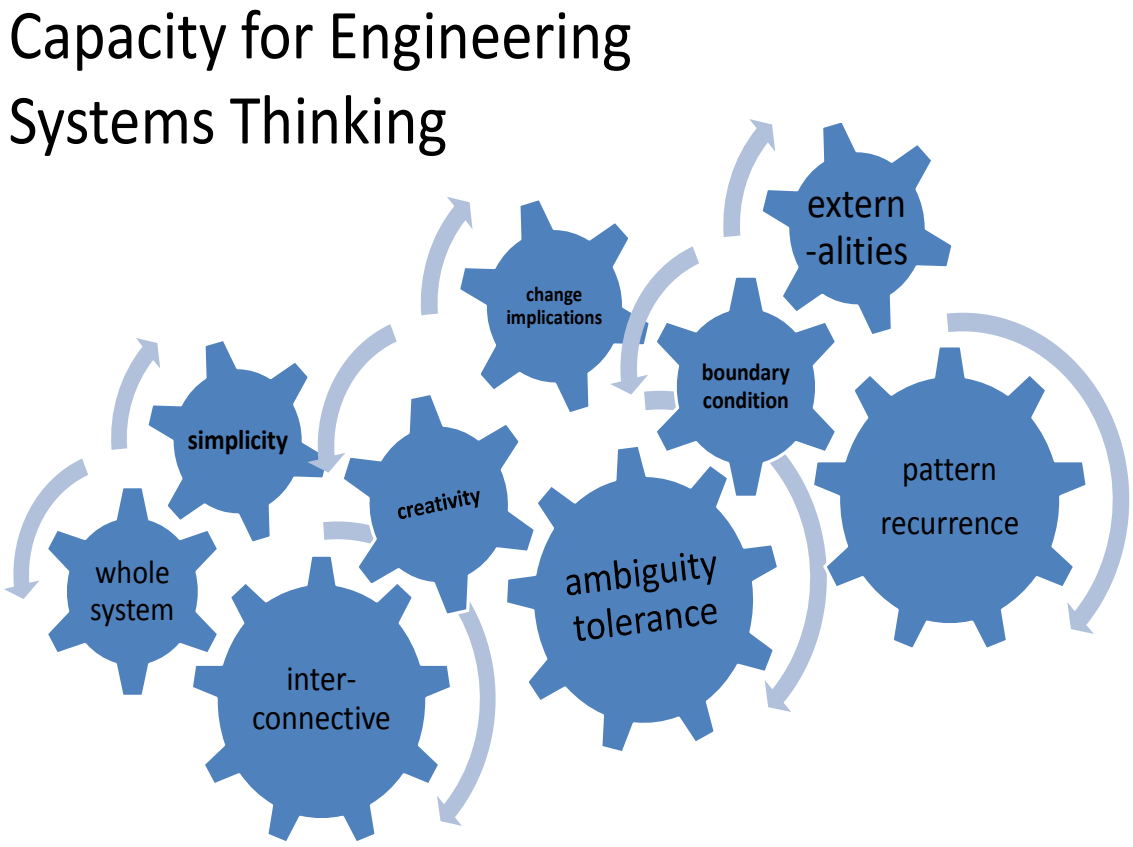

Figure 8: Capacity for Engineering Systems Thinking Illustrated

2.1.2 Cognitive Collaborative Model (CCM) and business leadership

Critical thinking is a cornerstone of engineering teams. Effective cloud collaborative environments enable shared mental models (Senge 2006) through Process

Asset Libraries (PAL) for common, record-of-authority, reference material. With the PAL framework familiarized throughout the interdisciplinary team, the desired synergy of collaboration has a fertile ground to grow and push out the less efficient and less effective cooperative compromise mode of teamwork. Leadership plays a role in promoting synergistic collaboration, especially through the speed of trust (Covey 2004) and enabling effective problem solving. The journeyman/pre-retiree mentor pairing would ideally occur with sufficient time for the journeyman to observe, author quality knowledge assets and teach a peer throughout all six stages of the CCM. Each stage is broken down into three phases, complete with collaborative modalities and cognitive expectations. The six stages are problem formulation, solution planning, solution design, solution translation, solution testing, and solution delivery, see Figure 9. (DeFranco, Collin and Clariana 2011)

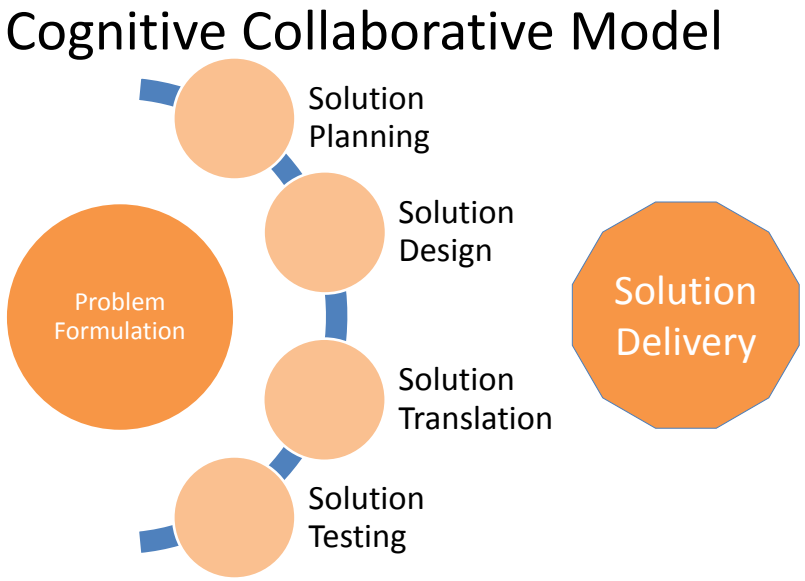

Figure 9: Cognitive Collaborative Model Illustrated

Organizations can be viewed as systems which use other systems to gain access to resources used to grow and survive in the marketplace. A basic task for an organization is to handle information efficiently. It is probable that open knowledge systems with social actors will address this task more efficiently than closed knowledge systems. (Fagerstrom & Olsson, 2002)

Knowledge is often a byproduct of data and information understanding. Data is differentiated from information by context. Data is recorded from observations within a context. It is factual but not necessarily meaningful in a standalone condition. Data becomes information when it is associated to a context. Information derived from communication, implementation or conclusion becomes knowledge when it is interpreted as valuable. (Fagerstrom & Olsson, 2002)

2.2 Knowledge Management Literature

Systems engineering activities work better with a knowledge management strategy focused on a bias toward personalization over codification, although both are known to be required for efficient organizational performance, see Figure 10 and Figure 11. Different parts of the literature on knowledge management strategy contain arguments for bias in either direction or a balance between personalization and codification. Activities like systems engineering, where dynamic tacit knowledge with properties of stickiness and casual ambiguity are needed for creativity and innovation, are best aligned with the personalization-biased approach. At retirement time, personalization optimizes the retiree's tacit knowledge transfer to the journeyman

mentee. Storytelling can be facilitated by shared physical locations and shared virtual locations. Key retiree social network contacts are shared with the journeyman mentee. The journeyman mentee authors the codified knowledge and becomes a source of knowledge in the expertise location capability of the cloud collaborative environment. (Kumar & Ganesh, 2011)

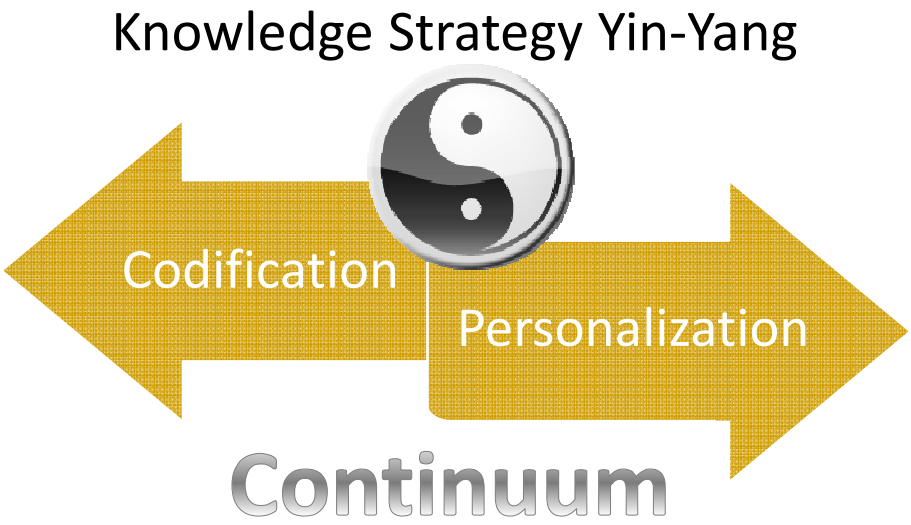

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Figure 10: Knowledge Strategy Continuum

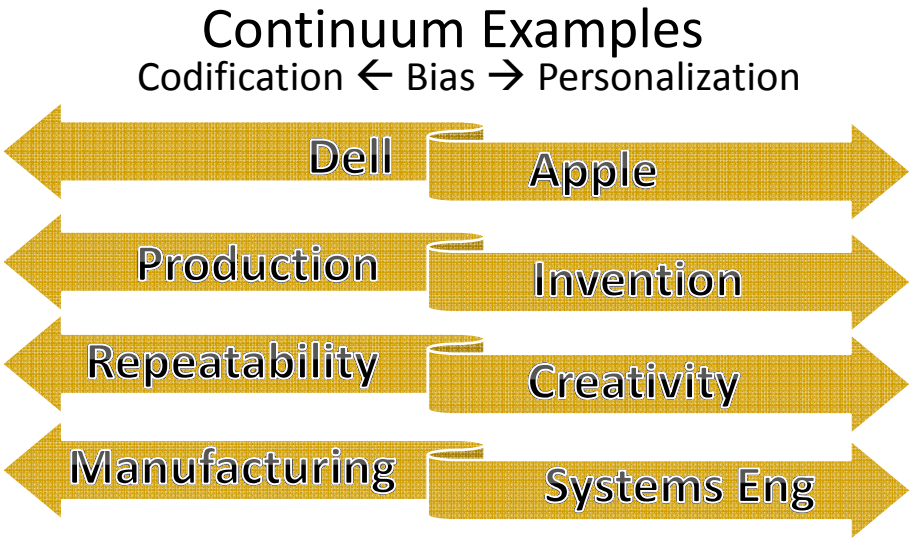

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Figure 11: Knowledge Strategy Examples

Michael Polanyi articulates the definition of tacit knowledge in part I of his 1962 journal article, quoting Michael (Polanyi, 1962):

- "Knowing a thing by attending to it, in the way we attend to an entity as a whole" is a "focal knowing", where an individual can tell another the knowledge. This can be referred to as explicit knowledge
    - Analogy: Books, documents, computer based training, etc.
    - Generally things that do not require practice or observed demonstration
    - Accessible full understanding and competence from reading/review

- "Knowing a thing by relying on our awareness of it for the purposes of attending to an entity to which it contributes" is a "subsidiary knowing", where an individual cannot tell another the knowledge. They can demonstrate it or enable practice but not communicate it explicitly. This can be referred to as tacit knowledge
    - Analogy 1: Riding a bicycle can be known by an individual but that individual cannot tell another individual sufficiently for the other individual to obtain the skill. The tacit knowledge of how to keep ones balance on a bicycle is developed through practice.
    - Analogy 2: Swimming is a skill that one can be told of the basics but the tacit knowledge of how to stay afloat and continue breathing is developed through practice.
    - Knowledge learned by observing another perform the action
    - On the Job Training
    - Safe area to practice before critical performance

Knowledge management systems acknowledge that it takes more than managing information referent to explicit knowledge, to be effective. Tacit knowledge must be considered. An effective knowledge management system provides guidance on practicing to develop tacit skill knowledge. Some literature refers to candidate explicit knowledge as tacit knowledge before is it Externalized.

Tacit knowledge is considered in human-factors and systems engineering literature contributions to knowledge management research in the form of dynamic knowledge collaboration recommendations. The Team Mental Model (TMM) and

Cognitive Collaborative Model articulate a higher team performance correlation to "shared" or "team" mental models and synergistic execution. The entire team does not have to be of one mind as there is "task specific knowledge" and "process specific knowledge", along with other valuable domain knowledge contributing to team performance. No one needs to know everything. (DeFranco, Neill, & Clariana, 2010) (Langan-Fox, Code, & Langfield-Smith, 2000) (McDermott, 1999) (Senge P. , 1990).

Nonaka & Takeuchi's Socialization, Externalization, Combination and Internalization knowledge creation model considers tacit and explicit knowledge to generate four interactions: 1) tacit to tacit, 2) tacit to explicit, 3) explicit to explicit and 4) explicit to tacit, respectively. (Nonaka, The Knowledge-Creating Company, 1991) (Mustapha, 2012) (Marwick, 2001) (Nonaka, 1994)

Figure 4 represents knowledge conversion's four modes. The Socialization mode enables knowledge transfer through personal interaction. Shared mental models and experiences can generate tacit knowledge through observation, imitation and on-the-job training. The Externalization mode is primarily writing, modeling, illustrating and generally articulating knowledge for reflection or use by others. The Combination mode creates new knowledge through mashing up different bodies of explicit knowledge to discover new insights. Filtering, sorting, adding, combining, rating, associating metadata and categorizing facilitate information manipulation and analysis. The Internalization mode is the conversion of experiences from Socialization, Externalization and Combination, into personal know-how. Input from the world becomes "known" in the individual's personal knowledge repository. (Nonaka & Takeuchi, 1995)

2.2.1 Knowledge management and information technology research

Information is not knowledge. Systematic sharing of information is simply a matter of networking and protocol handshaking. Decision making and business results usually depend on "human-in-the-loop". Humans process information and convert it to knowledge. Knowledge management literature provides six characteristics of knowledge to discern it from information, quoting Richard McDermott (McDermott, 1999):

1. "Knowledge is a human act"
2. "Knowledge is the residue of thinking"
3. "Knowledge is created in the present moment"
4. "Knowledge belongs to communities"
5. "Knowledge circulates through communities in many ways"
6. "New knowledge is created at the boundaries of old"

High performing teams commonly articulate a TMM as they circulate knowledge through their community. They collectively share new dynamic knowledge they generate at the boundaries of old known knowledge, allowing the new knowledge to mix with known knowledge. This becomes a common knowledge base owned by the community. Information records of this knowledge base can teach team members the concepts as consumption ignites the present moment human act of thinking, resulting in the residue referred to as "Knowledge". (DeFranco, Neill, & Clariana, 2010) (Langan-Fox, Code, & Langfield-Smith, 2000) (McDermott, 1999)

Knowledge management advancement needs to leverage a combination of systems and approaches. An open knowledge system interpretation combines elements where (McDermott, 1999):

