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A quantitative study of stem goal and role alignment across stakeholder leaders in California: advocacy for application of a systems solution approach

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A QUANTITATIVE STUDY OF STEM GOAL AND ROLE ALIGNMENT ACROSS STAKEHOLDER LEADERS IN CALIFORNIA: ADVOCACY FOR APPLICATION OF A SYSTEMS SOLUTION APPROACH

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

DEDICATION

To my husband Jim, and my sons Scott and Casey who inspire me daily and made it possible to complete this journey.

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ABSTRACT

Both the nation and California are faced with a critical threat to our long term strength and welfare due to an acknowledged deficit in STEM ready students and workers as we head into the 21st century. The STEM workforce gap requires integrated conversations and solutions as it impacts multiple stakeholder groups who do not necessarily fully comprehend each other's needs and challenges. There is a broad consensus that increasing the STEM workforce is critical to the U.S., impacting standard of living, as well as national security in areas such as international competitiveness, combating terrorism and addressing global warming, to name just a few. Historically, the world has looked to the U.S. as the globe's preeminent source of innovation. However, critical indicators have caused industry, educators, policy makers, and communities to take a deeper look at some alarming trends. For example, a U.S. Department of Commerce study noted that the U.S. has made no progress in its competiveness since 1999, and is beginning to lose ground to other countries that are actively building their scientific and technological infrastructures.

This study utilized the literature review to explore the power of applying system's thinking to this complex social problem. In addition, the study quantitatively demonstrated the current state of alignment in California across two key stakeholder group's leaders, industry and education by exploring the following areas:

1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?

3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?

The quantitative research demonstrated alignment of the key stakeholder leaders around what is important relative to the goals of California's STEM workforce gap as well as alignment around which stakeholder leaders should be executing specific tasks. The research also underscored an aligned understanding of the current lack of collaboration that exists across stakeholder leaders in California.

Chapter 1: Introduction and Problem

Introduction to the Study

The National Academies' (2007) report, *Rising Above the Gathering Storm,* defined the major workforce skills shortages facing Americans as they head into the 21st century, particularly in the areas of science, technology, engineering and math (STEM). In an effort to address this concern, legislation was enacted to focus on innovation in research and development as a way to improve the U.S.' ability to compete with other emerging global powers. Congress first signed the legislation, called America Competes, into law in August of 2007 as H.R. 2272; the funding was extended in December of 2010 as H.R. 5116. The funding was intended to target high risk, high reward investment in critical technologies, as well as increasing investments in targeting innovation and enhancing the nation's educational delivery system. This legislation was passed with bi-partisan support, at a time when there was little bi-partisan consensus. When the bill arrived for a vote on the Senate floor it was approved with unanimous consent under the parliamentary procedure (Landers, 2011). Additionally, the President's Council of Advisors on Science and Technology produced an executive report (Executive Office of the President, 2010) that indicated that the nation's ability to remain a leader among nations is tied to the skills and ideas of its people. The indicators from this executive report, however, are troubling, noting the U.S. is lagging behind other developed nations in elementary and secondary education achievement levels, placing their students at the mid-to-lower level of performance in math and science. Even more troubling, this study also illuminated both a lack of proficiency and lack of interest in STEM fields among

U.S. students, furthermore showing even lower levels of interest amongst women and minority students.

The focus of this study was to ascertain what was required to change in the current approach to address the documented workforce gaps across the critical stakeholder leaders in industry, government, education, non-profits, and communities. It should be further noted that this crisis is not only centered on education. If America is to rise to the unique challenges of the 21st century, any solutions must take into consideration the long-term strategic systems view (Executive Office of the President, 2010). More than simply addressing the K-12 educational pipeline, these solutions must also address how the system handles retooling the existing workforce so it is able to stay on top of rapidly evolving technology.

There is a broad consensus that increasing the STEM workforce is critical to the U.S., impacting standard of living, as well as national security, in areas such as international competitiveness, combating terrorism and addressing global warming, to name just a few (Hira, 2010). Historically, the world has looked to the U.S. as the globe's preeminent source of innovation. However, critical indicators have caused industry, educators, policy makers, and communities to take a deeper look at some alarming trends. For example, a U.S. Department of Commerce (2012) study noted that the U.S. has made no progress in its competiveness since 1999, and is beginning to lose ground to other countries that are actively building their scientific and technological infrastructures. Likewise, degrees in STEM represent only 15.6% of bachelor degrees awarded in the U.S., compared to 46.7% in China, 37.8% in South Korea and 28.1% in Germany (Business Higher Education Forum [BHEF], 2010). Another potential contributor to these alarming statistics is a shortage of highly skilled math and science educators entering the teaching profession or committing to long-term careers in education. The most significant shortage of these teachers is in high-minority and high-poverty classrooms (BHEF, 2007). To address these gaps in STEM knowledge, the U.S. educational delivery model needs to go further than the original standards based educational objectives of No Child Left Behind (NCLB). Additionally, while the U.S. is dealing with high levels of unemployment, there is a projected shortfall of over 35 million skilled workers over the next 30 years (Bozell & Goldberg, 2009). The total STEM system focus should include K-12 strategies, as well as skills readiness and a retooling of the blue-collar high technology sector, which needs to address both the introduction of new technology skills as well as accommodate technological shifts necessary for current members of the workforce to receive mid-career re-education.

The system also requires a redesign that addresses the under-representation of women and minorities in STEM fields that begins in a measureable way with student interest and engagement in STEM in elementary education. This under-representation gap could be seen as an opportunity for a real win-win situation. Though women and minorities are under-represented in STEM in both education and industry, by placing additional emphasis on this population, the U.S. workforce gap could grow the availability of critically needed workers, as well as address the current issues of under-representation. A system analysis of the STEM workforce should seek to understand what is driving the current representation shortfalls in women and minorities. Drew (2011) discusses the importance of destroying the barriers to studying and achieving in math and science. He notes that when this occurs the technical skills and knowledge that become available to the American workplace will dramatically increase and the lives of the enabled individuals will be transformed.

The U. S. STEM shortage is an issue of national importance. The good news is this is not a polarizing issue, so time does not need to be wasted gaining alignment across stakeholders around recognition and acknowledgement of the criticality of the high-level STEM workforce gap problem itself. The challenge, instead, is the lack of a collaboratively developed common strategy at the execution level across industry and educators, as they work to identify solutions that are able to sufficiently make a dent in this problem.

Background of the Problem

Creation of a common strategy requires integration of the demand and supply elements of the STEM workforce system. In order to create an integrated system, the consumers (employers) must be clear about what they require to operate over a defined horizon. This includes articulating specific skills, knowledge and attributes. Each giver and receiver in the chain should understand the expectations and needs of the other to ensure reasonably seamless handoffs. Once the needs are made clear, government, non-profits, industry, educators and the community need to synchronize their roles in this supply system. In addition to focusing on the consumers and providers (the educational system), the receivers (students and employees) must be considered critical stakeholders in the system when designing delivery approaches of the future. Moreover, the system design must consider the needs and motivators of the student and workforce populations to ensure an effective outcome. Closure of the STEM workforce gap requires attracting, enhancing, and retaining these stakeholders.

Fundamental changes in areas such as jointly developed educational content and approaches tend to take time, and are often encumbered by deep social, political, education, and economic debate by well-meaning constituents. There will likely be language, relationship, and value barriers hampering these stakeholders. For example, industry leaders tend to have a focus on a specific set of results driven by their business to remain competitive and profitable, whereas educators focus on student learning objectives as defined by their districts. Creating approaches that better integrate the focus of K-12 learning objectives and measures with the needs of the businesses that will ultimately employ students will require newly integrated stakeholder conversations.

In addition to communicating and understanding each other's specific needs and expectations, the stakeholders must define practical approaches to implementing the changes that are subsequently defined. It will be important to find palatable pathways to implementation of these aligned stakeholder objectives and measurements. An example of a potential pathway that has both federal and state funding already available can be found in the after school programs network. There are already non-profits, such as the California STEM Learning Network (CSLNet), that are engaged in helping to develop after school programs to provide a rich near-term laboratory to understand which strategies and tactics are most effective in creating STEM proficient students. The after school environment provides more flexibility for ideas to be developed and tested, and what works in this environment can then be adapted, where appropriate, into the mainstream classroom environment. Significant funding has been made available, both nationally and in California, to afterschool programs in underserved communities to specifically address education disparities in low-income communities. This example helps illustrate the importance of clarifying and integrating the objectives of each of the critical constituencies into a deliberate approach with measureable outcomes as a necessary first step to ensuring that proposed solutions in the STEM system are designed meet the integrated needs of the total system.

Over the last several years, industry, which has been directly impacted by the STEM workforce gap, has become more active as a critical STEM stakeholder. For example, while there were 200,000 students who graduated in STEM disciplines in 2004, this was not sufficient to meet the demands of the science and technology industry. The concern is growing because not only are there insufficient students graduating in the STEM disciplines, many of those who are graduating with STEM degrees are not adequately prepared with the necessary skills to perform the job (Elrod, 2006). Skill development reflects on the university programs educating students in STEM disciplines. Employers can apply their influence with educators and with government for solutions. Companies like Microsoft, Baxter International, Cisco Systems, Raytheon, Chevron, EXXON and many others have made a focus on STEM education an organizational priority. Part of the reason for this is that in a recent survey, a shortage of talent has been identified as the number one issue that requires attention, rising from 22nd place in 2009, and overtaking financial stability (Davis, 2012). More specifically, for California, it is projected there will be 1,148,000 STEM-related jobs that will need to be filled by 2018 (Stemconnector, 2011).

Leaders in industry are concerned about the ramifications of the growing gap in the quantity and capabilities of both college graduates and existing knowledge workers in STEM fields. Researchers in various industries believe this gap will create a significant loss of competitive edge in the STEM fields, which puts the U.S. at risk of falling behind in the area of science, technology, and innovation. Accordingly, there is a strong need for communication between industry and academia, government, communities and the program developers who will lead change by implementing robust STEM programs (BHEF, 2012).

These program developers represent an important new role in the STEM system, acting as change agents and systems integrators. In an effort to fill this new systems integration role, there are a variety of foundations, corporations, and non-profit groups that are forming with a common goal of addressing this national crisis in STEM education. However, because these integrators are independently emerging to address the gap, there is not yet a common integrated strategy across this group.

In summary, the STEM workforce gap is a systemic problem and as such it is important to understand the current roles and impacts of the key participants that are presently engaged in the STEM system. Clearly, educators play a pivotal role. However, as the ultimate consumer, industry must be clear about what its current and future needs will be both in terms of quantity and capability. Communities, including parents, are the most in tune with both the special gifts and the challenges facing their respective communities, and thus possess the best understanding of how things work in their environments and how policy plays a role. The education process begins at birth and continues through the working life of the individuals engaged in the system, cradle to career. How can a system work efficiently if it does not recognize and address its inherent interdependence?

Statement of the Problem

The STEM workforce gap is acknowledged as a national issue. Despite this common understanding, there has not been a systemic approach taken to synchronize the needs of the consumers with the products of the U.S. educational system. The national STEM crisis must be addressed strategically and deliberately. There is already significant fiscal investment being allocated to the problem through federal and state policy makers. Industry, non-profits and educational institutions are also putting both their ideas and financial resources to work. Key to the solution set is collaboration, adaptability, scalability, and sustainability.

Two themes repeated over and over at a recent STEM solutions leadership summit put on by *U.S. News & World Report* (2012) that was attended by over 1,500 individuals in the fields mentioned above were, the importance of collaboration and the challenge of scale. The collaboration discussion pointed to the need for integrated solutions across industry, educators, and policy makers, and the scale discussion pointed to numerous small success stories that must be scaled for repeatable successes in order to adequately address the STEM shortage challenge.

The current approach of ad hoc, localized solutions is helping to provide important information about what works. The problem with this approach is it creates islands of excellence that ultimately cannot be replicated en masse to solve our national problem. Fortunately, there are emerging organizations working together to create solution networks that can bridge this lack of integrated solutions. The California STEM Learning Network's (n.d.) mission is to create a network of educators, business leaders and other core stakeholders who are committed to building a world class STEM education system. This system would ensure that all California students graduate from high school with the necessary STEM knowledge and skills that will prepare them for success in college, work and their daily lives (California STEM Learning Network, n.d.).

The STEM problem is not a shortage of interest or ideas. Fortunately there is already significant alignment amongst the stakeholders about the importance of addressing the STEM workforce challenge, as demonstrated by the first national STEM summit in Dallas, three days of presentations by key stakeholders in industry, education, government, entertainment, non-profits and foundations, hosted by *U.S. News & World Report* (2012). The workshop tracks covered: the demand side (industry and jobs today), the supply side (education and America's STEM future), and sought to uncover the best return on investment and create a framework for STEM longevity, policy and performance. The goal of the summit was to align the thinkers and solvers. Ultimately, the conference regularly reinforced that the best value proposition in STEM exists in alignment of and collaboration between the critical stakeholders relative to approach, scalability, repeatability, and sustainability of the STEM strategy.

Purpose of the Study

The purpose of this study is to contribute to the understanding of how to approach a problem as complex and important as the STEM workforce gap that faces the U.S. and California, in particular. This was done by exploring problem solving through the application of systems thinking and modeling discussed in the literature review. Systems models can simulate various project approaches to understanding the range of likely results that help stakeholders determine where to best focus their energy and investments. Critical to a systems approach is goal and role clarity as well as measurement alignment across the stakeholders who influence the improvement activities of the systems. While the research shows there is alignment around the basic goal of closing the STEM workforce gap, there is not a California master plan with a common set of discrete objectives, defined measures, and stakeholder roles as to the appropriate, agreed-upon implementation level activities. To help bring clarity to this issue, this study explored the current level of alignment between two of the stakeholders groups, industry and education, and conduct a survey related to the specific goals of California STEM programs. The survey also asked these two stakeholder groups about the roles and responsibilities of respective stakeholder groups when it comes to creating and supporting the STEM environment of the future, specifically in the areas of (a) education, (b) industry, and (c) government. The intent of this approach was to introduce the importance of a systems approach to the California STEM solution as well as to provide research data that demonstrates some of the potential disconnects that may exist across a sample of the current stakeholder community. Without an integrated and aligned understanding of specific stakeholder objectives and an aligned understanding of their respective roles in moving California toward solutions, it is unlikely that integrated and aligned solutions will emerge organically. Top-level alignment about the critical nature of the problem is important, but ultimately insufficient. Lower levels of alignment must be developed in order to best to address the California STEM workforce gap.

Significance of the Study

Despite the fact that there have been notable success stories in the STEM arena, little statistically significant progress has been made towards addressing this national crisis in spite of the fact that interest, money, policy, and industry all support engagement. While solving the STEM workforce shortage is clearly a complex problem, there is cause for optimism due to top-level alignment between educators, industry, non-profits, government, and communities relative to the importance of solving the STEM shortage problem. There is a willingness to invest time and capital in both the public and private sectors to accomplish this goal. Moreover, there has been a great deal of research documenting the issues facing the U.S., as well as a wide array of recommendations. The challenge lies in the ability of stakeholders to develop a common strategy at the proper level that will result in practical, sustainable, and scalable solutions. Creation of a common strategy would be enabled by utilizing a collaborative systems approach, incorporating expertise from industry, educators, and policymakers, and defining common goals and alignment on roles and responsibilities of the stakeholders in the system, creating solutions that are sufficiently agile to address regional differences, while simultaneously being common enough to create a workforce that addresses the projected shortfall of STEM capable workers in the future.

The most significant economic challenge appears to be how the money in the system is spent. At a recent *U.S. News & World Report* (2012) STEM Solutions conference, one of the knowledge tracks was dedicated to “Return on Investment: Creating a Framework for STEM Longevity.” Foundations such as the Gates Foundation, the AT&T Foundation, and the Carnegie Corporation discussed more systemic strategies for identifying the best programs, while collectively investing in making these programs scalable. Furthermore, the stakeholders must align on the measurements of effectiveness in order to ensure chosen strategies achieve their intended results. To that end, corporations have been collaborating with universities to define measurement systems in this complex area. Likewise, it is evident that measurement systems must be in alignment with things that are important to educators, industry, and the workforce; unfortunately, this has not historically been the case. Therefore, it should not come as a surprise that an unaligned system of objectives would create unaligned results.

An example of unaligned objectives can be found with industry strongly desiring common standards and a system of accountability for outcomes with teachers. The content of common standards needs to be collaboratively agreed upon to ensure it is in alignment with workforce needs. All agreed, for example, that teaching to tests have contributed to some of the negative aspects of the present predicament, and therefore, there needs to be more organically embedded ways to assess students as part of a significantly more active project-based learning processes.

Two themes that continued to come up at the aforementioned STEM solutions conference were the importance of collaboration and the challenge of scale (U.S. News & World Report, 2012). The collaboration discussion pointed to the need for integrated solutions across industry, educators, policy makers, and the community. The scale discussion revolved around numerous small success stories that need to be scaled to large successes in order to adequately address the STEM shortage challenge. The challenge of this particular system is to synchronize consumer needs with the products offered by the educational system. It seems appropriate, then, that systems thinking should be applied when designing approaches to complex enterprise problems. The study tied these theories to the collaboration and sustainability challenges of the California STEM challenge. The significance of this study is that current stakeholder leaders may benefit from applying systems thinking approaches to complex social problems such as the California STEM workforce gap resulting in large-scale improvement ideas that have the opportunity to make significant positive progress towards closing this gap.

Focus and Theoretical Foundation

The theoretical framework of this study sought to approach social problems from a systems perspective, exploring a systems based approach to problem solving when taking on an enterprise challenge that features a multiplicity of discrete stakeholders. This methodology is fundamental to solving complex engineering problems in which there is little ambiguity in regards to the importance of all the various project elements having to fit together at the end in order to produce a product or solve a technical problem. Applying common industry applied systems thinking approaches to complex social problems such as the California STEM challenge has the potential to provide the dramatic large scale improvement ideas required to move the needle on this problem. It was expected that current stakeholders would articulate a variety of goals as well as have divergent positions about each other's desired roles in addressing this problem. Lack of alignment, even when intentions are all noble, still leads to potentially suboptimal problem solving. Once there is specific awareness of the needs and objectives of each of the stakeholders, there must be deliberate strategy applied in order to create an overall master plan with measurable outcomes and clear accountabilities.

Central Research Questions

1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?

3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?

Approach

This study employed a quantitative research approach to characterize the current state of alignment across stakeholders. A selection of education leaders (superintendents, community college, and CSU/UC leaders) and STEM engaged industry leaders was surveyed to both better understand their perspectives of the relative importance of specific STEM goals, as well as their perspectives on their leadership roles and the roles and accountabilities of other stakeholder leaders in the system. The study also assessed the current state perspectives of these respondent leaders relative to the current level of collaboration and integration across the California stakeholders. Additionally, this study used the literature review as the primary vehicle through which to explore systems thinking, thus enabling the development of more effective strategies with which to approach the complex California STEM workforce challenge. In order to ascertain the current level of alignment relative to specific goals of the California STEM activity, as well as the roles of respective stakeholders, a common understanding of these areas across the core stakeholders is critical to creating and implementing a strategic, integrated design approach. This was accomplished using a purposive quantitative survey.

Operational Definitions

Alignment. When this study discusses alignment it is referring to the state of agreement about the relative importance of identified goals and roles of the respondent stakeholders being surveyed.

Collaboration. *"*Cooperative arrangement in which two or more parties, which may or may not have any previous relationship, work jointly towards a common goal" ("Collaboration," n.d., para. 1).