(1) Addressing the technical Aspect, consider Portal, "expertise location", search, "natural language processing", "Big Data Handling" and collaboration capabilities – Technology pillar. These capabilities promote teammates thinking together through collaborative environment design. (McDermott, 1999) (Marwick, 2001) (Muntean, 2009) (Yang & Huh, 2007) (Raol, Koong, Liu, & Yu, 2003) (Zhou & Zhang, 2003) (Calabrese, 2005) (Rao, 2005) (American Productivity & Quality Group, 2003) (Jackson & Moulinier, 2007) (Saffron Technologies, Inc., 2005) (Aparicio IV, 2010) (Strictland, Eaton, & Conrad, 2003) (Stankosky, 2005)

(2) Addressing the social aspect, consider "Social Network Analysis (SNA)", – Organizational pillar. Diverse knowledge-worker teams should maintain collegial relationships. Organizational coaching can be informed and improved by awareness in multiple dimensions including structural analysis, relational analysis and analysis of critical stakeholders. (McDermott, 1999) (Filho, Lucena, Neto, & Maury, 2012) (Calabrese, 2005) (Rao, 2005) (Stankosky, 2005)

(3) Addressing the management aspect, consider actions of "Repeated recognition and reward", "catch employees doing things right", and "stewardship delegation"– Leadership pillar. Knowledge workers are invigorated to share their insights in a safe environment. A trust-based environment allows them to feel their contributions will receive fair consideration. (McDermott, 1999) (Blanchard & Bowles, 2001) (Covey S. R., The 8th Habit, 2004) (Calabrese, 2005) (Drucker, 1954) (Edersheim, 2007)

(4) Addressing the personal aspect, consider e-learning, self-regulated learning, meta-cognition, authorship, and "tacit knowledge mobilization"– Learning pillar. Knowledge-workers demonstrate a learning behavior. These elements support their ability to learn and develop innovative contributions. (Azevedo, Moos, Johnson, & Chauncey, 2010) (Quintana, Zhang, & Krajcik, 2005) (McDermott, 1999) (Nonaka & Takeuchi, 1995) (Muis, 2007) (Wilkesmann & Wilkesmann, 2011) (Calabrese, 2005) (Rao, 2005)

Maturing of the computer in the early 1960s sparked an interest in codifying knowledge into explicit information artifacts that could aid in the flow of knowledge. The receiver used information to generate human thought. The concept of computerizing the management of knowledge has been the focus of research for approximately forty-five years. Knowledge and information are inherently different and information-sharing techniques do not work for knowledge sharing. Human factors from psychology and cognitive science can help guide "information" presentation in ways that improve the human thinking act, and its residue, required to create knowledge in the present. A

common residue within a community can generate a shared mental model owned by the community and actively circulated by teammates for critical thinking to shortened project timelines. (McDermott, 1999) (Reed, 2006)

Processes and procedures are important to high-performing project teams but finding concepts to improve systems engineering that do not add new process and procedure complexity is valuable. Processes should adhere to a back-to-basics theme of concept of operations, requirements, architectural synthesis, design, test, deploy, operate and disposal. (Head & Virostko, 2009) It is acknowledged that it is insufficient to merely deploy Information Technology (IT) systems with file sharing repositories, connectivity linking stakeholders and capturing files (documents, procedures, etc.). These capabilities and availabilities do not provide the spark required to get the average systems engineering community to collaborate, develop shared mental models and generate innovative knowledge. Richard McDermott says "Ironically, to leverage knowledge we need to focus on the community that owns it and the people who use it, not the knowledge itself" (McDermott, 1999).

2.2.2 Big Data Handling – Semantic Search

SaffronOne is a product from Saffron Technologies, Inc. It is an example of a Natural Language Processing system to enable semantic search. These capabilities enable much larger and more diverse search with better results, effectively making "Big Data" viable.

Saffron's associative memory concepts are part of the semantic web, enabling connectedness between data to form informational representations of knowledge. When tacit knowledge is mobilized in humans, they have an opportunity to understand the

meaning. When systems start making sense of the meanings, they can assist with reasoning through the unifying framework for multi-strategy reasoning (Talbot, 2003). The framework enables five reasoning approaches: abductive, analogical, deductive, inductive, and probabilistic. SaffronOne, the core associative memory engine, successfully executed a link analysis of the connectivity metrics between nodes, using the multi-strategy reasoning framework and came to the proper conclusion in Northrop Grumman's laboratory experiment. This was accomplished by unsupervised concept classification using a counting algorithm to assess similarity in the content's underlying characteristics.

Saffron's tools discover knowledge to answer questions that were not known prior to the time they were asked, an important capability required for crisis management. This knowledge discovery identifies associations and relationships between triples fed in from entity extraction tools. Entities are people, places, things and behaviors that make up information representative of knowledge. Saffron's associative memories are created when data streams are ingested and managed in the software as the record of authority. The source documents' locations are maintained as well so users can reference the original material if so desired (Strictland, Eaton, & Conrad, 2003)

The Saffron approach is a new and innovative method for analyzing information stores and feeds that represent knowledge (Aparicio IV, 2010) (Saffron Technologies, Inc., 2005) (GWU Cohort, 2010). While most knowledge-management vendors are trying to make old methods more efficient and scalable, Saffron is taking artificial intelligence to the next level and providing real value with relatively simple concepts. These simple concepts truly are simplicity on the far side of complexity (Covey S. R.,

2004). As is usually the case, when concepts are simplified down to minimal archetypes, it takes keeping track of millions, and maybe billions, of them to do the job.

2.2.2.1 The Problem of Information Overload and Connecting the Dots

Storing information has largely been solved (GWU Cohort, 2010). Recall with precision, or lack thereof, is a large contributor to information overload. The user must work to filter through information that is not answering their question. If the systems would do a better job understanding the meaning in the knowledge base and understanding the meaning in the user's question, filter the results appropriately and deliver just the precise answer, then the user could efficiently use the information to formulate the follow-on question to learn and connect the dots faster.

Many national security examples demonstrate the ability to store the information, referred to as these dots, but not being able to recall information or understand the represented knowledge in time to prevent terrorist activity. This "left of Boom", thinking about a Gantt chart timeline, is obviously the objective. Connecting the dots after the boom, "right of Boom", is too late. Databases had data about the Christmas bomber, London bomber and other terrorist attacks but could not connect the dots to prevent the boom. National security is an important application but solving the connecting the dots problem has wide economic implications in many domains.

2.2.2.2 Concepts and Techniques

Saffron's associative memory concept is rooted in psychology, philosophy and artificial intelligence (Aparicio IV, 2010) (GWU Cohort, 2010). Their research focused on differentiating common computer indexing schema, search and query from human brain-like methods of remembering based on dynamic association. Most human brains

are not good at delivering all the accurate data elements ever known by the individual. It is good at reasoning to understand the meaning of keywords, phrases, concepts, pictures, maps and many other relationship-oriented inputs. Human brains effectively associate appropriate recall with pretty good precision when they understand meaning. Saffron's research and subsequent products are moving computers toward the goal of working like human brains.

2.2.2.3 How it works

Saffron's value proposition is analyzing link relationships using algorithms for unsupervised entity and relationship classifications. The analysis results produce entity-node connectivity assessments relative to those entity node's underlying characteristics (Talbot, 2003). The analysis is performed at time of ingestion (learn as you go) to make consumption time optimized. Fast, nimble ability to answer impromptu questions with quality information mobilizes more tacit knowledge in the user.

A user can navigate and interrogate unstructured content environments after entity extractors have fed Saffron with triples (subject, action, object) relationships. Saffron provides the associative memories of the knowledge represented in the unstructured content. Saffron generates these associative memories by building two-dimensional arrays for every link relationship and counts the occurrences. More occurrences equate to more association. What if information representing the knowledge-base is a mix of structured, semi-structured and unstructured content? Similar analysis works for semi-structured and structured content, allowing Saffron to comingle associations for a holistic knowledge-base analysis and deliver on-the-fly results across content type boundaries.

What would this look like: Figure 12 is a simple matrix where Object and Action have a relationship hit. Note: Subject and Object as well as Subject and Action do not have a relationship hit. The magic is analyzing all link relationships and counting the relationship hits.

Object		1	0
Action	1		0
Subject	0	0	
	Object	Action	Subject

Figure 12: 2-D Matrix of Semantic Link Relationship

2.2.2.4 Products

SaffronOne is the heart of Saffron's solution and is required for every deployment because all other products rely upon this associative memory engine for the informational representations, see figure 13 (Saffron Technologies, Inc., 2005).

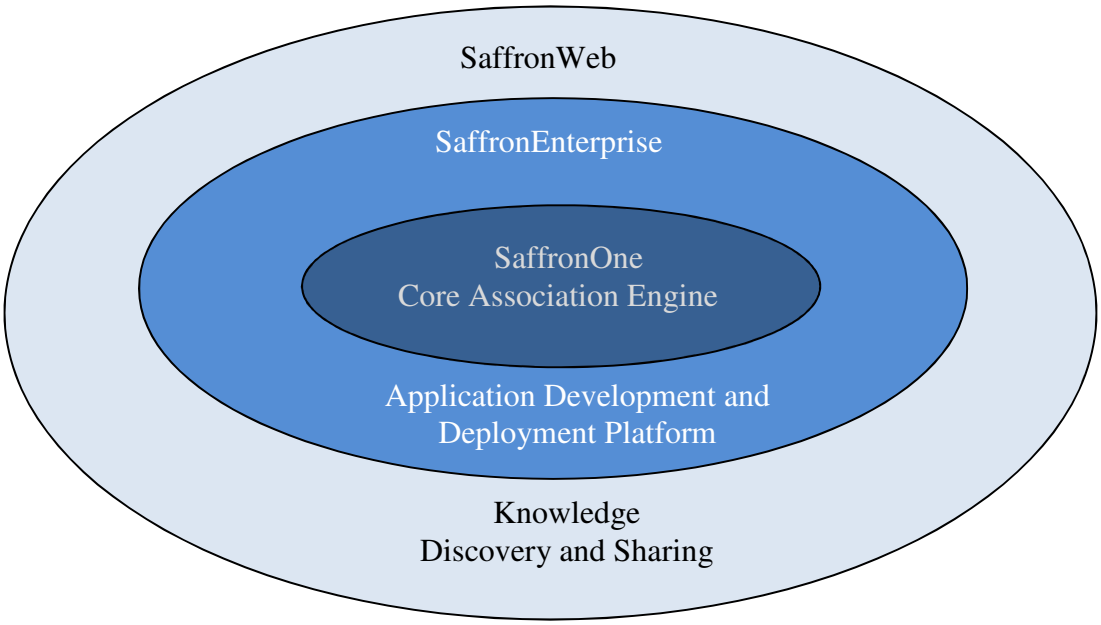

Figure 13: Saffron Product Stack

SaffronEnterprise provides the integrator with a platform for development and deployment. The product arrives with common JAVA development tools to get the programmers started. The development team enables the Saffron solution to leverage a huge number of automated agents to collaborate on the discovery of explicit and implicit link relationships (Saffron Technologies, Inc., 2005).

SaffronWeb is the user interface for the Saffron solution. It provides a presentation layer for interrogating the knowledge base through knowledge discovery and sharing. The database analogy is that every entity is a primary key so the user is free to

take any path through the discovery process, delivering results on the fly (Saffron Technologies, Inc., 2005).

2.2.2.5 Practical Considerations

Capacity planning is a common concern for the associative memory industry due to excessive storage requirements to characterize a given knowledge base's associations in ways that enable human brain-like recall. Saffron employs matrix compression and partitioning techniques to reduce their overhead storage requirements (Saffron Technologies, Inc., 2005).

Saffron solutions still require significant storage; the infrastructure engineer needs to plan for at least 3:1 more storage than the knowledge base consumes and, based on content, possibly 10:1. This is industry-leading efficiencies because the industry average is 30:1 and an upper bound somewhere around 60:1 (GWU Cohort, 2010).

2.2.2.6 Applications

Saffron's "Knowledge Discovery" (Saffron Technologies, Inc., 2005) is a better search than keyword searches using conventionally indexed schemas on information stores. Knowledge Discovery improves on Relational Database Management Systems (RDBMS). RDBMS typically use primary keys and are optimally used when the question is known at the time of database design, or at least with enough lead-time to have the SQL query built and tested. Knowledge Discovery builds the associations at the time of learning rather than waiting until the question is asked. This allows the user to ask their question, learn from it and ask another question, greatly improving timely tacit knowledge mobilization in the user. Two example domains have found useful applications for Saffron's products: National Intelligence and Business Intelligence.

A powerful consideration for SaffronOne is its flexibility to ingest and analyze virtually any consistent ontology of relationships. This allows analysis of geospatial information, with quality tagging. Similarly, facial recognition companies can leverage SaffronOne for developing memories of people based facial attributed tags fed into the associative memory engine (GWU Cohort, 2010).

2.2.2.7 National Intelligence

In 2003, Kenan-Flagler's Frank Hawkins Kenan Institute of Private Enterprise put forth plans to supply Boeing with SaffonOne Technology for their Boeing Log Net (Greis, Olin, & Kasarda, 2003). Boeing's responsibility included providing an integrated view of the military's logistics environment. This is where situational awareness of military forces around the world is required and effective responses are paramount. The military supplies have less excess capacity than afforded in earlier years so managing the right resources to the right places at the right time is key. Saffron's associative memory capabilities are a good fit for this enormous set of complex information flows.

2.2.2.8 Business Intelligence

SaffonOne is licensed by Open Field Software for use in their Electronic Learning Assistant (Ella) for Spam Control (Open Field Software, 2008). Open Field Software understands that spammers are a morphing adversary who does not give you time to design a system query to defeat them. Saffron's tools allow enormous data fields to be distilled on the fly for problem patterns. Saffron allows Ella to morph along with the spammers and filter with greater discernment than competitors. Ella handles non-linear data relationship while competitor's filters stumble. This discriminating service is a competitive advantage for Open Field Software.

2.2.2.9 Deployment Challenges for Saffron

The Saffron products provide a base infrastructure but rely upon third party tools to pre-process raw data and supply Saffron with tagged information. While providing a platform for development is a valuable offering, it implies integration costs and those can be significant. The knowledge base under analysis needs to be of high value like in the case of National Intelligence, to help justify the holistic cost borne by a Saffron deployment.

SaffronSierra is an open source offering to help orient perspective customers to the Saffron value proposition. A cost effective Commercial-Off-The-Shelf (COTS), shrink-wrap, offering could accelerate Saffron's visibility in the marketplace. This COTS could target some common application like 1 TB to 10 TB document libraries, provide bundled or built-in Natural Language Processing (NLP) tools for entities extraction and provide out-of-the box value. The knowledge management industry in general tends to suffer from "boiling the ocean" syndrome. Vendors develop highly abstracted functionalities embedded in platform capabilities that have to be integrated. Although this abstraction allows them to be everything to everyone, a little focus would go a long way toward value-oriented products that can be applied quickly to well defined problems in a cost effective manner.

2.3 Psychology and Cognitive Science Literature

Psychology literature shares a closed knowledge systems' concept labeled Self-Regulated Learning (SRL) hypermedia environment where knowledge consumers can fulfill their basic psychological needs of relatedness, competence, and autonomy.

Commercial SRL products produced and marketed include Digital IdeaKeeper, MetaTutor, Artemis, Knowledge Integration Environment and Web-based Inquiry Science Environment. These systems developed advanced delivery techniques. They use scaffolding to accelerate context aware learning and consumer driven non-sequential navigation. If the information / knowledge consumer identifies something of interest, he/she can hit hyperlinked words to explore the topic in more dimensions. Authors no longer need to predefine a single audience they are targeting for communication. (Azevedo, Moos, Johnson, & Chauncey, 2010) (Quintana, Zhang, & Krajcik, 2005) (Benitez, Pauleen, & Hooper, 2013) (Deci & Ryan, 2000) (Azevedo, 2005) (Azevedo, 2005)

SARA theory of signaling describes closed knowledge system text structures to aid consumer absorption. SARA concepts help guide the consumer's eyes as he/she parses through text searching for meaning and association. Rich meta-text formatting serves as guideposts, separators and highlighters for the consumer. SARA arranged text is an improvement but still further cognition enhancement and richer comprehension benefit is available through the application of the Dual Coding Theory. Dual-Coding Theory works at the neuron / synapse level of brain anatomy for supporting whole brain thinking. SARA and the text of a message excite synapses on left side of the brain. Dual-Coding Theory advocates adding a visual representation (picture, graph, illustration, diagram, etc.) that excites synapses in the right side of the brain. The visual representation should be a quality rendition that can be associated to the content of the text. This connects the right and left hemispheres of the brain to seed memories more quickly and allow memories to be retained longer. Multiple coding can provide a backup

memory when one forgets a paired memory. (Lemarie, Lorch, Jr., Eyrolle, & Virbel, 2008) (Paivio A. , 2010) (Reed, 2006) (Paivio A. , 1969)

Beyond the structure of content, the presentation layer can support meta-cognition through scaffolding panels for the User-Subjective Approach (USA) tenets of category, importance and context. Other presentation layer panels can host the non-sequential navigation system, reference material and portal perspective (Bergman, Beyth-Marom, & Nachmias, 2003) (Barreau & Nardi, 1995).

2.3.1 Dual-Coding Theory

Quality knowledge assets exploit the dual channel into human brains for higher efficiency through lower cognitive loading. This improves effectiveness through good knowledge mobilization in the consumer. The two channels into human brains are the visual and text/verbal. A quality knowledge asset would ideally represent essential concepts with both an illustration and description using either text or verbal content. Settings/venues drive context variations on the recommended representation, for instance, in a presentation the sentences spoken by the presenter should not appear on the slide but rather a summarized bullet of six words or less. This reduces the cognitive load on the audience, enabling more knowledge mobilization in them, see Figure 14. (Paivio 2010) (Mayer and Moreno 2003)

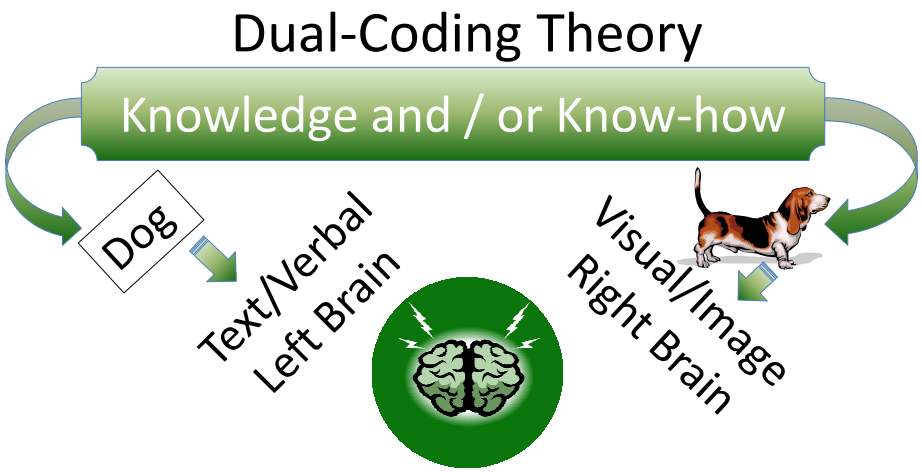

Figure 14: Illustrated Dual-Coding Theory

2.3.2 Cognitive styles and efficient mental processing

The author of quality knowledge assets needs to be aware of cognitive style preferences by knowledge consumers. Systems engineers, as well as the general population, can roughly be divided into a two by two matrix, based on where they fall on the analytic/holist dimension and where they fall on verbal/imagery dimension (Riding 1991). In the case of a mentor/mentee relationship, a journeyman should map in their mind where the provided information falls on these two continuums and ask questions to support the other end of the continuum. This allows them to prepare quality knowledge assets that support efficient mental processing by the knowledge consumer. The journeyman should optimize knowledge assets for essential processing on both channels into the consumer's brain while reducing or, optimally eliminating, incidental processing. Simultaneously, the knowledge assets and their presentation should minimize the requirement for representational holding of information used for learning. (Nguyen, Santos, Jr. and Russell 2011) (Mayer and Moreno 2003)

2.3.3 User-Subjective Approach

Knowledge management systems' developers should provide profiles for each knowledge consumer to access via a login process. The knowledge management system needs to use this user-awareness state to maintain private notes the consumer has made about knowledge assets, allow persistent subjective importance ratings, allow context re-enactment from previous visits, and allow personalized categorization of knowledge assets. Personal notes would not be shared with other users. Specific importance ratings, like one to five stars, would not be shared with other users but would be aggregated for global knowledge asset importance determination. Context from previous visits, like

color schemes and themes, would be restored and categorizations would be restored upon arrival. (Bergman, Beyth-Marom and Nachmias 2003)

2.4 Leadership and Business Literature

Engineering teams are adept at handling technical complexity but their brains experience collaborative work as a social exchange environment. Leaders can positively affect their influence with engineering teams if they are sensitized to the five social qualities their teams are experiencing. These five behavior-driving qualities are Autonomy, Relatedness, Status, Certainty, and Fairness. (Aidane, 2011) (Rock, 2011)

2.4.1 Scientific Management

Frederick Taylor's Scientific Management advocated management directing methods, the "how" work was to be done because workers were believed to be incapable of understanding physical fatigue and appropriate muscle recovery rates. To optimize productivity over a full day's work, management needed to control activities. This concept is stated pretty clearly in the first tenant of what management is to do: "They develop a science for each element of a man's work, which replaces the old rule-of-thumb method." (Taylor, 1911). Notice the focus on "each element of a man's work" where the whole of the work system is broken down into segments and linear thinking is advocated for "efficiency".

Scientific Management promoted controlling actions of workers as stated in the second tenant of what management is to do: "They scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best as he could" (Taylor, 1911). The Industrial Revolution belief was that

workers were incapable of remembering to work all day long so the third tenant promotes micro-management; what management is to do: “They heartily cooperate with the men so as to insure all of the work is being done in accordance with the principles of the science which has been developed.” Synergy between work teams was viewed as a fallacy, believing that any time a team of workers were assigned a task, less of the task would get accomplished in a day due to many of the workers not working hard. From this mental model, Scientific Management sought to breakdown the work to the point where each individual was isolated. This made it easier for management to measure the individuals’ productivity. Management would simply sum the productivity of each worker to get the day’s productivity. Note that under these conditions, 1+1 cannot equal more then 2, as is the case with synergy.

2.4.2 Theory X

Beliefs behind Theory X state about the worker: “He is by nature resistant to change”. This advocates for directing methods to effect change. Even the second proposition of Theory X says “… With respect to people, this is a process of directing their efforts …”. Linear thinking was invoked by Theory X because of its belief of workers “He is inherently self-centered, indifferent to organizational needs”, so why inform him of the causality loops driving organizational needs? (Burns, 1967) (Wren & Greenwood, 1998)

Micro-management and controlling worker’s action were primary in Theory X: “…motivating them, controlling their actions, modifying their behavior to fit the needs of the organization.”, and “Without this active intervention by management, people would be passive – even resistant – to organizational needs. Therefore, they must be persuaded,

rewarded, punished, controlled – their activities must be directed. This is management's task … in managing subordinate managers or workers." "The average man is by nature indolent – he works as little as possible" and "He lacks ambition, dislikes responsibility, prefers to be led" (Burns, 1967) (Wren & Greenwood, 1998). Theory X did not trust workers so individual isolation allowed management to more easily determine if a given worker was doing as he was told.

2.4.3 Fifth Discipline

The art and practice of the learning organization is built on the paradigm of systems thinking. Systems thinking, understanding the causality loops in work systems and the worker understanding his impact on that work system, is demonstrated to deliver more productivity through synergy (1+1=10 or more). Synergy is supported by the quote: "None of us is as smart as all of us" Japanese proverb. In the learning organization, systems' thinking is the integration of personal mastery, mental models, shared vision and team learning. Learning is enabled through flexible treatment and respect for all team members. Workers who understand the work system and desired results can focus on those results through collaborative synergy (Senge P. , 1990, 2006).

2.4.4 The 8th Habit

Voice, the 8th Habit, is leadership's opportunity to inspire knowledge-worker workforces entrusted to them, to ignite into energized, passionate, engaged, motivated, responsible problem solvers. Effective Accountability Reviews (EAR) take the 7-Habits' stewardship delegation one step further. That next step is embodied in three major parts of the EAR: "Triage Reporting" focused on results without wasting time to status

everything, Finding 3rd alternatives for collaborative synergy (not my way or your way but a better way), and clearing the path to enable empowered trust for delivery of superior results. Voice is the sweet spot where personal greatness, leadership greatness and organization greatness overlaps. The four segment of this overlapping area are EAR, Balanced Score Card (BSC), Translation and Wildly Important Goals (WIG). WIGs are aligning and sharing in visions, Translation is connecting shared visions to a tangible results focus, BSC is tracking Production(P) and Production Capability(PC), and EAR is orchestrating Knowledge-worker teams. The P:PC balance on the BSC displays the effects of results focus i.e. productivity and enabled learning. Knowledge building and skills development enhance future productivity.

2.4.5 Psychology HDBI, Myers-Briggs & DAAE

The Herrmann Brain Dominance Indicator (HDBI) evaluates a leaders' thinking preference in dimensions of Analytical (Blue), Process (Green), People (Red) and Strategy (Yellow). Managers with a Process (Green) dominate thinking style support and promote traditional and conservative methods (Herrmann, 1996) reminiscent of Talyorism. Knowledge-worker workforces thrive and are more likely to deliver superior results under the leadership of a Strategy (Yellow) thinking style leader who prefers integrative mental modes (Herrmann, 1996) reminiscent of Peter Senge's Systems' Thinking causality loops (Senge P. , 1990)

Myers-Briggs is a personality type indicator with four characteristic preference pairs. A Keirsey Temperament Sorter test can characterize participants in these dimensional pairs. Each pair represents a continuum and evaluation places an individual on those continuums. The four pairs are Extroversion to Introversion, Sensing to

Intuitive, Thinking to Feeling, and finally Perceiving to Judging (Keirsey & Bates, 1978) (Keirsey, 1998)

Social styles can be assessed using the Driver-Analytical-Amiable-Expressive (DAAE) evaluation model. Drivers can be thought of as the type A personality who are insistent on progress and action oriented. The thinking oriented Analytical social types favor details and bottoms-up approach. Amiable is the characterization of the go-along to get-along type of teammate who is relationship oriented. The Expressive social style is displayed by teammates who are often talkative, use excessive hand gestures, prefer bright colors and bold representations. They are intuition Oriented. (Merrill & Reid, 1981)

2.4.6 7-Habits' Stewardship Delegation

The 7-Habits stewardship delegation is the process of focusing on clear "what" results but not "how". Delegates emotionally sign the contract to take responsibility for superior results and judge themselves in a periodic review with their leader. It is important that the leader does not judge the delegates results or direct methods. The leader must empower the delegate with trust for ownership of the stewardship. The delegate is allowed, and encouraged, to ask for the leader's help. When the leader has time, he/she should take direction from the delegate and help achieve the desired results, especially in clearing the path requests. This delegation style of the second habit "Begin with the end in mind" (Covey S. R., 1989) supports alignment of expectations. Learning is enabled by leaders' support of double bottom line accounting on the balanced score card where Production (P) and Production Capability (PC) are balanced. The production capability (PC) is augmented through the seventh habit "Sharpen the Saw" (Covey S. R.,

1989). Knowledge-workers want to do a good job. Leaders treating them with respect and allowing their best work supports delivery of superior results through collaboration, the sixth habit "Synergize". (Covey S. R., 1989), This leadership conduct garners high retention rates.

2.4.7 GAO HC Strategy Plan

David McClure's 2001 congressional testimony influenced congress to change the style of management they supported for knowledge-worker workforces, stating "the problem is a long-standing lack of effective leadership" (McClure, 2001). This agreed with W. Edwards Deming's 1990 statement:

"The prevailing system of management has destroyed our people … The job of management in education, industry and government should be the optimization of a system … Peter Senge's book The Fifth Discipline, from which I've learned much, is a good place to begin" (Senge P. , 1990).

The GAO states "Organizations that effectively embrace the principles of modern human capital management realize that as the value of their people increases, so does their performance capacity. They also realize that investing in and enhancing the value of employees is a win-win goal for employers and employees alike" (GAO, 2004). McClure's ninth and last recommendation "Build in reliability, clarity, and transparency" (McClure, 2001), supports developing a shared vision with knowledge-worker workforces. All stakeholders clearly understand and support goals being sought for achievement. The government shall harvest collaborative synergy through "improved transfer of knowledge among GAO employees" (GAO, 2004) and Key Effort #9: "Knowledge-sharing and knowledge-transfer strategy" (GAO, 2004). Key Effort #7:

"Identify methods to improve staff development and utilization" (GAO, 2004) and Key Effort #8: "Design and deliver a training and development program that focuses on GAO's core competencies and creates a unified learning architecture" (GAO, 2004) enables learning on the behalf of knowledge-worker workforces. McClure's sixth recommendations "Promote work/life balance" (McClure, 2001) and GAO's Key Effort #10: "Promote an environment that is fair and unbiased, and values opportunity and inclusiveness" (GAO, 2004) for "Improved family-friendly policies that help staff balance work and family lives" (GAO, 2004) seem aligned. This flexible treatment supports McClure's recommendation #2 "Allow for flexibility in the treatment of individuals and occupations" (McClure, 2001).

2.4.8 Leadership Perspective

True management is the controlling of things (Covey S. R., 1989) (Covey S. R., 2004). True managers analyze objects, determine required changes and change things. The focus is on process and the minimization of variation to limit risk. Managers' time horizon of concern is typically short-term (Herrmann, 1996). To accomplish management preferences when managers are assigned a workforce, workers are treated as things by directing methods, micromanagement, linear thinking, individual isolation and controlling actions. Whole person employees become nothing more than "hands" (Drucker, 1954). It is postulated that:

True managers should never be entrusted with knowledge-worker workforces!