Stakeholders. For purposes of this research study 'stakeholders' refers to the key groups who most affect and who are most affected by policy, investment and decisions related to STEM in California. The stakeholder groups identified are industry, education, non-profits and foundations, government and the community.

Systems approach. "Management thinking that emphasizes the interdependence and interactive nature of elements within and external to an organization" ("Systems approach," n.d., para. 1).

Limitations

This research had some limitations, in that participants were responding to the questions with their own opinions, which may not necessarily reflect the reality of the current environment. The study also only surveyed two of the five stakeholder groups, industry and educators, as a representative indicator of the current state of CA STEM alignment across the larger stakeholder community with the belief that these two core stakeholders would illustrate the larger problem of misalignment across key stakeholder groups.

Key Assumptions

Key assumptions made by this study were that the leaders identified in both industry and education will take the time to respond to the research survey. The study also assumed that there are alignment issues within stakeholder groups and across stakeholder groups that are impacting California's ability to take consistent, integrated, focused actions to address the current workforce gaps. The proposed research survey would either support or disprove this theory. Finally, this research assumed that by illustrating the power and success of systems thinking in industry that the STEM community will embrace this and apply this concept as it defines California's STEM solution approach for the future.

Chapter Summary

Both the nation and California are faced with a critical threat to our long term strength and welfare due to an acknowledged deficit in STEM ready students and workers as we head into the 21st century. The STEM workforce gap requires integrated conversations and solutions as it impacts multiple stakeholder groups who do not necessarily fully comprehend each other's needs and challenges. This study utilized the literature review to explore the power of applying systems thinking to this complex social problem. In addition, the study quantitatively demonstrated the current state of alignment in California across two key stakeholder group's leaders, industry and education. The significance of this research is the potential for current leaders to use these findings to more deliberately design aligned, focused, solutions to the California STEM workforce gap at implementable levels so that real measureable progress can be made in the next few years.

Overview of the Chapters

Chapter 1 provides an introduction to this study, the statement of the problem, as well as the purpose and rationale of this study. This chapter begins a discussion about a theoretical foundation of systems thinking applied to social problems that will be explored further in the study. Chapter 2 provides additional background about the STEM workforce challenges and then looks at the thinking related to applying systems thinking to complex social problems, addressing open, parallel, and complex adaptive thinking, the importance of role and goal clarity and how to apply systems modeling approaches. Chapter 2 also explores critical STEM concepts such as sustainment, collaboration, alignment, partnerships and accountability, and the role of leadership. It concludes by discussing the current focus of the various key stakeholders in the STEM system. Chapter 3 characterizes the method that was employed to better understand the current state alignment around roles and goals in STEM in California. This includes the design of the research, the survey methodology, and the data analysis approach. Chapter 4 presents the results of the survey. Chapter 5 analyzes the survey results, their implications in approaching the STEM challenges in California going forward, as well identifying future research areas.

Chapter 2: Literature Review

Overview

The purpose of this quantitative study is to better understand the opportunities and challenges of designing timely, scalable solutions to the California STEM crisis. The objective of the literature review section is to better understand the current state of the STEM workforce space and why it has garnered so much attention and support across the country. Once that has been established, the framework for applying systems thinking and design as a proposed problem solving approach for the California STEM crisis will be explored. Inherent in systems thinking and design are various approaches to modeling that will also be assessed. Furthermore, a brief discussion about the importance of role clarity and clear goals when addressing a challenging systemic problem like California's STEM workforce gap will be investigated. Next, the discussion will review key process characteristics that have been widely socialized across the STEM stakeholder community, which is critical to addressing this national crisis. These include: sustainability and scalability; alignment, collaboration, and partnership; and the role of leaders in a systems design. These characteristics must be embedded in any proposed solution set. The study will then look at specific areas of focus across the broad stakeholder base of STEM, including: industry, educators, policy makers, non-profits, and the media. Finally, this review will conclude with specific stories exemplifying the successes that are possible when collaborative systems approaches are applied.

The STEM Crisis in the Literature

Despite basic alignment around the importance of addressing the STEM shortfall in the U.S. over the last 30 years, necessary improvements in workforce availability and competency have not been achieved (Axelrod, 2010; Camp, 1997; Haney, Madaus, Abrams, Miao, & Gruia, 2004). The National Research Council (2010), in a report revisiting a 2007 National Academy of Sciences study, concluded that despite considerable focus, America's competitive position has deteriorated when compared to demonstrable gains in other developed nations in math and science in K-12. While there is agreement about the problem, there is, unfortunately, insufficient integration around a solution approach that encompasses the critical stakeholders working the problem (Singer, 2011).

This lack of integration manifests itself in unclear roles and goals across the STEM delivery system. It is clear that understanding, aligning around, and communicating goals at each level of the STEM solutions system is vital to attacking the magnitude of the challenge.

An example of integration can be seen with accreditation programs like the Accreditation Board for Engineering and Technology (ABET), an engineering accrediting agency, which has identified specific learning outcomes, and must be able to demonstrate alignment with industry needs (Singer, 2011). The least damaging outcome of lack of integration in the STEM space is subsequent inefficiency and potentially suboptimal outcomes, as opposed to an ideal outcome. At its worst, this lack of integration can result in harsh warnings like the one from the U.S. Commission on National Security/21st Century (2001) which asserted,

> The U.S. need for the highest quality capital in science, mathematics, and engineering is not being met…Second only to a weapon of mass destruction detonating in an American city, we can think of nothing more dangerous than a

> failure to properly manage science, technology, and education for the common good over the next century. (p. 30)

Integration across the stakeholders is important because they are each dependent on the other for solutions. Industry has the workforce needs, whereas educators play a crucial role in helping to prepare the current and future workforce. Moreover, government and policy makers influence research and investment strategies, helping to support and develop our future technologies. Federal spending has long been one of the most important factors influencing high-technology research across industry (Logsdon, 2006). Communities understand the special needs of their constituents that make up the workforce. All students, as well as the current STEM workforce, must be made aware of the opportunities available to them to contribute and thrive in the STEM space. Media outlets can be particularly effective at disseminating these important messages. Because the problems and solutions are interconnected they cannot be effectively solved in isolation, but must be solved as the result of widespread cooperation and agreement. The America COMPETES Act of 2007 was a piece of bi-partisan legislation targeting three primary areas to address the 21st century innovation needs of the U.S., as identified by other studies (Council on Competitiveness, 2005; National Academies, 2007). The three areas covered were: increasing research investment, strengthening educational opportunities in STEM from kindergarten through graduate school, and developing an innovation infrastructure. These areas point to the criticality of creating systemic, integrated approaches that will involve educators, as well as the collective brainpower and financial support of the public and private sectors (Thomas & Williams, 2010).

Because there is such universal agreement relative to the STEM problem, the results continue to be disappointing. Although the rhetoric around the problem is urgent, reaction to the disappointing results is often more of the same: more money, more attention, more positive stories of pockets of success that are not able to be replicated into the kind of systemic, institutional, sustainable success required to solve the national STEM dilemma. This appears to point to the need for alternative problem solving approaches. An example of such an alternative approach, that ultimately proved successful, was when President John F. Kennedy declared that the U.S. was going to focus on Space, and two important things happened as a result, which ultimately led to success. The first was the establishment of a national sense of urgency and aligned importance; the second was a highly coordinated systems approach to attacking this unprecedented, national challenge. As President Kennedy stated in a 1962 speech,

> There is no strife, no prejudice, no national conflict in outer space as yet. Its hazards are hostile to us all. Its conquest deserves the best of all mankind, and its opportunity for peaceful cooperation many never come again. But why, some say, the moon? Why choose this as our goal?
>
> We choose to go to the moon. We choose to go to the moon in this decade…not because (they) are easy, but because (they) are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too. (paras. 15-16)

The next section of this literature review will look at a systems approach to problem solving.

A Systems Approach

The well-known industrial engineer, W. Edwards Deming (n.d.) once said; "It is not enough to do your best; you must know what to do, and THEN do your best" (para 2). The STEM realm is currently full of well-intended actors but it is not clear they all have clarity around their role in the overall STEM improvement project. The initial framing of the problem is one of the most important steps, but if the problem has not been properly characterized, the impulse to action can be counter productive. In complex multi-stakeholder problems, like the STEM challenge, this is particularly important. Pondering this theme, Moshe Rubenstein (1986), a noted systems thinker and problem solver, stated, "A problem well understood and well stated is often half solved" (p. 6). Therefore, presenting and re-presenting the problem from a variety of vantage points enhances our ability to both understand and be more creative about potential solutions. As a result, in addition to adequately characterizing the problem, the environment in which the problem exists must also be addressed.

How should the various stakeholders go about deconstructing the problem into actionable elements? There are a variety of systems strategies that are applicable, but whatever the strategy, it ought to be clearly articulated to the actors. Large enterprise problems share many similarities with complex natural systems. Systems thinkers that have studied natural systems have observed migration to order to complex scientific, technical, social, and organizational problems. Scientific, business, and social thinkers have discovered many congruencies by comparing problems to organisms, both of which are influenced by constantly changing environments as they constantly strive toward equilibrium (R.A. Johnson, Kast, & Rosenzweig, 1967; Meadows, 2008). In an effort to better understand existing theories and techniques with applicability to the current national STEM crisis, systems thinking, techniques of systems modeling, and human system strategies will be further explored.

Systems Thinking

Meadows (2008) defines systems as a collection of interconnected elements, and as a result they produce a behavior of their own over time. There may be forces acting within this system; therefore, how the system responds to those forces is an important characteristic to understand for one who is attempting to attain a deeper understanding. These responses, however, are seldom simple to interpret.

Systems are more than a summation of their component parts. Systems are dynamic, they can be both goal seeking and self-preserving, and they are capable of evolving. Applying a systems approach to solving complex problems is a common tool taught to engineers, scientists, and technologists. The techniques used to solve complex design problems are ironically often not applied in these same fields when it comes to social and infrastructure-oriented problems. These problems, it would seem, are not fully understood as possessing identically challenging characteristics to the typical technical design problem. To illustrate why this is erroneous, below are some examples of why the two are incredibly similar in nature. Both areas:

- Force review of the interrelationship between the various subsystems;
- Are dynamic processes that integrate all activities into a meaningful total system;
- Systematically assemble and match parts of the system into a unified whole;
- Seek an optimal solution or strategy to solving a given problem.