Knowledge-workers should be led, not managed. Knowledge-worker workforces typically have a higher level of education and higher level of competitive compensation. It is counter-productive to pay for the whole knowledge-worker and reduce their value by

using them as “hands”. True leaders engage knowledge-workers to co-develop shared visions so the whole employee can help focus on and deliver superior results. This requires understanding of the systemic causality loops, systems thinking, and the employee’s impact on that work system. Affordability is not supported by having a manager and a knowledge-worker assigned to every task, the true leader enables productivity through empowering the knowledge-worker with trust and stewardship over methods. True leaders understand the value of balancing the P : PC ratio and therefore advocate for enabled learning. They understand this “Production Capability” will provide the enterprise with more Production in the future. Respect for workers is a hallmark of true leadership, as they understand that the workforce is an enterprise’s most valuable asset. Flexible treatment of this most valuable asset drives job satisfaction and retention as well as an engaged and motivated workforce capable of producing innovative and creative solutions to problems, which generate business value. True leaders optimize synergy with collaborative environments. Knowledge-workers can learn from each other and avoid making the enterprise pay for labor to “re-invent the wheel” because if they were isolated, they would not know the wheel had been invented.

2.4.8.1 Directing Methods

A key tenant of Scientific Management was strict demarcation separating “work” and “planning work” tasks into assignments for different employees. There was a belief that those who were suited to do the work were not mentally capable of planning tasks to scientific standards. Theory X echoed the belief that manual labor workers were inferior intellectually and indolent (lazy). Therefore, management must direct their efforts on a continual basis, i.e. supervisor, “this is a process of directing their efforts, motivating

them" (Burns, 1967). Worker initiative muscles atrophied because supervisors keep workers operating at the lowest level of initiative/ empowerment. Stephen Covey's continuum of 7-Levels of initiative calls this lowest level "wait until told" (Covey S. R., 2004). Frederic Taylor, talking about management's assignment, said "They develop a science for each element of a man's work, which replaces the old rule-of-thumb method" (Taylor, 1911). An analogous measure in the 21st century is the number of written guidance rules on "how" employees are to do their job, instead of explaining the strategy and "what" needs to be done and "why".

2.4.8.2 Micro Management

Scientific Management, talking about management responsibility, states "They heartily cooperate with the men so as to insure all of the work being done in accordance with the principles of the science which has been developed" (Taylor, 1911). Theory X refers to the man (manual worker) as "he works as little as possible", and "he lacks ambition, dislikes responsibility, prefers to be led" (Burns, 1967). An analogous measure in the 21st century is the number of labor hours committed to tracking, recording and analyzing task specific activities of workers so as to ensure work is being done in accordance with policy.

2.4.8.3 Linear Thinking

Scientific Management believed that teaming men up would cause the aggregate delivered work to decrease to less than work delivered by a worker in isolation. The perspective's philosophy was that maximum work product came from workers focusing on as few tasks as possible, ideally one "time and motion" per worker (Taylor, 1911). This breaking of the work apart, into its constituent parts (Burns, 1967) (Wren &

Greenwood, 1998), generated short term (years) of positive output productivity to the detriment of long-term productivity. Long term detriment was due to a loss of agility, worker psyche damage, cultural divisiveness, and labor disputes in terms of strikes, slowdowns, and malicious obedience. A key driver to the loss of agility was due to the workers' inability to adapt to new technology and other changes because this linear thinking did not allow them to understand their impact on the systemic causality loops. Several generations lost the agilely to adjust effectively to change due to this blindness (Drucker, 1954) or learning disability (Senge P. , 1990, 2006). An analogous measure in the 21st Century is a count of the work instructions provided without causality loop situational awareness.

2.4.8.4 Individual Isolation

Scientific Management states a desire for management to be equally assigned to segments of work to ensure workers are following the scientific method designed for them. It was easier for management to discern the productivity of an individual worker if they were isolated from comingling results with other workers. This was designed to make the workers work harder and did produce short-term efficiency gains. Theory X amplified the desire to isolate workers so they could be controlled better. An analogous measure in the 21st century of this isolation work is "thrown over the fence" in terms of the number of assignments management expects worker's to perform in a vacuum instead of collaboratively.

2.4.8.5 Controlling actions

Theory X states about workers "They must be therefore persuaded, rewarded, punished, controlled – their activities must be directed. This is management's task … in

managing subordinate managers or workers" (Burns, 1967) (Wren & Greenwood, 1998). Scientific Management states about management duties: "They scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best as he could." (Taylor, 1911). Taylor's observation was that workers could not understand efficiencies from science. Taylorism believed management, who could understand the science, must control workers' actions. An analogous measure in the 21st would be the number of command media directives that specify "how" workers are to show their work. This way management can identify errors and specify corrections.

2.4.8.6 Shared Vision

Leaders reap more productivity form knowledge-worker workforces when they are included in the development of strategy and objectives that make up shared visions (Senge P. , 1990, 2006). Mission statements and line of sight objectives "handed down" without involvement from workers have a difficult time gaining tangible traction toward knowledge-worker productivity (Covey S. R., The 8th Habit, 2004). Knowledge-workers use their whole brain in differing degrees for different tasks but the shared vision conduct of leaders stimulates the right hemisphere (creative side) and the upper portion (cerebral neocortex). These visionary integrative elements clarify the feedback paths enabling knowledge-workers to engage and align energetically with common goals. (Herrmann, 1996) McClure's ninth recommendation "Build in reliability, clarity, and transparency" (McClure, 2001), supports developing a shared vision with knowledge-worker workforces. All stakeholders are enabled to clearly understand and support the goals that

are being sought for achievement. An analogous measure in the 21st century for shared vision is the number of strategic goals developed in concert with knowledge-workers.

2.4.8.7 Results Focus

The second-habit from 7-Habits "Begin with the end in mind" is a direct articulation of results focus, along with clear agreement of the "what" in stewardship delegation (Covey S. R., 1989). The Fifth Discipline concept advocates that results focus must be at the system of work level instead of optimizing any local linear segment of the work (Senge, Kleiner, Roberts, Ross, & Smith, 1994) (Senge P. , 1990, 2006). When knowledge-workers understand the work system they are operating in, they can more effectively evaluate when their product is "good enough" because any better quality in this segment would not be utilized in the remainder of the system. It avoids "gold plating" or re-designing a wheel for 3% gain but at a 100% cost adder. An analogous measure in the 21st Century for Results Focus is the number of assignments leaders convey to knowledge-workers with "what" definitions only, leaving "how" up to the delegate.

2.4.8.8 Systems Thinking

Peter Senge advocates for the integrative thinking embodied in work-system causality loops where the concept of systems thinking builds a learning organization out of personal mastery, shared vision, mental models and team learning (Senge P. , 1990, 2006). Psychology research shows knowledge-workers have more job satisfaction, take on more responsibility, deliver superior results and are retained when they are respected and trusted to understand the systems thinking requirements of their work (Keirsey &

Bates, 1978) (Keirsey, 1998) (Herrmann, 1996) (Merrill & Reid, 1981). An analogous measure in the 21st Century for Systems Thinking is the number of assignments leaders convey to knowledge-workers with transparent explanations of "why".

2.4.8.9 Empowering Trust

Tom Peters discovered in his research on IBM in 1982, that trust is the single most powerful leadership conduct to engage and motivate knowledge-workers. Just because 8% of knowledge-workers will abuse this trust is no reason to discard the 92% value (Peters & Waterman, Jr., 1982). Business cultures steeped in industrial revolution management styles, such as was the case for the United States government in 2001, find that knowledge-workers' initiative muscles have atrophied. When the paradigm shift to information age leadership styles begin to occur, leaders will find that knowledge-workers will need to exercise these initiative muscles some before they can be effectively applied to business value creation (Covey S. R., 2004). Psychology research shows that knowledge-workers deliver more and better results when their mental preferences are understood and applied (Keirsey & Bates, 1978) (Keirsey, 1998) (Merrill & Reid, 1981). Leaders who are sensitive to these preferences find that trusting knowledge-workers, who are allowed to work in ways they prefer, is easy and reliable. Leaders who empower knowledge-workers with clear understandings of the "what" and trust knowledge-workers to figure out the "how", are often amazed by the creative and innovative solutions delivered to the enterprise (Covey S. R., 1989). An analogous measure in the 21st Century for Empowering Trust is the number of assignments leaders convey to knowledge-workers where knowledge workers' education and experience is depended upon for "how" deliverable are accomplished.

2.4.8.10 Enabled Learning

The Fifth Discipline is all about building a learning organization through systemic understanding (Senge P. , 1990). Both 7-Habits and the 8th Habit advocate a Production: Production Capability balance where Production Capability is enabled learning (Covey S. R., 1989) (Covey S. R., 2004). The GAO Human Capital Strategy Plan Key Effort #8 is "Design and deliver a training and development program that focuses on GAO's core competencies and creates a unified leaning architecture" (GAO, 2004). An analogous measure in the 21st Century for Enabled Learning is the number of diverse learning opportunities supported by leadership.

2.4.8.11 Flexible Treatment

Psychology research has determined that knowledge-workers are more productive when leaders play to their strengths and preferences (Keirsey & Bates, 1978) (Keirsey, 1998). Knowledge-workers' treatment is fair when they are treated differently. Mental models are filters through which knowledge-workers see and think about the world (Senge P. , 1990, 2006). Leaders who can afford knowledge-workers latitude and flexibility to optimize results production, based on their mental models, will enable additional knowledge-worker productivity. The GAO Key Effort #10: "Promote an environment that is fair and unbiased, and values opportunity and inclusiveness" (GAO, 2004) for "Improved family-friendly policies that help staff balance work and family lives" (GAO, 2004) supports flexibility. This flexible treatment supports McClure's recommendation #2 "Allow for flexibility in the treatment of individuals and occupations" (McClure, 2001). The GAO clearly advocates for flexible treatment as an

enabler of knowledge-worker productivity. An analogous measure in the 21st Century for this Flexible Treatment is the number of approved deviations from established norms, such as telecommuting, flexible start and stop work hours and workweeks.

2.4.8.12 Collaborative Synergy

The GAO positions of "improved transfer of knowledge among GAO employees" (GAO, 2004) and Key Effort #9: "Knowledge-sharing and knowledge-transfer strategy" (GAO, 2004), show a desire to drive out isolation and encourage knowledge-workers to collaborate for synergy. The 7-Habits' habit # 6 is "Synergize" (Covey S. R., 1989) and the 8th Habit's collegial concept of Mutual Accountability and teamwork "we are all in this together" promotes helping each other out and find "3rd Alternatives" through energetic, synergistic problem solving (Covey S. R., The 8th Habit, 2004). The Fifth Discipline is not the learning person but the learning organization where teams must cooperatively work the system-of-work for collaborative and synergistic optimization of value delivery to the enterprise. Psychology research indicates a natural human need for association and the desire to work with others. A Pair of humans do more work together than the sum of two individuals' work efforts added together (Herrmann, 1996) (Merrill & Reid, 1981). An analogous measure in the 21st Century for this Collaborative Synergy is the number of team-based incentives for reward and recognition.

2.5 Summary: Literature Review

Observations from this set of literature, from the systems engineering, knowledge management, psychology and leadership/business domains, can be combined to guide future enterprises toward faster learning and improved enterprise productivity.

Leaders should conduct themselves in accordance with best-known practices to energize systems engineers and stakeholders who are the women and men knowledge-workers of the 21st century, see Figure 2. Whole-brain employees can be more effective when leadership and enterprises support teamwork in collaborative environments. These collaborative environments have a place in information/knowledge intensive systems engineering activities across the full Systems Development Life Cycle. Quality Information Technology-based collaborative environments enact better knowledge management when they focus on the teams who need and use knowledge, rather than the knowledge itself. Advanced techniques are emerging. A few of these techniques include concurrent metadata display in scaffolding around content, non-linear navigation using hyper media environments, Natural Language Processing semantic search/reverse search, and Dual-Coding. The structure of knowledge assets within collaborative environments affects knowledge transfer. Cultural and systemic paradigm shifts toward improved productivity are known; now the hard work of change is before us.

CHAPTER 3. RESEARCH METHODOLOGY

A complementary dual-posttest-only control-group true experiment was selected to avoid pre-test confounding (Creswell, 2009). Random selection and unbiased grouping allows this popular methodology to produce solid, statistically significant results. This original true experiment produced results with thirty QKA data points and thirty BSA data points. This reaches the sampling magic number for actionable statements of causality. (Salkind, 2009) (Anderson & Whitcomb, 2007) True experiments with thirty data points of treatment and thirty data points of non-treatment can be expected to have their t-distributions approach normal distributions (Anderson & Whitcomb, 2007).

A data collection instrument with over three hundred pages of content was produced. It referenced a common technical superset knowledge base. Three mutually exclusive subsets were segregated and the exhaustive elements in all three subsets were prepared in both MIRRoR Knowledge QKA form and traditional BSA form. Consider Knowledge Base 1 (KB1) as the treatment QKA content for a "Group A" and Knowledge Base 2 (KB2) as control content in BSA form. In complementary pair fashion, consider Knowledge Base 2 (KB2) as the treatment QKA content for a "Group B" and Knowledge Base 1 (KB1) as control content in BSA form. The third mutually exclusive subset of the technical superset knowledge base, termed Knowledge Base 3 (KB3), was used as a QKA Tutorial for both "Group A" and "Group B", to familiarize them with the MIRRoR knowledge QKA concept, presentation metadata and non-sequential controls.

The original true experiment of this investigation constructed a knowledge base in a 3-way MIRRoR knowledge QKA scheme. The QKA scheme versions of KB1 and KB2

were compared to Book Style Asset (BSA) scheme versions of the same two knowledge bases, KB1 and KB2. The investigation collected raw data with demographic information. Post experiment analysis used the demographic information to analyze the data in two separate subsets:

- Systems engineers Vs. stakeholders
- Women Vs. men

The investigation looked for high confidence that learning of dynamic knowledge was better from QKAs than from BSAs, simply due to the structure and presentation of the information. The evaluation probed the human act of thinking and the residue resulting as tacit knowledge mobilized from information consumption.

A sample of test-subjects was randomly offered an opportunity to participate in the experiment. Thirty participants accepted the offer and executed the process to generate data. Posttest evaluations were used to measure residue from the human act of thinking. All thirty test-subjects explored subsets of the common knowledge base with mutually exclusive MIRRoR knowledge QKA and traditional BSA. Demographics show that seventeen women and thirteen men were included in the sample, as well as fifteen systems engineers and fifteen stakeholders.