It seems evident that much of the current STEM challenge could be improved if problem-solving techniques were approached through the above lenses.

Kerzner (1979) goes on to describe the phases of a system life cycle:

- Translation: Terminology, problem objective, and selection criteria and constraints are defined and accepted by all participants;
- Analysis: All possible approaches, or alternatives, to the solution of the problem are stated;
- Trade-off: Selection criteria and constraints are applied to the alternatives in order to meet objectives;
- Synthesis: The best solution in reaching the objective of the system is the combined result of analysis and trade-off phases. (p. 33)

Systems thinkers understand that looking at the whole is crucial to ensuring success of the overall project.

Just as no one would imagine building a complex machine, performing a complex surgery, or hosting a large social event without an integrated, detailed master plan, there are a multiplicity of environments in which problem solvers must operate. Some are relevant to the STEM challenge and will be further explored. These include open systems, parallel systems, and complex adaptive systems.

Open systems. The idea of open systems was first developed by Ludwig von Bertalanffy in the 1930s. Living systems were characterized as open systems constantly maintaining themselves as they interacted with the environment building up and breaking down their components (von Bertalanffy, 1950). Open systems thinking was expanded beyond classic scientific applications to applications in the social sciences, and therefore appear to be particularly relevant in helping to understand the environmental challenges related to the STEM problem. Open systems are essentially leaderless systems, at least as they are defined by our traditional organizational sense, which focuses on the participants as opposed to the leaders. Another way to think about open systems is that they trend toward a heavily decentralized structure. Brafman and Beckstrom (2006) developed a set of principles that are in play in these kinds of environments:

- When attacked they tend to become even more open;
- It is easy to mistake starfish for spiders (the authors describe starfish as analogous to more decentralized environments, if a starfish loses a leg, it grows another. A spider, on the other hand, is analogous to a centralized structure, and will die if it loses its head);
- An open system does not have central intelligence, as intelligence is spread throughout the system;
- These organizations can sneak up on you because of their ability to rapidly transform and mutate;
- As industries become decentralized, overall profits decrease.

Brafman and Beckstrom also posit 10 questions to identify whether one is operating in an open system environment:

- Is someone in charge?
- Is there a headquarters?
- If you thump it on the head, will it die?
- Is there a clear division of roles?
- If you take out a unit, is the organization harmed?

- Are knowledge and power concentrated or distributed?
- Is the organization flexible or rigid?
- Can you count the number of employees or participants?
- Are the groups funded by the organization or are they self funded?
- Do working groups communicate directly or through intermediaries?

By evaluating the characteristics of the environment in which the problem is being solved, the designers are more likely to discover appropriate solutions. The intent is not to argue that open systems are better than closed systems. The objective is to understand the nature of the problem and the environment, and then with that information, to be deliberate about which approach is more appropriate. In the STEM arena, by its very nature of multiple stakeholders and organizational structures, the answers to these questions show the environment to be very decentralized. There are several leaders of activities within the system and it is not obvious which have been charged with solving the overall problem itself. That is not necessarily a problem if the system is designed to optimize a collaboration model. Wikipedia is an example of an open collaboration, where the users manage information, as opposed to a central core of identifiable experts. In this environment there is also an identified and emerging concept of operations that has evolved steadily through use. That evolution is made possible because of the feedback that is a critical and constant element of any successful open system. In thriving open systems environments, the system fosters connections and keeps them fed with information. The system must be clear about its purpose and understand that people can and will self-organize and trust them to do exactly that (Wheatley &

Kellner-Rogers, 1999). Figure 1 presents a model of an open system, as described by Hanna (1997).

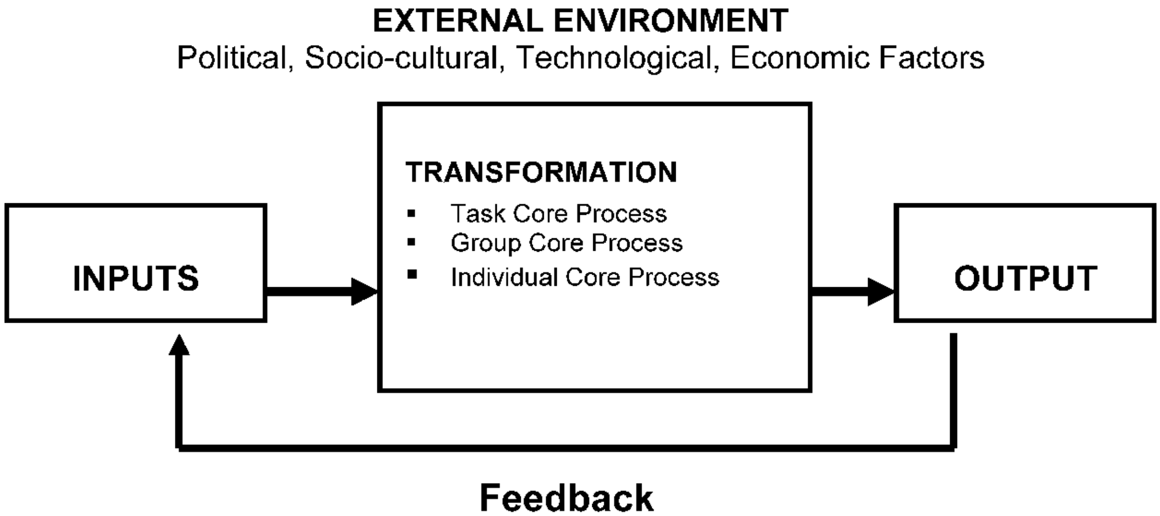

Figure 1. Open systems model. Adapted from "The Organization as an Open System" by D. Hanna, in A. Harris, N. Bennett, & M. Prevy (Eds.), *Organizational Effectiveness and Improvement in Education* (p. 16), 1997, Buckingham, United Kingdom: Open University Press. Copyright 1997 by Open University Press. Adapted with permission.

Parallel systems. There are a variety of methods that can approach solving large systems problems. Parallel systems help in the migration from a lot of messy creativity towards solutions. This methodology allows for simultaneous activity that helps move activity towards solutions quicker than from a controlled serial design process. In open systems, parallelism can be seen with an innovation challenge that is given to a large base of virtual designers. Some technology companies such as Procter & Gamble (P & G) are expanding their traditional research and design (R & D) space by going to the Web and having innovators register to compete for cash awards as a reward for providing ideas for products and services (Tapscott & Williams, 2008). This kind of unstructured parallelism allows for broad creativity, as opposed to perfection, and though some errors may be created in the process, the potential for reward is much larger than it would be from just looking for solutions with the network (Wheatley & Kellner-Rogers, 1999).

There are also more structured forms of parallel thinking. Large design projects, for example, generally involve teams of diverse thinkers with different roles. Traditional design moves from one step to the other in a linear series moving from one functional expert group to the next. Parallel processing allows for a cross-functional group of thinkers to be presented with the challenge as a group. As other perspectives are raised earlier in the design process with insights that would not have come from individual subject matter experts, this forces a more integrated form of problem solving. Moreover, this allows for minimization of rework downstream as cross-functional expertise is exploited (Imai, Nonaka, & Fakeuchi, as cited in Galanakis, 2006). Another application of structured parallel thinking was developed by de Bono (1999), who addressed the problem by assigning different specified roles to participants, with the intent of forcing issues to be looked at from all sides, thus ensuring any blind spots are minimized.

The national STEM challenge already exhibits significant parallel processing behaviors due to the fact that a multitude of ideas are piloted in parallel. Some projects, for example, organize across functions to create mini systems of success. The challenge of an unstructured parallel systems environment is that there is no operational framework feeding the ideas. The P & G example illustrates a framework of a controlled open system using parallel thinking to collect innovative ideas. When a framework is lacking, however, ideas can become free-floating with potential, while ultimately lacking a coherent mechanism for actualization.

The STEM challenge, therefore, could benefit from a deliberate systems approach designed to create alignment across the broad stakeholder base. The stakeholder base has demonstrated strong interest in the challenge as evidenced by the current levels of investment and activity even though their collective efforts have not yet delivered sufficient results to bridge the gap.

Complex Adaptive Systems (CASs). CAS thinking is important when trying to find solutions inside a systems network with elements that are highly dependent upon one another. In this area, an important distinction must be made between complicated and complex. A complicated system may contain a multitude of elements, but interdependencies between these elements are less significant. In other words, if you change an element within a complicated system, it will still function. However, if you change an element within a complex inter-related system, it can fail (N. Johnson, 2009; Miller & Page, 2007). This distinction is particularly important to keep in mind when designing a systems solution approach because it impacts how innovation can be introduced inside that system. In a complicated system you can isolate variables, take an action and then interpret results that are directly related to the action taken. In complex systems, on the other hand, the interactions occur simultaneously across multiple elements, impacting some to a greater or lesser degree, thus making it considerably more difficult to analyze a single variable for cause and effect.

To assist in determining whether the system is complicated or complex, the following is a series of characteristics that have been identified for complex systems:

- The systems has a collection of interacting elements or people;
- These elements or people are affected by memory or feedback;
- Elements can adapt their strategies based on their history;
- The system is typically open;
- The system seems to be alive;

- The system demonstrates emergent phenomena which are generally surprising and may be extreme (e.g. stock markets, traffic wherein events can cause extreme often unanticipated reactions);
- The emergent phenomena generally occurs without an obvious controller;
- The system shows a complicated mix of ordered and disordered behavior (N. Johnson, 2009).