3.1 Investigational elements

3.1.1 3-way MIRRoR knowledge Quality Knowledge Asset

Organization of the 3-way MIRRoR knowledge QKA starts at the top representation, the bulleted presentation style. This is the first representation presented in the open knowledge self-regulated learning hyper-media environment, see example in Figure 15. Based on mentoring advice the author received and through experience, the

bulleted presentations should contain approximately six bullets or fewer and each bullet should have approximately six words or fewer, referred to as the 6x6 rule. Miller's magical number, 7 +/- 2, chunks of information that the average person can hold in active memory, generally supports this advice. It could be the 7x7 rule or the "rule of 7" but the concept is significant summarization for a terse representation. Bullets should be sentence fragments that do not wrap to a second line and should generally not end with punctuation. Simultaneous display of textual and associating illustrative content, the DCT concept, will minimize representational holding memory required to enable a wider audience to understand in an expedited manner. (Mayer & Moreno, 2003) (Miller, 1956)

The knowledge base exploration is enabled for non-linear exploration through hypermedia links. The consumer can decide when they meta-cognitively and cognitively understand the SEKA sufficiently to move on to another SEKA. Meta-cognition is supported by scaffolding around the SEKA content, displaying user-subjective approach meta-data about the content, consumer-centric architectural orientation information, navigational controls and use-frequency analysis. The scaffolding orients the consumer with information about the information to help "thinking about the thought process" for accelerated cognition. (Shelby Jr., Sarkani, & Mazzuchi, 2012)

Since the consumer has the power to decide when they understand the SEKA sufficiently to move to another SEKA, they get full credit for their education and experience. Expert community-member consumers with deep domain experience and educational background knowledge can stay at the bullet level and quickly consume all the SEKA in a given set, with full tacit knowledge mobilization, to know what is going on with the project. Novice community-member consumers can leverage the synopsis

and may need the expository to more fully mobilize their tacit knowledge. In either case, the project community can learn faster by each member only taking the minimum time they require to comprehend the SEKA.

Figure 15: SEKA Top Level QKA , Bulleted Presentation Style

The middle level of a 3-way MIRRoR knowledge QKA, 2) Synopsis summary Style, see Figure 16, should distill the main points down to a terse representation. Text should use complete sentences, punctuation and wrap as margins dictate. The text should have a balance of embedded image(s) to amplify the textual meaning that enhances tacit memory mobilization, anchors right brain/left brain synapses linking, enhances comprehension and builds lasting memories.

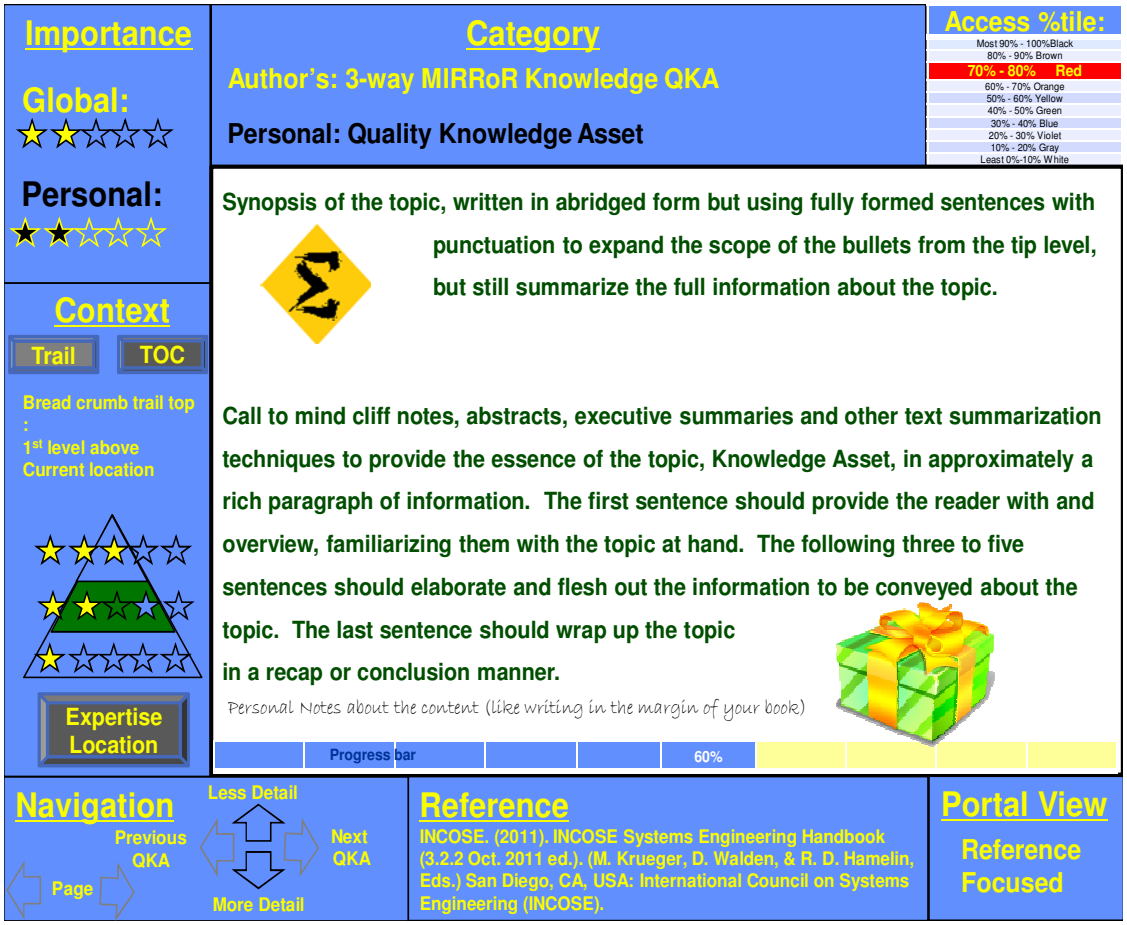

Figure 16: SEKA Middle Level QKA, Synopsis Summary Style

The bottom level of a QKA, 3) Expository white-paper style, see figure 17 below, is the long, detailed explanation of the SEKA, still using a balance of images to amplify the text's key points. Full sentences, punctuation, information functions and Textual

Architectural Model (TAM) signals are appropriate to aid the consumer with their exploration.

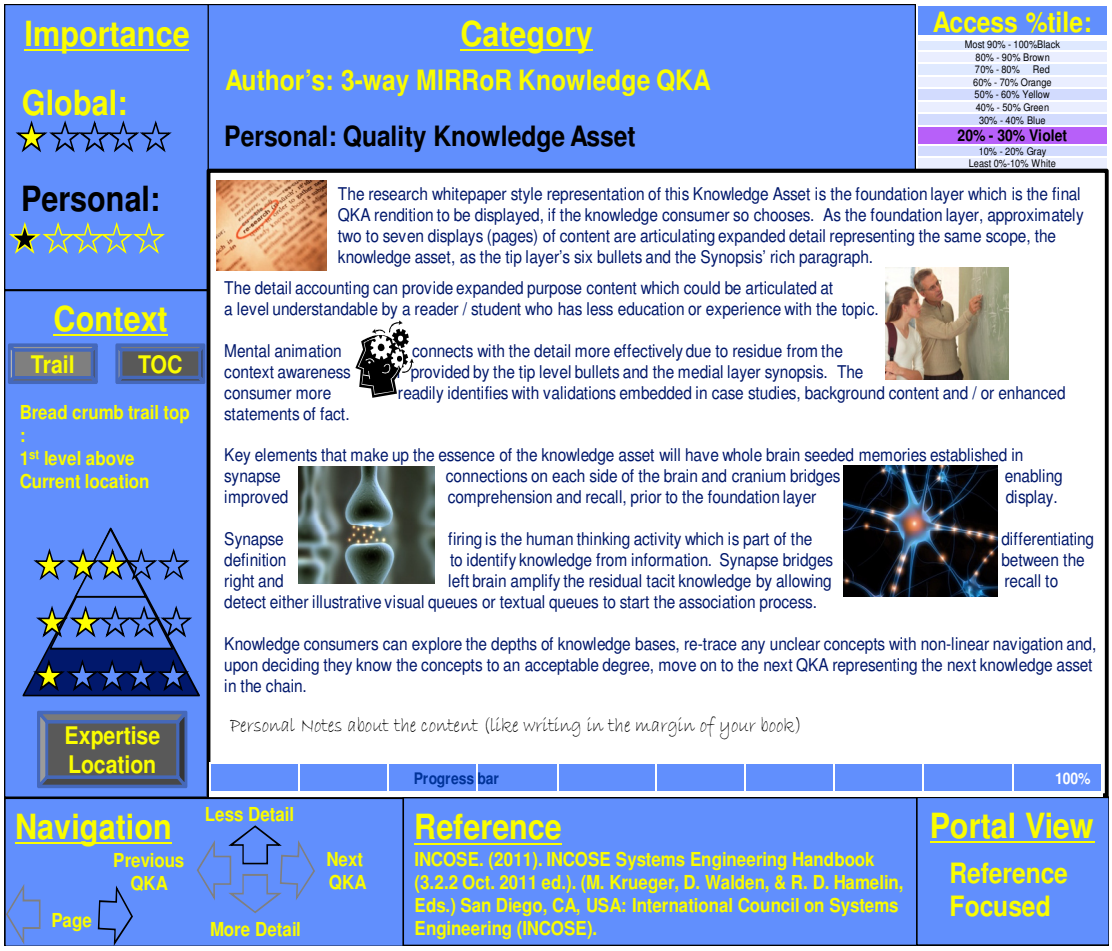

Figure 17: SEKA Bottom Level QKA, Expository White-Paper Style

Font color and context triangle coloration were used to augment association for the level of QKA being explored. A consistent base color of blue was used to signify the bottom layer of information while green and red signified middle and top layers, respectively. This scheme allows accelerated meta-cognition to determine where in the information stack the consumer is exploring. Consistency in color renditions and limiting the variation to three colors stays under the five-variation limit. Prior research shows

interpretation complexity retards the value equally or more than the highlighting associative gain when five or more variations are used. (Hershberger & Terry, 1965)

Meta-data in the scaffolding drives meta-cognition. In the upper right corner, there is a ten-bin analysis of access percentile. The ten bins are highlighted with colors following the electrical engineering resistor color code standard (Bird, 2010). To the left, the first of the user-subjective approach concepts, "Category" displays the author's and the consumer's category name for this content. Continuing to the left, the next user-subjective approach concept "Importance" displays the community's average importance and consumer's individual importance in "Star-rating" form. Below is the third and final user-subjective approach concept of "Context" displaying a levels triangle to orient the consumer to which part of the SEKA QKA is being viewed, with super imposed importance rating for all three levels. In addition, the consumer can choose breadcrumb trails or Table of Contents (TOC) context information. Below context is a scaffolding panel with non-linear navigation buttons. To the right, Reference information is displayed for further research and / or study. The final scaffolding piece is to the right, "Portal": displays the consumer-centric architecture portal through which this SEKA is being viewed. (Shelby, Jr., Sarkani, & Mazzuchi, 2012)

3.1.2 Book Style Assets (BSA)

A traditional construct, termed a Book Style Asset (BSA), typically follows the Textual Architectural Model (TAM). It is the familiar linear text found in books and journals. An author selects an audience and logically develops and organizes content for them. If the author is writing for a novice, the experienced professional will be wasting a lot of time retreading ground that is not efficiently mobilizing new tacit knowledge. If

the author is writing for the experienced professionals, a novice consumer may waste a lot of time being confused and not be able to comprehend the essence of the material.

The BSA typically uses signaling theory's information functions to set the consumer's expectations for overviews, introductions, background, discussion, summary and/or conclusion. Content availability is typically supported by demarcation, organization and labeling. Relevance is dependent on consumer's background knowledge, motivation and goal. Accessibility relies upon the ease with which the consumer can use the information. (Lemarie, Lorch, Jr., Eyrolle, & Virbel, 2008)

3.2 Selection and Analysis of Hypothesis

Cognitive sciences provide that learning is simply thinking and doing. When some people learn more than others, it is not because they are doing something different. They are still "thinking and doing" but the difference is the depth of awareness (Senge P. , 2004). Meta-data driven meta-cognition deepens awareness; therefore, the Hypothesis, H_1, is "A knowledge base of SEKA in QKA construct can be explored by the women and men knowledge-workers, who make up a project community of Systems Engineers and stakeholders, with better knowledge transfer than a knowledge base of SEKA in BSA construct".

The null hypothesis, given H_1, is "A knowledge base of SEKA in QKA construct can NOT be explored by the women and men knowledge-workers, who make up a project community of Systems Engineers and stakeholders, with better knowledge transfer than a knowledge base of SEKA in BSA construct".

3.3 Reliability and Validity

Random selection of the experimental population and unbiased group assignment method produced samples with Group A being considered capability equivalent to Group B for experimental purposes. Group A explored KB1 in the QKA construct and KB2 in BSA construct while Group B explored KB2 in QKA construct and KB1 in BSA construct. This approach supported reliability by ensuring selected SEKA content did not bias the results. Validity was supported by Group A functioning as a control group for KB2 and Group B for KB1.

3.4 Context

Environments mimicking common virtual knowledge worker settings were recreated for execution of the experiment. The test-subject and the investigator agreed to a mutually convenient time and place for the one-on-one session. The environments were reasonably free of distractions, allowing the test-subject to focus and concentrate on the material.

Knowledge workers are expected to have varying levels of education and experience but there exists an underlying tacit knowledge of operating in a virtual knowledge worker environment. The use of technology in general, computer/OS/mouse, collaboration software, and phone/teleconference are all examples of familiarity expected of the average virtual knowledge worker.

Valid claims of causation must consider context and the underlying complexity (Mumford & Anjum, Effects of context, 2012). If the test-subjects were not initiated in the use of technology, then the background conditions would have limited the conversion

from information into knowledge. Similarly, if the test-subjects' environments were noisy or distracting then defocused attention would have diminished the effect.

3.5 Approach

This experiment was an original experiment. It used a novel investigational instrument and a dual post-test only modified true experiment format. The investigational instrument was originated based on principles from psychology, knowledge management and systems engineering. A given SEKA was represented three ways: bulleted presentation style, synopsis summary style and expository white paper style. All three representations of the SEKA considered the human factors theory of Dual-Coding where imagery and text reinforce the key point(s). Cognitive effectiveness is enhanced through a balance of analytic and holist perspectives to address cognitive style preferences across a wider audience. Information Technology was leveraged to allow non-linear knowledge base navigation during the user's exploration. The knowledge transfer was compared between QKA method and BSA method to investigate efficacy.

The experiment was conducted independently for each test subject. The test subject was provided with an introduction to the QKA concept and they provided demographic information. Demographic information included Job Level (entry, mid-career, senior), work location (State: 3 prime locations), male/female (M/F), assigned job description (12 possibilities including "other"), education level (highest degree: HS, BS, MS, Ph.D), and experience level (number of years:0→5, 5→15, 15+). When introduction and demographics completed, the test subject was given a tutorial primer of QKA's non-linear exploration technique. They were then asked to explore a systems

engineering body of knowledge for ten minutes using the QKA method followed by answering ten Certified Systems Engineering Professional (CSEP) style test questions. Subsequently, test subjects were asked to explore a second, mutually exclusive, systems engineering body of knowledge using the BSA concept for ten minutes and answering ten CSEP style test questions. The test subject's time commitment was targeted at one hour.