It seems an appropriate fit to directly apply CAS to STEM. This is because if the STEM ecosystem is addressed as a complex collection of agents that fit the above characterizations, then the current independent, linear approaches will not yield the desired results. Despite decades of focus and commitment, the current linear, non-systemic approaches are not closing the STEM gap (Stephens & Richey, 2011).

Systems thinking: Summary. Exploration of open systems, parallel systems, and CASs provide insight into the challenges and opportunities inherent in thinking about the national STEM challenge from a systems perspective. The value of this perspective is, ideally, to derive solution approaches that might help to make a dent in the problem. There are two other core considerations when designing a solutions approach. The first requires actors within the system to be clear about the goals of the effort, and there must be, as a result, feedback built into the system. The second consideration is that system designers must be sensitive to the power of paradigms in how the environment is designed and interpreted. Paradigms lock individuals into a pre-defined way of thinking about an issue based on their past experience and may limit openness to new ideas or approaches.

A great deal of discussion should go into the goals of any system. A commonly held belief is that systems in and of themselves are perfectly designed to get the results they are currently getting, and for that reason designers must understand what they are trying to achieve. It is important that in a complex systems environment, with so many stakeholders, alignment around the goal(s) must be a very deliberate process. Drucker (1999) uses the American school system as an example of what happens goals and objectives are misaligned. Drucker introduced the idea of the knowledge worker as differentiated from the historic blue-collar workers who had very routine work with discrete instructions for completion. The knowledge worker often knows more about his or her work then their supervisor and must be able to think and problem solve to execute their work versus performing predetermined work. The educational system has not evolved to consider the required skills of the knowledge worker including problem solving and critical thinking. The system must consider what industry needs from the knowledge worker as well as what the educational system should be focused on addressing and delivering. Requiring stakeholders to vigorously address these questions is critical to driving desired outcomes. A familiar exchange from Lewis Carroll's (1865/1993) beloved classic *Alice in Wonderland* illustrates the importance of focus. Though the following exchange between Alice and the Cheshire Cat is fictitious, unfortunately it takes on a great many characteristics of the current state of results in STEM:

> "Would you tell me, please, which way I ought to go from here?"
>
> "That depends a good deal on where you want to get to," said the Cat.
>
> "I don't much care where–" said Alice.

"Then it doesn't matter which way you go," said the Cat.

"–so long as I get SOMEWHERE," Alice added as an explanation.

"Oh, you're sure to do that," said the Cat, "if you only walk long enough." (p. 41)

Just wanting to get *somewhere* is not sufficient, as current results are demonstrating. Just going anywhere without direction is not necessarily an improvement and can in fact be a waste of energy, making it potentially worse than doing nothing at all.

The gravity of the STEM workforce gap necessitates clarity with respect to stakeholder roles and goals when taking action and expending resources in this system. The good news is that ample research exists characterizing the nature of the current state identifying both spot successes as well as some areas that appear to be high lift areas of focus such as targeting the retention of STEM students in STEM degrees during the first 2 years of college, or understanding the impact of STEM capable teachers in K-8 on student interest in STEM in subsequent grades (BHEF, 2007; Bozell & Goldberg, 2009; Complete College America, 2011; U.S. Department of Commerce, 2012). These studies should serve as resources to design the models that will create outcome predictions for the stakeholders to use as they decide about how best to focus attention and critical resources. Moreover, stakeholders in this complex STEM system should take the time to understand how they can best contribute to enhancing the ecosystem. The Business Higher Education Forum (BHEF, 2007) created a list of the discrete roles of five stakeholder groups:

1. The federal government should play a leading role in bolstering research efforts to identify and disseminate promising practices, and to support

programs that are effective in increasing student achievement in mathematics and science;

2. State governments need to establish more coherent statewide policies as well as coordinate the efforts of other stakeholders;
3. School districts must establish district-wide policies that are suited to local needs and conditions, yet aligned with federal and state policies;
4. Higher education activities should focus on investing in and strengthening teacher preparation and professional development programs in mathematics and science, and on research that can led to new insights into effective teaching and learning methods;
5. Business and foundations need to publicly champion policies and support effective programs. (pp. 5-6)

The importance of these role descriptions is not necessarily in their specific content but rather in the notion that stakeholders take the necessary time to create those definitions collaboratively, thus ensuring alignment of focus moving forward.

After aligning on the *what* and the *who*, the system must then be designed to include measureable feedback mechanisms in order to determine if it is properly designed to accomplish its stated objectives. In this critical discussion, CASs have been presented, and one of the lessons learned has been that results from these systems are often neither linear nor easy to predict, and may even be counterintuitive (Meadows, 2008). Feedback provides the design team information about what the current model is capable of delivering. If the current stated results are not consistent with the desired results, the system must be tweaked and the results monitored as the inter-relationships of the elements become better understood.

Finally, the power of paradigms should be addressed when the goals and associated structures of any complex problem are considered. Paradigms inform how individuals perceive how things work. Generally, little discussion is required to obtain alignment around paradigms, because they are generally accepted ways of understanding the workings of the world (Meadows, 2008). The challenge, then, is that when solving new complex system problems, old paradigms may or may not fit, and if this is the case, they can be very hard to change. When scientists in the 1600s were evolving theories that the motions of the planets were centered around the Sun and not the Earth, it took decades of proof and a great deal of personal risk to alter this widely accepted paradigm. This is because it is hard to see something differently from the way people have been hardwired to see them. This is where systems modeling can be a very powerful tool.

Systems Modeling

Systems modeling is a technique utilized in science, technology, and engineering to understand the effects of integrating various solution options. Modeling can help to predict how systems will react through simulations. Interestingly, the very disciplines that STEM stakeholders are working hard to ensure future sustainability may also hold the key to defining the future robust solutions to the STEM workforce problem. Before looking into specific modeling approaches, there a few considerations that will help set the stage for successful modeling.

Within a systems model there are multiple levels of understanding the problem. When addressing systemic problems such as the STEM workforce gap, solutions must focus on moving the nation from a mode in which we are constantly putting out fires to a more preventative mode. In order to assess the stakeholders' articulated, shared vision, stakeholder problem solvers must simultaneously look at the various levels of the current state challenge. At the ground level, there must be an understanding of specific symptoms or events, such as STEM students' education and vocational interests as they progress through our education system. Above that level the analyst must look for patterns across these events in which common characteristics can be identified. Furthermore, problem solvers need to understand what is systemically creating these patterns in the organization or the existing infrastructure and all of these levels of activity should be assessed against the stated goal (Kim, 2000).

Especially when looking at the California STEM problem, we have multiple levels within levels. Each of these levels described exist within the local, district, regional, state and federal levels. This must be understood and strategically analyzed when creating a systems modeling approach. When the problem is assessed against all these levels simultaneously, it ensures the problem will be deeply understood so that the resulting solutions are not one-dimensional. When analyzed in this fashion, solutions can be more skillfully designed to move the current state into the future.

In the STEM space, there needs to be consistency and alignment from the local level, before aggregating at the district or regional level, ultimately moving to the state, and them finally to the federal level (Collins, Weinbaum, Ramon, & Vaughan, 2009). If we are going to get to the root of the problems and define systems models that will impact the major leverage points in a system, the system must consider the goals and needs of all levels and stakeholders. If the systems design team does not possess an adequate characterization of the problem they will not be able to set up accurate models to simulate options.

Another common mistake that can impact a modeling effort is when the real problem gets ignored. Often the most serious issue is deemed too difficult to tackle, and so teams will take on something else they believe they can better handle. While this approach may at least lead to a perception that progress is being made, the truth of the matter is that often it may be better to do nothing than to tinker at the margins while the main issues remains unsolved (Collins et al., 2009). When communities or investors commit to a plan and see nominal or potentially negative results, well-intended actions run the risk of resulting in disillusioned stakeholders who, as a result become less likely to support future efforts.

A final key element that should be considered before beginning a modeling effort is ensuring all stakeholders share a common language and have access to the same information. This is important to consider, because educators generally do not speak the language of industry, likewise industry is generally not oriented to the themes and challenges of the educator's framework. These language and framework knowledge gaps exist across the board in all facets of the STEM stakeholder networks, including government, non-profits, the community, and the students; and some of these gaps are easier to bridge than others. Often, these groups work almost entirely in their own silos and do not have the opportunity to interact outside their network. In an interdependent network, the language and framework issues must be addressed to up front to insure basic alignment in the language and objectives. It should never be assumed this alignment is a given. The language and framework must be deliberately articulated and designed into the up front process.

Models are useful tools in approaching complex systems because they allow developers to simulate potential solution areas to better understand potential outcomes. While models can be powerful enablers, they are also tools, and leaders must be able to both set up the models with specific pre-defined objectives, values and options, and also assess potential outcomes of the models so they can make the right decisions (Rubenstein, 1986).

A model is a calculator that can be wielded to better understand complex social problems. This power can only be actualized when complex scientific models are developed with thought and care. Though a model may be characterized as being successful, a decision maker must ultimately be sufficiently knowledgeable about how the inputs are designed and the outcomes are applied (Miller & Page, 2007).

When deriving information from a STEM model, one must be clear about the problem being addressed. For example, while examining why students are dropping out of STEM studies could be the problem around which a systems model is designed, a different model would also be required if the inquiry was to determine the key factors impacting student selection of, and success with, a STEM path (Kokkelenberg & Sinha, 2010). These are different frameworks, and they will result in different outcomes informing the decision makers. As a result, it is critical that questions be framed correctly. A current real life example of applying a systems model to the STEM problem can be found in work done at Raytheon by a group of systems engineers. As former co-chair of BHEF, the CEO of Raytheon, Bill Swanson, committed the energies of his company's systems engineering expertise to exploring the STEM workforce challenge. His goal was to determine the most effective set of actions that would need to be put into place in order to double the number of STEM graduates by 2015. The engineers used a dynamic systems-engineering model of the P-16 STEM education system. The primary objective of the model was to inform decision makers as they determined the effectiveness of various policy alternatives relating to STEM outcomes. A secondary objective was to share the approach with a community of researchers and model users in order to validate and further develop the model, and then to release the model as an open source tool that could be enhanced through use in the STEM community (BHEF, 2010; Wells, Sanchez, & Attridge, 2009). It should be noted that this secondary objective of sharing and further developing these kinds of models through use and critique is a critical to improving any system.

There are various questions that need to be directed at these models once they are developed, such as: do the defined driving factors act as modeled? If they do, does the model appear to emulate the way the system would likely act? And finally, is there a good understanding of what is driving the drivers (Meadows, 2008)? Miller and Page (2007) expand upon the challenge of this science by comparing the creation of a model to attempting to solve a brainteaser. The challenge is very difficult and requires the application of art, practice and theory to figure it out. The solution once found, using the integration of these approaches, often has a compelling appeal and seems obvious.

The power of a good model in helping to move the needle on complex social issues should not be underrated, particularly in a landscape currently peppered with significant activity and investments but disappointing results. Strategic policy decisions in STEM can be significantly improved by addressing the workforce problem as a system with interdependencies, many feedback loops, and the need to be adaptive (Hira, 2010). The benefits of utilizing system dynamics modeling have been long apparent and applied in scientific and engineering problem solving. Social systems problems exhibit many of the same characteristics as complex technical challenges. Utilizing these techniques to address policy issues can:

- Demonstrate the capacity of the system to support the desired outcomes, often revealing unintended consequences in the process;
- Display the time lag between the implementation of a program or policy and the desired outcomes;
- Depoliticize discussions of education improvement by using systemic outcomes (i.e., increasing the number of STEM graduates in the U.S.), rather than specific programs or policies, as a starting point;
- Allow for examination of the relative cost associated with implementing different policies. (BHEF, 2010, p. 5)

The objective of exploring systems thinking and modeling is to arm decision makers with new tools that will improve the outcomes in a real social system problem (Miller & Page, 2007; Subotnik, Tai, Rickoff, & Almarode, 2010) such as the STEM workforce challenge.

Human Systems Strategies

So far, this study has explored how systems thinking and dynamic systems modeling capabilities can be used to enable decision makers as they collectively create strategies to address the STEM workforce gap. A systems focus requires clarity and alignment around the roles and goals of stakeholders across the system. Human systems in any organization are focused on people and how they interact and respond within a management framework. This research will address organizational design approach, the social side of the organization, the impact of the leader's behavior on the organization, and leadership training, development, and selection strategies that impact human systems. Assessing the human systems environment allows researchers and leaders to look at how theory is put into practice within organizations, whether deliberately strategized or randomly evolved. The STEM human systems strategy framework sits inside an open system, as there is no specified leader of California STEM.

Human systems design sets the stage for the internal and external interactions of an organization. The sequential model discussed by Bush and Frohman (1991) is used by a multitude of organizations. This model is often exercised on very complex technology projects in which design rigor is applied to create a market innovation or address a specific identified threat. In the sequential model, designs move through prescribed phases and functions in a serial fashion. They cite positive elements including attributes of clear accountability, high specializations, and clarity of specialist roles. On the other hand, this model is slow, requires many handoffs and inherent rework of outputs, as each receiver will identify deficiencies as they relate to their specific phase. Because this process is sequential by its nature, Bush and Frohman note several inherent downsides: slow and costly product development cycles, the danger of picking the wrong programs to focus on due to a lack of information about other opportunities, and organizations' inability to tap into the available creativity of their functions due to the cumbersome nature of their formal communications structures. At its worst, the sequential model has the potential to result in communication breakdowns, such as the space shuttle disasters of the Challenger and Columbia.

Contrasting the sequential model is the development model in which innovation is goal oriented, functionally interactive, and can emerge from anywhere within the organization (Bush & Frohman, 1991). All members share the same goal and commitment as well as an integrated understanding of the challenges facing their team as well as their respective capabilities and contributions. This developmental model was described as a network design.

Transitioning from a sequential model to a network model requires a deliberate strategic shift by the leadership. According to Bush and Frohman (1991), several traditional human system mechanisms will need to be restructured in order to enable network design. Subject matter specialists require new roles and rewards models, and program and project goals need to be integrated across team members in order to ensure alignment. Functional managers must refocus to enterprise perspectives when analyzing impacts as well as manage and reward in a different fashion than they may have historically operated. This is particularly true in an open systems model where recognition and rewards are much more intrinsic to the individual stakeholders, and not managed through any formal central system. Critical leadership and individual contributor skills required in this framework include the ability to collaborate and interact as team members. Leaders and team members must encourage and tolerate mistakes that promote rapid and continuous learning. Another important characteristic of a network organization is to develop policies and operating models that function for networks. In summary, network organizational design extends the widely accepted concept of integration inherent in systems engineering to other broad networks of stakeholders in order to bring innovations to market.

In another study, Weston et al. (2001) created a modeling tool that addressed the elements of human resources systems. Several use cases were developed in creating this model, such as evaluating the human assets of an organization through defined elements, training programs, and their fit and change assessments; evaluating and creating new roles tied to collaborative expectations in a new strategic model; developing an enterprise model around processes and resources; and rolling out a new information system.

Particularly intriguing was the authors' analytical engineering methodologies applied to the soft science side of human systems. The authors noted that in a mixed environment with stakeholders representing technical, business and policy-makers, incorporating this kind of math-based approach provides a methodology that results-oriented leaders may be more comfortable with. Even more important is ensuring that these leaders actually experience systems engineering approaches being applied to complex social systems to execute a major non-technical joint initiative.

Lazarus (Lazarus & Davis, 2006) illuminates another example of human systems design with attributes that are a good fit in an open systems environment, in an interview with successful leader, Richard Davis, who transformed a small family optical retail business into a large high-performing enterprise employing almost 35 million people. Davis accomplished this through what he referred to as organic management, believing that by being clear and consistent about the framework and organizational systems, an environment that allowed individuals to thrive can be created. By establishing clear corporate values and measures, what Davis calls the *framework*, expectations are clear and his employees are expected and empowered to solve the challenges of *their* company. In so doing, Davis has created a culture of alignment that is solutions-oriented, as opposed to problem-oriented, in which employees as co-owners evaluate their own performance against the framework of the existing values and goals (Lazarus & Davis, 2006). This model, incorporating frameworks designed in up front, incorporating both alignment and empowerment, appears to be a good fit for an open systems framework.

There are many potential organizational models that can meet the human systems objectives of a systems challenge. All large initiatives must have a human systems structure in place, and the challenge is for systems design leaders to be deliberate about the chosen structure in order to enable the overall initiative strategy. In order to be effective in deliberation, leadership must recognize the fact that social factors play a key role in optimizing the solution approach. Likewise, institutional designs of organizations play an important role in the structure and quality of inter-organizational relationships (Fornahl & Brenner 2003; Keeble & Weever, 1986).

An example that helps to demonstrate the importance of focusing on the social aspects of strategy and design can be seen in how business acquisitions are managed. Approximately 85% of acquisitions fall short of their projected goals because they have not been adequately prepared for the social side of the challenge (Chatzkel & Saint-Onge, 2007). A strategy presented by Chatzkel and Saint-Onge (2007) known as the generative value approach, identifies the importance of integrating both the cost synergy and growth synergy aspects of any acquisition. The argument is that this approach will advantageously pre-position the new acquisition within the acquiring organization for success and or growth.

Leaders must play an active role in all stages of an acquisition, including the communications and behavior approaches that are used at all stages, from negotiation through integration. Specifically, they must focus on the importance of ensuring the existence of integrated conversations by modeling these behaviors and utilizing their extensive knowledge, experience and insights across all levels and functions of an organization. It should be noted that these integrative behaviors could be difficult for leaders who have operated in more traditional constructs. Leaders, however, must understand that their employees watch them closely, and therefore it is critical for there to be alignment between what they say and what they do. The challenge facing STEM leaders is much like that of executive management mergers, who must work in alignment with stockholders, even though their respective internal working language, interests, and concerns are likely to be different. Furthermore, there may be issues of trust that come up even if all parties accept the premise that union throughout the stakeholders community is vital to addressing the problem, which in this case is addressing the STEM workforce gap. The STEM community has already taken steps towards addressing this through STEM connector non-profits such as the California STEM Learning Network (CSLNet), whose mission is to create a network of stakeholders focused on building a world-class STEM education system that prepares students to succeed in higher education and in life while emphasizing STEM.

Connector organizations like the CSLNet are critical, particularly in an open system, where no one traditional stakeholder has the role of ensuring system integration. Social dynamics are critical to all organizations, and in order to optimize organizational performance, leaders must strategically determine how to tap into the human power of their organization (Kets de Vries, 2001).

Fortune Magazine publishes the 100 best companies to work for list annually, in which they emphasize such critical characteristics as inspirational leadership and a sense of purpose. Employees in the firms on the Forbes list had trust in their management, a sense of pride in their work and company, as well as a spirit of camaraderie (Kets de Vries, 2001). These companies deliberately designed human systems that would positively impact their employees. Therefore organizations of the future will need to compete for people, their most critical resource, in different ways than organizations have in the past. As a result, in order for organizations to attract the best talent, according to Kets de Vries (2001), they must create:

- A sense of purpose for their employees by defining their corporate values and beliefs;
- A sense of self determination so that employees feel some control over their lives as contributors not pawns;
- A sense of impact, that they make a difference;
- A sense of competence with continued growth and development;
- A sense of belonging, creating attachment and affiliation;
- A sense of enjoyment and meaning in what they are doing;
- A sense of meaning that the employee is personally invested in via their imagination and creativity. (pp. 108-109)

These attributes carry even more significance for a voluntary alliance of stakeholders like STEM, where engagement is not compulsory.

Billis (2008) discussed the importance of the social side of business in a review of people systems done for the purpose of achieving policy purposes. Billis observed that even though many social ideas appear obvious, they are often not enacted in the workplace. Integration and interaction, if not enabled by strong human resource processes and common incentives, will not materialize inside traditional organizations. Alignment is a bi-product of common goals in a systems focused environment. There is not a one-size-fits-all answer for this human systems strategy. That is not the point of the discussion. The point rather, is that initiative leaders must address the social side as seriously and strategically as they do the other more traditional business strategy elements.