The design is a treatment→post-test schema where:

- H_{1a} test team R_A------$X_{QKA(A)}$-----O------ $X_{BSA(A)}$-----O
- H_{1b} test team R_B------$X_{QKA(B)}$-----O------ $X_{BSA(B)}$ -----O

Group A (R_A) experienced the treatment for KB1 ($X_{QKA(A)}$) then answered KB1 post-test questions (O). Following, Group A experienced non-treatement for KB2 ($X_{BSA(A)}$) and took the KB2 post-test (O).

Group B (R_B) experienced the treatment for KB2 ($X_{QKA(B)}$) then answered KB2 post-test questions (O). Following, Group B experienced non-treatement for KB1 ($X_{BSA(B)}$) and took the KB1 post-test (O).

A graphical representation, see figure18, of the experimental method depicts the progression in stepwise fashion through the process.

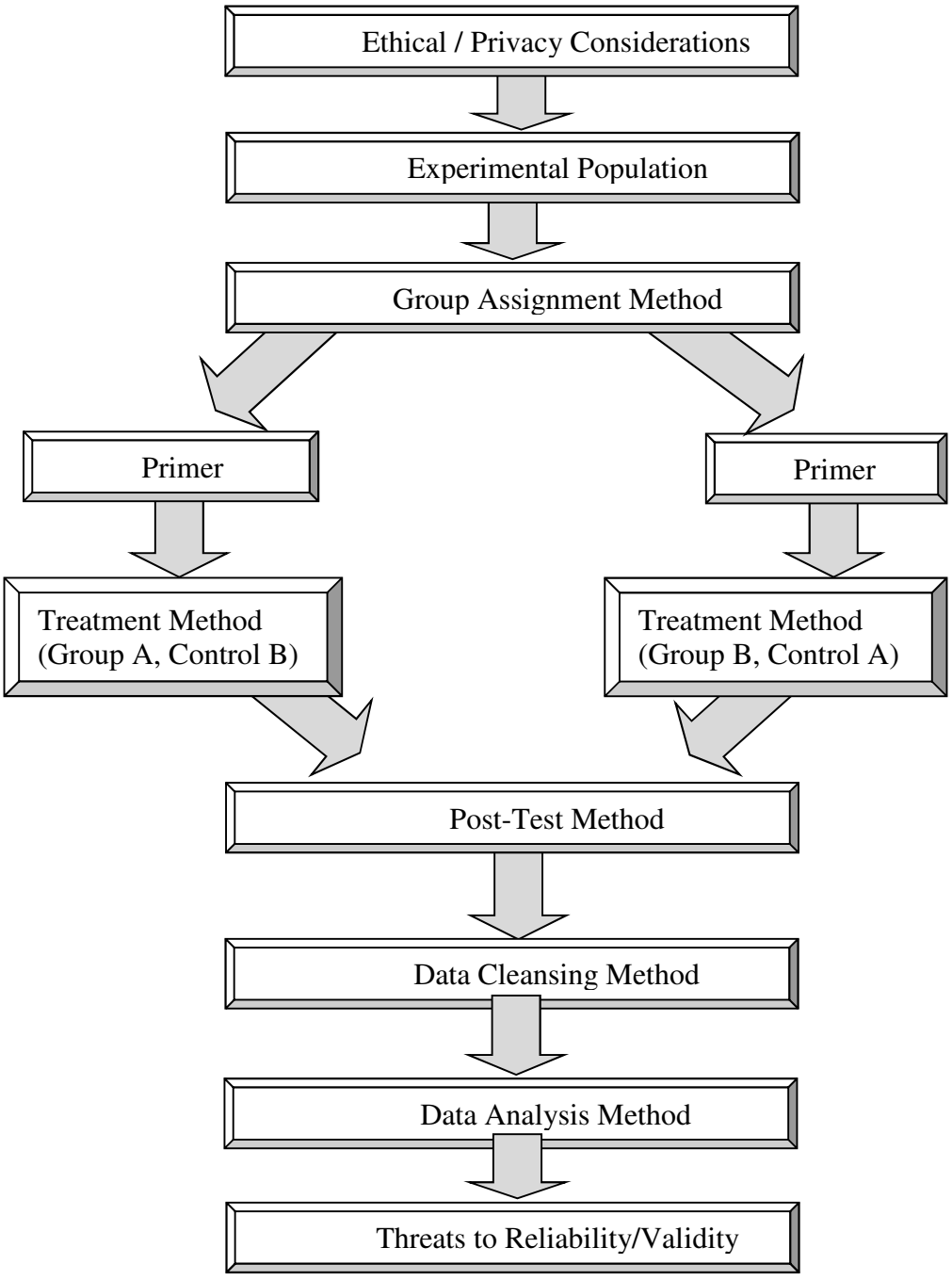

Figure 18: Research Methodology Illustration

3.5.1 Ethical/Privacy Considerations

No personal or private information was requested beyond the basic demographic information. Most of this studies demographic information is work related or intuitively obvious through observation. The raw and cleansed data maintained information referencing a specific individual, but the identity was abstracted away through a numbering system. No association to the identity of participants was reported, or made available outside of the investigation team. Results reporting focused on conveying knowledge in the form of aggregate information. The QKA and BSA constructs fell under compare and contrast scrutiny for knowledge transfer efficiency and effectiveness instead of any compare and contrast analysis of participants' skills, aptitudes or abilities.

3.5.2 Experimental Population

Randomly selected test-subjects produced a wide demographic. It was a diverse representative sample of project community members. Participants represented United States geographic diversity from all continental United States time zones. Test-subjects varied in educational background from Ph.D. to high school education. There was a large number of males and females in each group. Each group had significant participation by both stakeholders and systems engineers.

3.5.3 Group Assignment Method

The investigator made test-subjects aware of the study and invited them to participate. Those who accepted became the pool of participants. Assignment to groups used a ping-pong approach as each experimental session was executed. The first test-subject joining the investigator for experiment execution was assigned to Group-A and

the second was assigned to Group-B. This A-B cycle continued throughout the first quarter of 2013 experiment execution time window until thirty test-subjects had executed their way through the investigational material.

3.5.4 Primer

The third knowledge base, KB3, was used with both group A and B to orient them to the QKA construct and exploration method prior to the timed knowledge transfer trials.

3.5.5 Treatment Method

Two mutually exclusive knowledge bases, KB1 and KB2, were derived from the systems engineering body of knowledge. A treatment version in QKA form and a non-treatment version in BSA form was created for both KB1 and KB2. "Group A" and "Group B" had a separate file that contained their QKA and BSA representation of the systems engineering knowledge bases to explore. Each knowledge base was explored for ten minutes.

3.5.6 Post-Test Method

The same ten, CSEP like, exam questions were asked for each of the two knowledge bases, regardless of the QKA or BSA construct for a given group. Correct answers are represented in the data as a "1" and a "0" represents incorrect answers.

3.5.7 Threats to Reliability/Validity

Test-subjects were not tested for color blindness. The male population experiences approximately an 8% affliction rate while the female population is much less

at under 1%. Missing one meta-data cue would have been minor and the probability of having more than one afflicted test-subject was low (Thogmartin, 2010).

Content bias could skew the results if one knowledge base was simpler to understand than the other. A complementary dual posttest approach supplied balancing factors and statistical analysis for content bias. If one knowledge base had been significantly easier, then a consistent shift in the posttest scores would have shown the bias.

Influence of the first reading could have provided a threat to the second reading. To combat this possibility, all three knowledge bases were built with mutually exclusive content. The second reading covered completely different material than the first reading.

3.6 Summary: Methodology

The experimental method, leveraging a true experiment design, was the chosen model for this investigative study to compare and contrast the QKA construct and the BSA construct. Key criteria are the systems creation project community's tacit knowledge mobilization, comprehension and memory retention sufficient to answer the questions after the ten-minute exploration of a SEKA knowledge base.

CHAPTER 4. DATA RESULTS, ANALYSIS AND FINDINGS

4.1 Overview: Data

Experimental data was first analyzed for effects on systems engineers versus project stakeholders. Systems engineers were anticipated to be more knowledgeable in the systems engineering domain than project stakeholders. This experiment looked for the delta between the knowledge residue deposited by the QKA treatment and the traditional BSA, not the absolute knowledge by individual test subjects.

Demographic data allowed the separation of men and women to investigate any bias based on gender. Additionally, the demographics allowed separation by role: systems engineer or stakeholder.

4.2 Raw Results

4.2.1 All Posttest Scores as Collected

Results listed in the order of experiment execution. Posttest results are recorded as the correct number of answers out of a possible 10. Table 1 shows the data by test-subject, Group, QKA treatment and non-treatment BSA.

Table 1: Table of the number of correct answers by test subject and group

	All			
	Group A		Group B	
Test Subject #	QKA (a)	BSA (a)	QKA (b)	BSA (b)
1	9	8	10	7
2	10	5	10	6
3	10	8	10	7
4	9	9	10	6
5	10	9	10	6
6	10	6	10	8
7	10	8	8	7
8	10	9	9	8
9	9	8	10	6
10	10	6	10	10
11	10	4	10	7
12	9	9	10	7
13	10	8	10	6
14	7	6	10	6
15	10	8	9	7
Ave	9.53	7.40	9.73	6.93

4.2.2 Dataset Differentiation Investigation

Combining the QKA arrays from both groups and BSA arrays from both groups provides raw data to determine if differentiation is sufficient between the datasets to support causality. The confidence interval analysis is shown in Figure 19.

	QKA	BSA
Average	*9.63*	*7.17*
Std Dev	0.72	1.37
sample Size	30.00	30.00
Confidence Coefficient for 99%	2.58	2.58
Margin of Error	0.34	0.64
Upper bound	9.97	7.81
Lower bound	9.30	6.52
Max	10.00	10.00
Min	7.00	4.00
Range	3.00	6.00
Alpha Significance Level	0.01	0.01
Conf.norm	0.34	0.64

Figure 19: Dataset Differentiation Analysis

Based on the collected sample dataset for BSA, ninety-nine percent confidence analysis shows the real population average would fall in the range from 6.52 to 7.81. Similarly, the QKA real population average would fall between 9.30 and 9.97.

4.3 Systems engineers Vs. stakeholders Results

4.3.1 Demographic Results by Systems Engineers and Stakeholders

Demographic information allowed separation of the data, see Table 2, by systems engineers and stakeholders.

Table 2: Data separated by Systems Engineers and Stakeholders

	Systems Engineers			
	Group A		Group B	
Test Subject #	QKA (a)	BSA (a)	QKA (b)	BSA (b)
1				
2			10	6
3	10	8		
4	9	9		
5	10	9	10	6
6			10	8
7	10	8	8	7
8			9	8
9	9	8		
10				
11	10	4	10	7
12	9	9	10	7
13	10	8		
14				
15				
Ave	9.63	7.88	9.57	7.00

	Stakeholders			
	Group A		Group B	
Test Subject #	QKA (a)	BSA (a)	QKA (b)	BSA (b)
1	9	8	10	7
2	10	5		
3			10	7
4			10	6
5				
6	10	6		
7				
8	10	9		
9			10	6
10	10	6	10	10
11				
12				
13			10	6
14	7	6	10	6
15	10	8	9	7
Ave	9.43	6.86	9.88	6.88

4.3.2 Content Bias Check between Groups A and B

Content bias check is performed with 98% Confidence ANOVA. Data for the systems engineers in Group A, systems engineering in Group B, stakeholders in Group A and stakeholders in Group B provide the F-Number and F-Critical results in table 3.

Table 3: Content Bias Check ANOVA

	F-Number	F-Critical
Group A Systems Engineers	8.27	6.89
Group B Systems Engineers	36.00	7.19
Group A Stakeholders	13.50	7.19
Group B Stakeholders	36.66	6.89

4.3.3 Combined data by systems engineers and stakeholders

Demographic and attribute information filtering allowed combining of groups while still isolating data by role and treatment, see Figure 20.

	Systems Engineers	
SE count	QKA	BSA
1	10	8
2	9	9
3	10	9
4	10	8
5	9	8
6	10	4
7	9	9
8	10	8
9	10	6
10	10	6
11	10	8
12	8	7
13	9	8
14	10	7
15	10	7
Ave	9.63	7.88

	Stakeholders	
SH Count	QKA	BSA
1	10	7
2	10	7
3	10	6
4	10	6
5	10	10
6	10	6
7	10	6
8	9	7
9	9	8
10	10	5
11	10	6
12	10	9
13	10	6
14	7	6
15	10	8
Ave	9.88	6.88

Figure 20: Posttest scores by role and treatment

4.3.4 ANOVA for Systems Engineers

ANOVA: Single Factor, Systems Engineers

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
QKA	15.00	144.00	9.60	0.40
BSA	15.00	112.00	7.47	1.84

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34.13	1.00	34.13	30.50	6.66E-06	7.64
Within Groups	31.33	28.00	1.12			
Total	65.47	29.00				

Figure 21: ANOVA, Systems Engineers in Groups A+B

Combining groups A and B data for QKA versus BSA provides the overall systems engineers' results subset of the data. Performing a single factor ANOVA for 99% confidence, see Figure 21, on the systems engineers' subset of the data reveals F-Number and F-Critical results in table 4.

Table 4: Single Factor, 99% Confidence, ANOVA for Systems Engineers

99% Confidence	F-Number	F-Critical
Systems Engineers	30.50	7.64

4.3.5 ANOVA for Stakeholders

ANOVA: Single Factor, Stakeholders

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
QKA	15.00	145.00	9.67	0.67
BSA	15.00	103.00	6.87	1.84

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	58.80	1.00	58.80	46.95	1.91E-07	7.64
Within Groups	35.07	28.00	1.25			
Total	93.87	29.00				

Figure 22: ANOVA, Stakeholders in Groups A+B

Combining groups A and B data for QKA versus BSA provides the overall stakeholders' results subset of the data. Performing a single factor ANOVA for 99% confidence, see Figure 22, on the stakeholders' subset of the data reveals F-Number and F-Critical results in table 5.

Table 5: Single Factor, 99% Confidence, ANOVA for Stakeholders

99% Confidence	F-Number	F-Critical
Stakeholders	49.95	7.64

4.4 Women Vs. Men Results

4.4.1 Demographic Results by Women Vs. Men

The data parsing is by QKA and BSA results for both "Group A" and "Group B". Isolating the posttest results by gender provides Table 6.