In addition to focusing on structural enablers within the organization, it is critical to explore the importance of leaders as role models. Consistent with the premise that there is not one answer for all companies, van Marrewijk (2004) presents a model that starts with determining the organizational objective relative to the contribution of people within the organization. Van Marrewijk characterizes four models with fundamentally different organizational purposes: compliance driven, profit-driven, care/community driven, and systemic driven synergy. Each of these models then further characterizes other relevant factors, such as values, which enable organizational structures, decision methodologies, key stakeholders, interaction with the community, appropriate leadership styles, communication approach, people management style, functional people management, workplace environment, health and safety, diversity focus, consumer focus, product pricing models, and supplier interface, all of which must be looked at individually. The importance of this model is to illustrate the depth that leaders must go to deliberately create an operating model that is consistent with their principles. In an open systems environment the stakeholders must create this model deliberately and collaboratively, and be prepared to adjust as the measures of success dictate.

Once the model is defined and communicated, executing the model through active leadership example is critical to establishing credibility. A study by van Quaquebeke, Kerschreiter, Buxton, and van Dick (2009) looked at the importance of consistency of values between employees and their leaders, both in ideal values and in counter-ideal values, to understand the impact of that consistency on performance. According to their research, leaders with values that are consistent with those of their employees tend to evaluate those employees more favorably. Employees with values that are comparable with those of their supervisors felt greater commitment to the company and reported a higher level of job satisfaction.

Likewise, supervisors play a particularly important role in modeling the values of the corporation and thereby impacting the organizational commitment of their direct reports. Employees that are highly committed adopt the goals and values of their workplace and go to great lengths to ensure organizational goals are met. Because supervisors act as the primary cultural influences of the company as employees are socialized to the organization through their supervisors, the importance of this front line influence is critical to guaranteeing adequate staffing and training, thus ensuring leaders at all levels represent the moral values of the firm (Jiang, Lin, & Lin, 2011).

While the STEM challenge must be addressed in an open systems environment, many of the stakeholder groups that support this open system simultaneously exist within the framework of a traditional management infrastructure, which themselves will likely be evolving as a result of STEM recommendations. As a result teachers will need extensive communication, potential retraining, and deep engagement and alignment with education reform strategies. Human systems strategies will need to be addressed at all levels of implementation as STEM strategies are developed and rolled out.

A final aspect of leadership is demonstrated in the actual compensation schemas of the organization. If organizations incentivize their leaders or other personnel with specific expectations, they should expect their behaviors to conform similarly (Greenfield, Norman, & Wier, 2008). Healy (1985) showed that the incentives around earnings management, driven by compensation bonuses, often motivated less-than-desirable organizational behaviors. Therefore it is important that leadership evaluate their goals, performance evaluation systems, and reward processes in order to best understand their own contribution to incentivizing behaviors that might be inconsistent with the values of their firms.

Again, with respect to STEM, there will be a need for some revised internal compensation strategies for groups like teachers and industry subject matter experts who are contributing to CA STEM enrichment in order to ensure there is alignment and value associated with the desired outcome. Many current contributors operate based on their own intrinsic motivation, but leaders should ensure that robust reinforcing models are also put in place. Stakeholder leaders in the open system environment must be clear about what is in it for them and make sure the interdependent system is designed to deliver to the varied needs of the critical stakeholders.

Finally, the exploration of human systems, selection, assessment and training of current and future leaders will be addressed. STEM leadership is the focus of this study and one of interesting gaps identified in the required course work of engineers (who often become the future leaders in STEM industry), is a lack of human systems engineering training to ensure readiness to address areas of trust, conflict, commitment, accountability, and human systems leadership strategies that are consistent with the organizational mission. Confirming this gap, ABET-certified university engineering courses lack emphasis of knowledge and skills in human systems engineering (Hayden, 2006). In addition to addressing the education focus of the social side of leadership for engineers and business students, future leaders should also be assessed, during the orientation process, for emotional intelligence, social judgment, and problem solving skills (Connelly et al., 2000; Zaccaro, Mumford, Connelly, Marks, & Gilbert, 2000). Research in the area of emotional intelligence, as opposed to base IQ, indicates that while almost all executives score in the middle-to-upper ranges in IQ, emotional intelligence is a higher predictor of leadership effectiveness (Harshman & Harshman, 2008).

Cherniss (2000) asserted that an individual's social and emotional capabilities were four times the importance of IQ in ascertaining the success and prestige of that individual. When leaders make organizational mistakes, it is not because they are not intellectually smart. They often lack critical emotional intelligence that enables situational awareness, which is important to effective executive decision-making. Imposing assessments on executive candidates is often perceived as a tactic that will scare perspective candidates away. On the other hand, statistics show the average tenure of CEOs is less than 2 years, a very short time for such a complex role, which points to the need to do a more thorough vetting (Harshman & Harshman, 2008). Therefore it is critical to refocus on the education and leadership development of future leaders, as well as the establishment of additional rigors related to the process of recruiting executive leaders.

Additional STEM Environmental Requirements

An examination of the literature relative to systems thinking, systems modeling, and human systems design indicates considerable potential for successful application to the STEM workforce challenge facing California. Next, the literature review will explore additional characteristics that have been identified as critical success factors for STEM success. These characteristics include scalability and sustainability of solutions that are being proposed for implementation. Across the U.S., there have been spots of brilliant successes, but over the last couple of decades these spots have not individually been able to move the STEM needle on a large scale. Another area of importance to STEM success, then, is the need for alignment and collaboration across the core stakeholders in this open system. Partnerships and accountability create mechanisms that ensue stakeholders do indeed have a personal stake in the initiative outcomes. Finally, the review will look at the role of leadership in an open systems environment.

Scalability and sustainability. The discussion about scalability in this literature review will be rather brief, because efforts to date have not succeeded in closing the workforce gap, despite the fact that some efforts have been effective on a small scale. As previously mentioned, scalability is one of the primary challenges to addressing the STEM workforce gap. Despite over a decade of focus, investment, robust pilots, and noble policy efforts like NCLB, the results are not yet achieving scalable success. It is evident that this is not a one-size fits all problem; as such, solutions must be designed with agility to adapt to the existing state, regional, and community issues in order to design in success. A couple of other success attributes to scalability are robust measurement and the ability to replicate the approach (Bozell & Goldberg, 2009; Goldstein, 2011).

Successful sustainability, on the other hand, has been a characteristic of many positive trends, which will be discussed later in the literature review. Attributes that enable sustainability include repeatability by players who will likely change over time. Successful, sustainable programs must be designed with a long-term professional development and training strategy so that no single individual's presence will make or break the program (Bredin et al., 2010). Sustainable programs also must build in a lessons learned component in order to ensure that the program continue to thrive, while also continuing to polish aspects that are working well while improving elements that are not. Meadows (2008) describes resilience as a critical element of sustainment in systems. Resilience comes from systems with robust feedback loops and built in redundancy to avoid single point failures. Resilience needs to be deliberately, strategically, and affordably built in. It is also an important characteristic that leaders within the system need to embody; this is because persistence and the ability to bounce back are critical to success, particularly when new systems approaches are being designed and introduced (Myers, Jahn, Gailliard, & Stoltzfus, 2011).

In a large complex system like the California STEM system, the whole needs to be designed as an interdependent open system with the upper layers serving the needs of the lower levels. In addition to individual and system resilience, a sustainable system must have enough autonomy to self organize as required, and the inherent hierarchy of a large system has to balance the responsibilities, freedoms, and welfare of the subsystems and the overall system (Meadows, 2008). To achieve this balance, all levels of the system need to be designed with the capacity of the intended user in mind. This is best achieved by approaching the design as a collaboration opportunity between actual representatives of the user communities, thus helping to build ownership and voice from the beginning.

Furthermore, a large complex system must be designed with evolution in mind (Bredin et al., 2010). A specific example of integration and collaboration ensuring sustainment occurs when certifications and college credit classes are offered by the education system based on specific requirements for the workforce as defined by prospective employers (Bozell & Goldberg, 2009). This must not be a one-time discussion between industry and academia as workforce needs will continue to evolve.

An additional negative indicator of sustainability currently plaguing the STEM system is the inability to both attract and retain STEM workers. Employers, educators, and the media must understand how best to channel the existing opportunities within STEM fields, finding better solutions to retaining STEM workers over the long term (Myers et al., 2011). Three years after attaining their degrees, fewer than 45% of those who receive STEM bachelor's degrees end up working in STEM-related jobs or pursuing STEM post-graduate degrees (Lowell, Salzman, Bernstein & Henderson, 2009). It is critical to understand the reasons behind these STEM-educated individuals drifting away from the discipline after graduation. If the system cannot even retain such individuals, what is the likelihood of attracting even more individuals to STEM?

Alignment and collaboration. Creating a STEM environment that can allow for great ideas to scale and be sustained requires a level of alignment and collaborative willingness across stakeholders. One of the initial challenges is in acknowledging who comprises the broadest base of stakeholders that should be involved in defining solutions California's STEM gap. If this base is not well defined, although subgroups of dependent stakeholders may achieve alignment, progress towards closing the gap will still not be achieved. An example of this exists in K-12 education, in which stakeholders within that network collaborate toward students achieving a seamless transition from elementary to middle school, and then from middle school to high school, as it relates to the exit and entry needs of each of the respective levels.