Table 6: Data Segregated by Gender, Group and Treatment

Men	QKA(a)	BSA(a)	QKA(b)	BSA(b)
1	9	9	10	6
2	10	9	10	6
3	10	6	10	8
4	10	9	8	7
5	9	8	10	6
6	9	9		
7	10	8		
8	10	8		
9				
10				

Women	QKA(a)	BSA(a)	QKA(b)	BSA(b)
1	9	8	10	7
2	10	5	10	6
3	10	8	10	7
4	10	8	9	8
5	10	6	10	10
6	10	4	10	7
7	7	6	10	7
8			10	6
9			10	6
10			9	7

4.4.1 Content Bias Check between Groups A and B

Ninety-nine percent single factor ANOVA results provide the F-number and F-critical numbers, see Table 7, for women in "Group A", women in "Group B", men in "Group A" and men in "Group B".

Table 7: Single factor ANOVA results for 99% confidence by group and gender

	Group "A" Women	Group "B" Women	Group "A" Men	Group "B" Men
F-number	16.13	45.24	11.29	28.12
F-critical	9.33	8.28	8.86	11.25

4.4.2 Combined data for Women and combined data for Men

Demographic and attribute information filtering allowed combining of groups while still isolating data by gender and treatment, see Table 8. Data for all women from both groups and all men form both groups combined into gender arrays.

Table 8: Combination of groups with gender and treatment isolation

Women	QKA(a+b)	BSA(a+b)
1	9	8
2	10	5
3	10	8
4	10	8
5	10	6
6	10	4
7	7	6
8	10	7
9	10	6
10	10	7
11	9	8
12	10	10
13	10	7
14	10	7
15	10	6
16	10	6
17	9	7

Men	**QKA(a+b)**	**BSA(a+b)**
1	**9**	**9**
2	**10**	**9**
3	**10**	**6**
4	**10**	**9**
5	**9**	**8**
6	**9**	**9**
7	**10**	**8**
8	**10**	**8**
9	**10**	**6**
10	**10**	**6**
11	**10**	**8**
12	**8**	**7**
13	**10**	**6**

4.4.1 ANOVA for Women and Men

True Experiment Data Anova: 99% Confidence, Single Factor Groups A+B (Women)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
QKA(a+b)	17.00	164.00	9.65	0.62
BSA(a+b)	17.00	116.00	6.82	1.90

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	67.76	1.00	67.76	53.74	2.46E-08	7.50
Within Groups	40.35	32.00	1.26			
Total	108.12	33.00				

Figure 23: ANOVA, Women in Groups A+B

True Experiment Data Anova: 99% Confidence, Single Factor Groups A+B (Men)

SUMMARY

Groups	***Count***	***Sum***	***Average***	***Variance***
QKA(a+b)	**13.00**	**125.00**	**9.62**	**0.42**
BSA(a+b)	**13.00**	**99.00**	**7.62**	**1.59**

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	**26.00**	**1.00**	**26.00**	**25.83**	**3.37E-05**	**7.82**
Within Groups	**24.15**	**24.00**	**1.01**			
Total	**50.15**	**25.00**				

Figure 24: ANOVA, Men in Groups A+B

Ninety-nine percent single factor ANOVA, see Figure 23 and Figure 24, results provide the F-number and F-critical numbers shown in Table 9.

Table 9: 99% Single Factor ANOVA Results for all men and all women

	Women Groups "A" & "B"	Men Groups "A" & "B"
F-number	53.73	25.83
F-critical	7.49	7.82

4.5 Summary: Results

The table of overall results shows an average QKA improvement of 2.47 (9.633-7.166) on 10-question posttests, about a 25% improvement, see Figure 25.

Overall				
Count	Test Subject	QKA	BSA	
1	1a	9	8	
2	2a	10	5	
3	3a	10	8	
4	4a	9	9	
5	5a	10	9	
6	6a	10	6	
7	7a	10	8	
8	8a	10	9	
9	9a	9	8	
10	10a	10	6	
11	11a	10	4	
12	12a	9	9	
13	13a	10	8	
14	14a	7	6	
15	15a	10	8	
16	1b	10	7	
17	2b	10	6	
18	3b	10	7	
19	4b	10	6	
20	5b	10	6	
21	6b	10	8	
22	7b	8	7	
23	8b	9	8	
24	9b	10	6	
25	10b	10	10	
26	11b	10	7	
27	12b	10	7	
28	13b	10	6	
29	14b	10	6	
30	15b	9	7	
	Ave	9.63	7.17	

Figure 25: Table of Correct Answers by Test Subject

4.5.1 ANOVA for knowledge-worker community

The ninety-nine percent single factor ANOVA results for all thirty tests subject are shown in Table 10.

Table 10: Thirty test-subject ANOVA results

True Experiment Data ANOVA: 99% Conf. Single Factor (SE & SH, Project Community)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
QKA (SE & SH, Project Community)	30.00	289.00	9.63	0.52
BSA (SE & SH, Project Community)	30.00	215.00	7.17	1.87

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	91.27	1.00	91.27	76.57	3.43E-12	7.09
Within Groups	69.13	58.00	1.19			
Total	160.40	59.00				

Combining the systems engineers' and stakeholders' data for QKA versus BSA gives the data set for analyzing project community performance. Performing a single factor ANOVA for 99% confidence on the overall project community data reveals F-Number and F-Critical results in table 11.

Table 11: Single Factor, 99% Confidence, ANOVA for Project Community

99% Confidence	F-Number	F-Critical
Project Community	76.57	7.09

Following good DCT, a graphical representation of the occurrences of correct posttest scores can be viewed in figure 25.

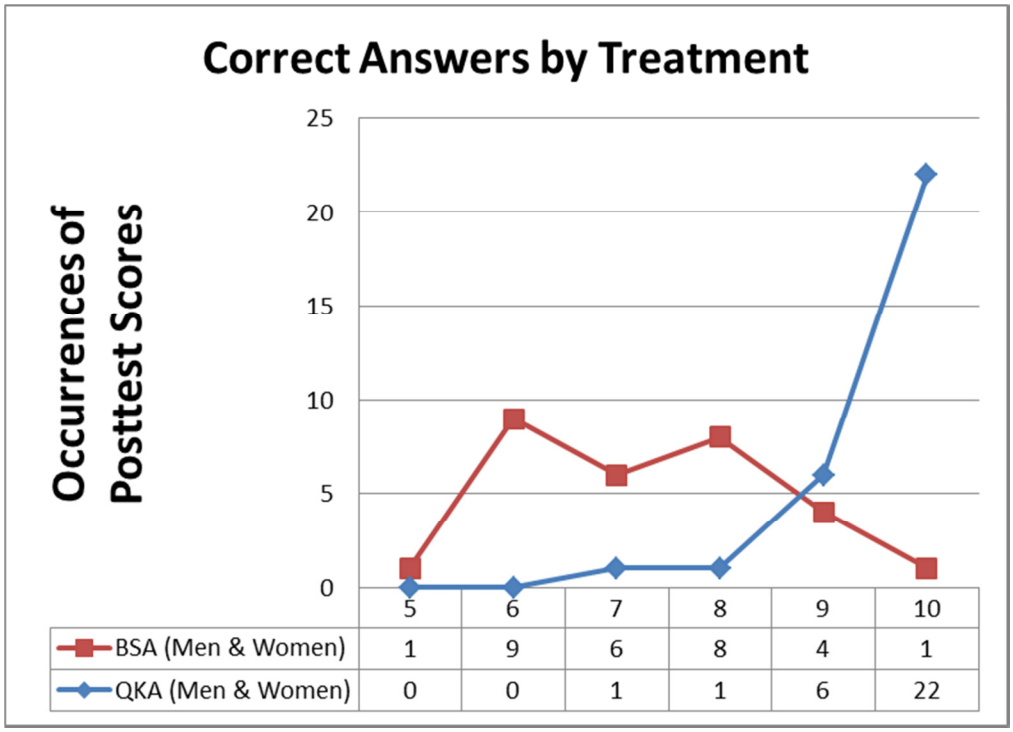

Figure 26: Occurrences of Posttest Scores

4.6 Analysis and Findings

4.6.1 Raw Data observations

Review of the raw data shows higher scores were more prevalent on 3-way MIRRoR knowledge QKA constructed knowledge bases than on BSA constructed knowledge bases, as shown in Table 1. QKA averages are 9.53 and 9.73 while the BSA averages are 7.40 and 6.93 correct answers out of a possible 10.

4.6.2 Systems engineers Vs. stakeholders analysis

Looking into the data by demographic separation of systems engineers and stakeholders, see table 2, it is noted that similar average trends exist.

The systems engineers in Group A averaged 9.63, and Group B averaged 9.57 on QKA constructed knowledge bases. Systems engineers' BSA results average 7.88 in Group A and 7.00 in Group B. QKA average improvement for systems engineers is 1.75 (9.63-7.88) and 2.57 (9.57-7.00) for Groups A and B, respectively, see Table 2.

The stakeholders in Group A averaged 9.43, and Group B averaged 9.88 on QKA constructed knowledge bases. Stakeholders' BSA results average 6.86 in Group A and 6.88 in Group B. QKA average improvement for stakeholders is 2.57 (9.43-6.86) and 3.00 (9.88-6.88) for Groups A and B, respectively, see Table 2.

Content bias was one of the threats to reliability. A 98% confidence factor ANOVA was performed to investigate effects on results related to the content in the two knowledge bases, KB1 and KB2. Systems engineers and stakeholders in both A and B groups had F-numbers that exceeded F-Critical, see Table 3, indicating content was not significantly influencing results. Both systems engineers and stakeholders scored better on both knowledge bases when they were constructed in QKA form. This insight allows for a valid combination of the Group A and Group B data for further analysis

Systems engineers, with combined Group A and Group B data, show a 99% confidence that QKA constructs improved their ability to learn. The single factor ANOVA provides an F-Number of 30.50, which is significantly above the F-Critical threshold of 7.64, see Table 4. Similarly, stakeholders' combination of groups A and B data indicate a 99% confidence that QKAs are superior to BSA in terms of tacit knowledge generation. Stakeholders' F-Number of 49.95 significantly exceeds the threshold of 7.64, see table 5.

4.6.3 Women Vs. Men analysis

4.6.3.1 Refuting H_0 for women's portion

As shown in Table 1, a review of the women's results was analyzed for content bias effects using ANOVA. As shown in Table 2, the ANOVA results indicate women learned better on both knowledge bases when the knowledge bases were constructed and presented in QKA form. Group-A and Group-B F-numbers, 16.13 and 45.24 respectively, both exceeded the F-critical numbers, 9.33 and 8.28 respectively. Therefore, the content was not determining of how fast women learned.

Now that it is known that both data sets about women show a preference in the same direction, they can be combined and analyzed to determine the overall affect QKA has on women as shown in Table 3. ANOVA analysis of this combined data set shows the women's F-number, 53.73, is larger than the F-critical number, 7.49. See Table 4. Therefore, H_0 is rejected for the women's portion.

4.6.3.2 Refuting H_0 for men's portion

As shown in Table 1, a review of the men's results was analyzed for content bias effects using ANOVA. As shown in Table 2, the ANOVA results indicate men learned better on both knowledge bases when the knowledge bases were constructed and presented in QKA form. Group-A and Group-B F-numbers, 11.29 and 28.12 respectively, both exceeded the F-critical numbers, 8.86 and 11.25 respectively. Therefore, the content was not determining of how fast men learned.

Now that it is known that both data sets about men show a preference in the same direction, they can be combined and analyzed to determine the overall affect QKA has on men. See Table 3. ANOVA analysis of this combined data set shows the men's F-

number, 25.83, is larger than the F-critical number, 7.82. See Table 4. Therefore, H_0 is rejected for the men's portion.

4.6.4 Overall Findings

Refuting H_0 in overall data: women and men are independently showing support for the 3-way MIRRoR knowledge QKA construct as superior to BSA construct, allowing the thirty data points to be combined for overall knowledge worker analysis. To investigate the effect on the project community, systems engineers' QKA data is combined with stakeholder QKA data to generate the QKA-array. The BSA-array is generated in the same manner, combining BSA data from systems engineers and stakeholders. Comparing the QKA-array with the BSA-array, using 99% confidence single factor ANOVA, provides an F-Number of 76.6 that exceeds the threshold F-Critical of 7.1, see Table 6. This analysis can be interpreted to indicate a project community can consume SEKA more efficiently using the QKA construction of a knowledge base, as compared to traditional BSA. The null hypothesis, $H_{0,}$ of "A knowledge base of SEKA in QKA construct can NOT be explored by the women and men knowledge-workers, who make up a project community of Systems Engineers and stakeholders, with better knowledge transfer than a knowledge base of SEKA in BSA construct" is rejected because the 76.57 F-Number is larger than 7.09 F-Critical.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Dissertation Discussion

5.1.1 Gaps in Research discussion

A gap in collaborative environments stem from their reliance on knowledge-workers to author SEKA. They are usually professionals in domains other than writing and publishing. They default to the familiar BSA construct when they articulate their knowledge in codified form for IT system publication. Psychology has focused on advancing techniques for computer-based training using self-regulated learning hypermedia environments

The new information structure is Multiple Informational Representations Required of Referent (MIRRoR) knowledge. It allows matching the number of levels to the open knowledge system. This research project used a true experiment investigational instrument with each piece of knowledge represented three ways. This 3-way construct, termed a Quality Knowledge Asset (QKA), implemented a top-level representation in the bulleted style, the middle-level in synopsis summary style and the bottom-level in the verbose whitepaper style. Some complex, detailed and / or technical content may benefit from more than three levels of representation. Even a two-level MIRRoR knowledge scheme may benefit the consumer. This experiment used a three level QKA, targeting a wide audience for balanced benefits in both “speed of consumption” and “speed of comprehension” dimensions.

Posit a learning organization, of men and women knowledge workers, who develops common knowledge in less time and collaborates with teammates more

effectively. This study contributes the improved open knowledge system idea and proceeds to experimentally verify that both men and women knowledge workers in systems engineering and stakeholder roles learn faster i.e. improved tacit knowledge mobilization. The experiment mocked up a simulation of this idea with the investigator in the author role for Externalization mode and test-subjects in consumer role for the Internalization mode. This Externalization to Internalization transfer is highlighted with an oval in Figure 4.

The Internalization transfer is the domain of Educational psychology. These closed knowledge systems assume all the informational representations of knowledge on the training topic are included. This is reminiscent of a book or regular training course material.

The concept of an open knowledge system is different in the assumption that knowledge exists beyond the codified material in the system. It supports expertise location for Socialization where knowledge transfer can be tacit-to-tacit.

The application of computer based training techniques to open knowledge collaborative environments is a gap.

5.1.2 General discussion

Professionals in fields other than writing and publications can learn to author knowledge assets in MIRRoR knowledge schemes. These MIRRoR knowledge constructs enable immediate publication in collaborative environments. Information/knowledge consumers can rely on the collaborative environment to present the multiple levels of information for their exploration. Thirty Information/knowledge consumers from a project community of systems engineer and stakeholders were test-

subjects for an original true experiment where an information technology system presented a 3-way MIRRoR knowledge QKA construct for evaluation. The study investigated these knowledge-workers to determine if these new structures and techniques only improved results for one demographic, multiple demographics or universally.

A sampling technique was used to represent a project community population. A sample size of thirty was selected because this volume of experimental data is the point where, for practical purposes, the t-distribution becomes normal (Anderson & Whitcomb, 2007) (Salkind, 2009). To support generalizability, the data was analyzed to estimate the sampling error. The project community QKA-array analysis shows a margin of error at 0.34. This means the true population average posttest scores would fall between 9.97 and 9.30 with 99% confidence. The project community BSA-array analysis shows a margin of error at 0.643. This means a range of 7.81 to 6.52 would contain the true populations' average BSA posttest score, with 99% confidence. This QKA and BSA analysis relative to the true population indicates causality can be validly claimed with these two data sets with thirty QKA data points and thirty BSA data points. The upper bound on BSA (7.81) is lower than the lower bound of QKA (9.30); the treatment makes a difference.

5.1.3 Overall project community discussion

The project community consisted of women and men knowledge-workers in roles of systems engineers and stakeholders. Group A's eight systems engineers were combined with Group B's seven systems engineers to provide the fifteen systems engineers' QKA-array and BSA-array. Similarly, Group A's seven stakeholders were combined with Group B's eight stakeholders to generate the stakeholders' fifteen data

point QKA-array and BSA-array. These arrays allow the determination that stakeholder and systems engineers can both learn better from QKA constructed knowledge bases.

The QKA results for both systems engineers and stakeholders were stacked into an overall QKA-array. Similarly, a BSA-array was generated. A ninety-nine percent confidence single factor ANOVA of these overall QKA-array and BSA-array, revealed a threshold F-Critical of 7.09F, which was handily exceed by the F-Number of 76.57.

Interpretation tells us that the whole of the project community learns better form QKA constructed knowledge bases.

5.1.4 Consumer-Centric Architecture discussion

Good open-knowledge collaborative environments bring multiple software application tools, types of knowledge assets and myriad capabilities including portals, see Figure 3. Each portal can bring the appropriate tools, artifacts and capabilities into focus for the Systems Engineer or other user when they navigate to the view.

A reference-focused portal might organize QKAs and historical artifacts of published works e.g. books, manuals, corporate policy statements (CPS), Process Asset Library (PAL) & research publications.

An objective-focused portal could facilitate the development of the strategic plan through geographically dispersed collaboration. If an objective like the Disaster Recovery (DR) plan needs to reference a CPS, the objective focused portal can appropriately organize the presentation of the link to that central knowledge asset.

For the event focused portal, participates can more efficiently find relevant knowledge assets due to the date/meeting/session orientation of the presentation layer content. They can confidently interact with the content, knowing it is associated with the

event. Events can be any of the Systems Engineering milestone "R" meetings e.g. Systems Concept Review (SCR), Systems Requirements Review (SRR), Systems Design Review (SDR), Test Readiness Review (TRR), Operational Readiness Review (ORR), Post Implementation Review (PIR) or conferences, off-site meetings, seminars and classes.

Day-to-day activities can be tailored in the group-focused portal where the presentation layer organizes role-based tools, artifacts and capabilities for engineers to do their job. Workflows may facilitate efficient coordination between roles.

Product focused portals facilitate answering questions like what stage is a given product in and what has been done to date on that product. Product examples might be a given space vehicle, an airplane, or weapon. For instance, if space vehicle #3 is going into SDR, then this portal should have a presentation layer representation of the past SCR and SRR, linking the central knowledge assets created in the artifact library and other activities from those events.

Key capabilities in a Personalization biased knowledge management strategy (Kumar & Ganesh, 2011) include expertise location, found in the expertise-focused portal. People can find out which other people know information or have skills in a domain needed to advance a current effort. Reverse search allows documents like Requests For Proposals (RFP) to be fed into the system to search for people. Skills inventory profiles with pictures of the individual & contact information allow people to contact people for tacit-to-tacit knowledge collaboration in an improved trust atmosphere.

Engineering teams should work in the collaborative environment including all drafts and work-in-progress instead of working off-line and depositing only finished

artifacts. Final drafts should be labelled and version locked for future reference and traceability. All of the knowledge assets are central to the collaborative environment and all portals have access to select the applicable assets to display, organize and manipulate.

5.1 Null Hypothesis

A dual-posttest true experiment was conducted to investigate if SEKA construct and presentation style could affect learning efficiency. The Null Hypothesis, H_0, of "A knowledge base of SEKA in QKA construct can NOT be explored by the women and men knowledge-workers, who make up a project community of Systems Engineers and stakeholders, with better knowledge transfer than a knowledge base of SEKA in BSA construct" was used. Analysis confirmed consistent observations that the QKA treatment caused an effect. The effect in gender and role dimensions supported QKA constructs as superior to BSA constructs. The full set of thirty QKA data points and thirty BSA data points for the project community refute the Null Hypothesis.

5.2 Recommendations

5.2.1 Experimental recommendations

The idea to fill the research gap between computer based training environments and collaborative environments is to build an Information Technology system that elicits knowledge asset creation in a new information structure. When the new information structure is filled-out, the presentation layer can immediately make it available to collaborators. When consumers explore the knowledge base, the presentation layer leverages dual-coding, metadata scaffolding and non-linear navigation.

5.2.2 Literature review recommendations

A significant portion of the literature review is reflected in the experiment. The recommendations from portions not reflected in the experiment are leadership conduct and semantic search.

Leadership conduct affects knowledge worker productivity both positively and negatively. Leadership can aid productivity by remaining results focused (what, not how), explaining causality loops for systems thinking, empower with trust, incentivize learning behaviors, and treat people differently to treat them fairly. Additionally, leaders should promote and participate in shared mental models for synergistic collaboration. Leadership should not treat knowledge workers like "Hands". Leaders should not direct methods (how), micromanage activities, break work into linear segments, isolate knowledge-workers from one another, or control their actions.

5.3 Benefits / Contributions

5.3.1 Knowledge transfer before retirement

Conveying more than information is involved in mitigating the risk of losing institutional memory at time of retirement. It is important to identify critical knowledge and "know how", but equally important to proactively identify knowledge that does not need to be transferred. Knowledge assets transferred should be linked directly to activities that drive performance on core processes. A recommended method for filtering this knowledge is to have a mentee "shadow" pre-retirees on live projects. The mentee should be tasked with more than just tagging along, but to learn and codify the knowledge and decision making process for themselves. A good way to motivate mentee

journeymen to thoroughly understand the knowledge is to set their expectation that they will be teaching the material to someone else. The journeymen is instructed on methods to author quality knowledge assets and publication techniques within a collaborative cloud environment. Following publication, the pre-retiree validates the knowledge was essentially captured and represented accurately. This is known as vertical knowledge transfer. The journeyman author would use these new knowledge assets to teach another journeyman or early career professional the material. This is known as horizontal knowledge transfer. (Beazley, Boenisch and Harden 2002) (Powers 2002) (Hu 2010) (McLaughlin 2010)

5.3.2 Shortened project completion timelines

Efficiency gains in systems engineers and stakeholders collaborating on project completion activities have an opportunity to shorten the timeline. When understanding is accelerated, the project community develops better-shared mental models. These shared mental models, based on common knowledge base collaboration, allow communication and agreement to accelerate at the speed of trust.

The people dimension is supported by leveraging natural abilities of the brain to comprehend better with dual-coded information. Concurrently displayed metadata in scaffolding surrounding the dual-coded content supports accelerated meta-cognition. Leadership can learn to get out of knowledge-workers' way and conduct themselves in ways that allow the highest productivity.

The technology dimension enables information technology collaborative environments. These environments take cost out of the system-under-development by avoiding team co-location. A project requiring co-location may not have access to the

best resources because some resources are not willing to move their homes or travel extensively. Collaborative environments allow the best resources to contribute from their location of choice. The virtual team can collaborate with dynamically created SEKA that supports accelerated learning and collaboration.

The process dimension enhances authors' ability to fill out the SEKA QKA form and know the presentation layer will be able to publish and display the information correctly. Upon submitting the QKA form, the process indexes the content in keyword and semantic aspects for immediate discovery.

Business value is created through less labor to support longer timelines. Profit margin has an opportunity to increase through same or better quality systems being delivered sooner. Earlier delivery of systems drive increased customer satisfaction. Systems' cost reductions could be passed along the funding source, a value-engineering enhancement that also drives customer satisfaction. Alternatively, the efficiency value could be shared between profit margin and price to the funding source.

5.3.3 Left of Boom Collaboration

Intelligence teams working in collaborative environments recommended here, increase their probability of connecting-the-dots in time to thwart explosive events. Information overload and big data analysis limit timely use of captured data.

The people dimension allows agents to learn faster, collaborate sooner and understand causality loops in larger data sets. Dual-coding doubles the number of memories about a topic, increasing the likelihood of recall when needed.

The process dimension can automatically collect big data from sensors and process it at ingest time. This pre-question processing allows agents to interrogate the data in any direction his/her investigation takes him/her.

The technology dimension can commingle structured and unstructured information using Natural Language Processing. This allows semantic search and reverse search. Search allows agents to interrogate the data based on meaning. Reverse search allows a set of data to return lists of other agents who have worked in this area. The inquiring agent can use this lists to facilitate tacit-to-tacit knowledge collaboration on a topic.

5.3.4 Medical practice – keeping up with drug changes

Medical doctors have expressed an interest in ways to keep up with change information on available drugs. They expressed difficulty in having time to read the volumes of data about drug offerings. They say they already know most of the information published but have to re-read the verbose renditions to find the new information.

The people dimension allows doctors to review information at the bulleted style level and / or the synopsis style level to save time over reading all the expository style representations of the material. They get credit for their education and experience.

The process dimension has the drug companies authoring the QKA to share their information faster, enabling their products to be understood and used more.

The technology dimension supports cross-company collaboration with drug companies and doctors in the same collaborative environment. Reverse search would allow doctors to put in their notes on a patient visit and the result would list other doctors

with whom they could consult. Forward search would allow these same notes to find relevant drugs to treat the condition.

5.4 Conclusions

Within the context of virtual knowledge-worker environments common to systems engineers and stakeholders, causality can validly be claimed with a randomly selected thirty-person sample, segregated without bias, in to groups. This is commonly an effective sample size for experimental data, where the t-distribution becomes normal (Anderson & Whitcomb, 2007) (Salkind, 2009). Analysis of the experimental data leads to a proffered conclusion that, with 99% confidence, project communities learn better when SEKA is presented in 3-way MIRRoR knowledge QKA constructed knowledge bases, than BSA constructed knowledge bases. With an F-number of 76.57 exceeding F-critical of 7.09, the data analysis reveals, with 99% confidence, that QKA constructed knowledge bases are superior to traditional BSA constructed knowledge bases. A project community, who comprehends a common knowledge base sooner and collaborates more efficiently, builds Capacity for Engineering Systems Thinking (Frank, 2010). Higher Capacity for Engineering Systems Thinking supports higher performing engineering teams, who can deliver more business value sooner.

These higher preforming teams need the right kind of leadership support to flourish. People in leadership roles need to adopt information-age leadership styles and drop industrial revolution styles. Managers manage things; people are not things. Knowledge-workers need leaders, not managers.

5.5 Summary Statement

Systems engineers and their stakeholders' ability to learn SEKA was investigated using a dual posttest-only true experiment. A sampling of thirty test-subjects was randomly selected. This is commonly an effective sample size for experimental data, where the t-distribution becomes normal (Anderson & Whitcomb, 2007) (Salkind N. J., 2009). These thirty test-subjects were placed into groups A and B using an unbiased ping-pong approach. A data set with thirty QKA and thirty BSA data points was generated from this experimentation. The resulting data was analyzed for margin of error. The QKA-array showed a margin of error of +/- 0.34 and the BSA-array at +/- 0.64. The BSA upper bound was lower than the QKA lower bound; indicating an actionable causality claim is valid with this data set. With 99% confidence, it is generalizable to claim that the treatment caused an effect.

The treatment was a QKA where three informational representations of referent knowledge were developed for each SEKA: bulleted, synopsis and expository. Each representation included Dual-Coding Theory content. The presentation layer displayed content with scaffolding of User-Subjective Approach meta-data and non-linear navigation capabilities.

Closed knowledge systems such as computer based training modules, have advanced the presentation techniques more than open knowledge systems such as collaborative environments. Professionals in fields other than writing and publications can learn to author knowledge assets in MIRRoR knowledge schemes. These MIRRoR knowledge constructs enable immediate publication in collaborative environments. Information/knowledge consumers can rely on the collaborative environment to present

the multiple levels of information for their exploration. Thirty Information/knowledge consumers were test-subjects for an original true experiment where an Information Technology system presented a 3-way MIRRoR knowledge QKA construct for evaluation. The study investigated systems engineer and stakeholder knowledge workers to determine if these new structures and techniques only improved results for one demographic, none or all.

The bottom line is that QKA is shown to be superior to BSA. Psychology was brought to systems engineering for improvement through natural brain abilities. Capacity for Engineering Systems Thinking was targeted for enhancement through Dual-Coding Theory, User-Subjective Approach and the Cognitive Collaborative Model. The knowledge strategy continuum from codification through personalization was identified. It was revealed that systems engineering activities prefer a bias toward personalization but codification is required, too.

Now that we have a way to enable efficiency in project communities, what externalities do they need?

Technology needs to comingle structured and unstructured knowledge assets for holistic semantic search. Natural Language Processing using an engine like SaffronOne can efficiently index and store semantic search information for comingled data.

People in terms of leadership need to understand knowledge-workers and provide them with work environment treatment conducive to their productivity.

Process is best when simplicity is discovered on the far side of complexity. A back-to-basics Systems Development Life Cycle is advised unless solid business justification warrants deviation.

There is an identified enterprise value opportunity through systems engineers and their stakeholders collaborating more effectively and leadership conducting themselves for the productivity of the team.

5.6 Implications for Future Research

A follow-on study is needed to investigate the QKA construct's effect on a new system creation project community over the full Systems Development Life Cycle. The short-term primer and ten minute QKA construct knowledge base exploration by the test subject participants only serve to build confidence that cognition and knowledge transfer efficiency can be improved. The positive effects are anticipated to build as a community becomes familiar with the concept and learn to rely upon the systems to facilitate knowledge transfer.

An evaluation of new knowledge contributor's learning curve to author MIRRoR knowledge assets is needed. Initially, the preparation of each piece of knowledge in multiple ways will be slow. A follow-on study should investigate the shape of this learning curve and the authoring efficiency after the learning curve. With this consumption study and the authoring learning curve study above, a pilot project should be ventured with a team of knowledge workers immersed in a MIRRoR knowledge collaborative environment to detect the long-term effect on enterprise value creation.

An opportunity to extend this collaborative environment research exists in augmented reality with MIRRoR knowledge presented in "heads-up displays", think Google glasses. The MIRRoR knowledge content semantic search could locate specific assets based on the brainwaves of the wearer, leveraging the brainwave → picture

dictionary. The system can determine what the wearer is seeing. Collaborative environment knowledge assets associated with the wearer's vision could be displayed in the heads-up display.

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