While aligning at each level within the K-12 educational system is a very necessary step, it does not address the total needs of the overall ecosystem of STEM, which must also encompass the needs of the community, which represents a large portion of after school program providers. The K-12 alignment would also not be assessing the needs and concerns of the community colleges or four-year universities, who are currently spending much of their time in remediation with newly enrolled students. Moreover it does not integrate the needs of regional employers. All of these additional stakeholders have a critical stake in the outcomes of the K-12 system. To address this need, there are now certain stakeholders in government and academia as well as specific non-profits in California that are being tagged across the country as STEM connector organizations. Their purpose is to create collaborative environments designed around aligning a vision and strategy for the future. In California, for example the California STEM Learning Network (CSLNet) has been tagged as the connector organization committed to working with all the regional stakeholders as well as the identified state government and industry leaders and partners (STEMconnector, n.d.)

Another key enabler is having an infrastructure that allows for collaboration; however, it is just one of the building blocks. Once the ecosystems of stakeholders have been identified and gathered, there must be a deliberate approach that is applied toward collecting, translating, and organizing the goals and aspirations of these variant stakeholders into a coherent, implementable strategy. Currently, stakeholders are being gathered and sharing stories of successes and challenges. In so doing, they are beginning to learn one other's languages and challenges, which is vital to creating an environment in which ecosystem-appropriate solutions are discovered and nurtured (Kerzner, 1979).

Another recent example in California is the third Annual California STEM Summit 2012, whose focus was 'Transforming Ideas into Action"(California STEM Summit, n.d.). CSLNet gathered over 300 people from government, industry, education, non-profits, and the community, including individuals from the after school network. The objective was defined as an opportunity to build a network of stakeholders committed to developing a new capability to bring the needed innovation, and sustainable scale, to enable effective teaching and learning in California (Roe, 2012). These kinds of alignment events are critical to creating a common language across stakeholders in California, and to create alignment around the need for collaboration. Moreover integrated forums are being created to illuminate the issues and perspectives across the stakeholder base. The challenge now is to generate a master plan that makes sense for a state as large, and rich in resources as California.

The strength of the strategy will ultimately lie in aligned and shared objectives. The strongest collaborations are tied to those whose stakeholders share common goals (Alexander et al., 2008). Large, complex collaborations require flexible and innovative approaches. They need to share ideas about appropriate policy and values, and be open to fundamentally new research and ideas that can then be translated to actionable plans (Boyer, Orpin, & Walker, 2010). Transparency is also vital to the success of these collaborations, and a lack of it is the critical downside of these collaborations, speaking to the complexity inherent in establishing true alignment.

At the highest level, it is typically easier to align on noble goals such as education that is aligned with workforce needs, or education that meets the needs of 21st century students. The challenge is to then translate these higher-level goals into specific methodologies that can be both skillfully executed and provide clarity to the specific roles of individual stakeholders (Gambert, 2010). For example, if all the stakeholders focus on defining new curriculum approaches but no one is working on teacher preparation, expected outcomes are likely to fall short. The other challenge is that even if a clear understanding of roles and goals exists, if there are trust issues across the network, the project will not have transparency and will thus be challenged to achieve optimal results.

As alignment is created across the base of stakeholders, a collaborative partnership must be nurtured. STEM is a highly inter-dependent network that requires an infrastructure, whether formal or informal that allows for the pooling of resources, including both information and finances. Stakeholders need to share goals and balance power in order to optimize the decision-making processes (Casey, 2008).

Partnerships and accountability. The partnerships for STEM will occur within an open systems environment. Open systems, by definition, are comprised of members who have chosen to come together, as opposed to those who have been compelled together by a more traditional organizational design. Alignment and collaboration, then, are prerequisites to creating partnerships and accountability. Therefore, trust is a necessary enabler for alignment and collaboration. In open systems, individuals and organizations build the relationships that they require to be successful, and open systems grow as they recognize when they are missing key stakeholders. This recognition occurs through conversations across stakeholders that hold variant opinions and positions (Wheatley & Kellner-Rogers, 1999). As stakeholders exchange these viewpoints in open discussion, language barriers will be bridged, and awareness and trust will grow across the network. These conversations and interactions are what compel groups in this open system to then choose to work together. When trust is not present, open systems will achieve suboptimal results.

An example of this can be seen in another open systems environment in the bio-medical industry. During the 2002 SARS epidemic that impacted China, the Genome Sciences Center published SARS genetic sequencing in an open source environment. Although it was a relatively small Canadian lab, the Genome Sciences Center was able to accomplish this feat because they were working in an open source environment that already utilized many tools and participatory networks that allowed for their success in an open solutions environment. Contrast this with China, which had both a significant research infrastructure and high incentive to get SARS mapped and understood, and yet their results lagged far behind. The reason for this is that the Chinese government had restricted access to the collaborative environment. Although they had top human resources and excellent facilities, their choice to not participate in collaboration, due to issues of trust, caused them to miss out on the opportunity to multiply their internal resources in a time of crisis (Shirky, 2008).

There are multiple examples of incredible successes in open system collaborative environments. Another example is Wikipedia's success of self-management and monitoring in a completely open environment that has changed the paradigm for closed system encyclopedia creations. Likewise, open source logic sharing agreements exist in the biomedical solutions space, which advances more timely problem solving, while still protecting end product innovation (Tapscott & Williams, 2008).

The following are principles that have evolved from successful open system partnerships in the industry-university realm that can be used to inform the establishment of other open source partnerships. These include:

- The use of partnerships to shake up the current state roadmaps of the parties;
- Ensure the partnership is designed as a win-win, offering desirous outcomes for both parties;
- Deepen and expand the collaboration across research communities;
- Keep the base logic and concepts from these collaborations open and available, while simultaneously understanding how to protect any commercial applications;
- Keep a regular pulse on the ultimate consumer throughout the development and implementation process, and start taking that pulse as early as possible (Tapscott & Williams, 2008).

In addition to defining the potential value and principles recommended for these partnerships, there are a two other important elements to consider in an open system environment. The first is the role of a system coordinator. In a large complex system like STEM, a system coordinator acts as the manager. In addition to helping create forums for interaction across the stakeholders, they facilitate the development of how the open system will function. The coordinator must oversee the effectiveness of the overall system on behalf of the partners, and watch to ensure a balance of interests is maintained across the network, as the stakeholders will not voluntarily participate in an open system that is ineffectively servicing their needs. Moreover, because the system coordinator's mission is for the system to prevail, they are uniquely positioned to be the objective stakeholder (Casey, 2008).

In the STEM environment, the coordinator would have the ability to monitor the ecosystem and help identify opportunities inherent in the workforce capacity building challenges facing our state (Stephens & Richey, 2011). Because these open systems are human based, a coordinator can also help identify any dysfunctions that may emerge and act as an independent arbiter, helping to navigate the network through complex issues as they arise (Gandy, Pierce, & Smith, 2008).

In addition to the system coordination role, there should also be a defined accountability system for the partnership in order to create a mechanism by which progress can be assessed. Defining a clear set of goals and agreeing to how they will be evaluated and measured builds accountability within the system. The STEMconnector organization publishes an annual report card by each state that characterizes measures such as the number of projected STEM jobs, which fields they will be in, the average compensation of individuals in these jobs, as well as diversity and gender statistics, workforce requirements for a college degree, and significant educational, demographic, and economic indicators that are relevant to California (STEMconnector, n.d). This information can be then be used to develop agreed upon areas to evaluation and monitor progress. Measures may also include commitments such as forum participation or engagement in collaborative initiative investments. The point is that in order for a partnership to understand its progress it must first identify how it will hold itself accountable.

Open systems with effective collaborative partnerships that hold themselves accountable can be very powerful. Theoretically, almost any social or economic problem could be resolved with a coalition of self-organized contributors with a passion to solve a given issue. Open systems unleash innovation beyond the boundaries of traditional organizational walls. They solve problems no single organization can solve independently. Furthermore, they are comprised of interdependent stakeholders who all have the potential to benefit from a successful collaboration (Tapscott & Williams, 2008).

Role of leadership in a systems design. While these open systems are basically leaderless in the traditional organizational sense, there remains an important role for leaders in this model. Senge et al. (1999) discuss the importance of developing leadership capability across the organization, as opposed to seeking out a hero leader, who is expected to provide all the answers. In an open systems environment this is even more important. Stakeholder leaders must examine every motivation to ensure they have thought through their commitment to what may result should there be any significant changes to their current models. They should be able to ask questions like: why am I doing this?; what am I doing?; what are the potential consequences and expected results?; and, perhaps most importantly, am I willing to see this change through?

Another related phenomenon that must be contemplated by leaders is why alternative approaches remain mostly unimplemented, despite the fact that they have been well documented to be effective (Gummer, 2000). This illustrates how resistant systems can be to change, even when all the data points to a pressing need for change. Resistance to change should not be underestimated by the leaders engaged in the partnership.

A study of teachers by McKenzie and Scheurich (2008) showed that failures are classically seen as externally caused by factors that are beyond the executor's control. Individuals might feel threatened by new accountability expectations; they might also have had a negative experience in the past resulting from making critiques. New reluctant leaders may be required to emerge in this new environment. These are often emerging leaders who have a vision about what needs to be done and now must harness the courage to lead in new territories. These are clearly issues for leaders who must broker the pathway to change by understanding how to create an atmosphere that makes it safe to propose, incentivize, model, and make change happen.

In addition to these questions and challenges, leaders must understand how they fit into this collaboration and be able and willing to surrender their egos as systems solutions impinge on their current approaches and the greater good becomes clear. Distributed, collaborative leadership introduces different leadership dispositions than a traditional leadership model (Helterbran, 2010). Issues such as balancing and sharing power and control, between emphasis on process and results, between formal and informal procedures, all come into play, making it even more important that partners forge interpersonal relationships (Casey, 2008; Moss Kanter, 1994; Somekh, 1994; Spekman, Forbes, Isabella, & MacAvoy, 1998). One of the most significant contributions of leaders to collaboration is in dedicating structured time to demonstrate commitment and establish the tone for a new culture (Love, 2010). More than simply being stated, these open system relationships must be nurtured and grown intentionally.

The open system STEM environment requires leaders to exhibit new behaviors. The most important attribute leaders must bring to the CA STEM challenge is a sense of urgency with a bias to action. This is a very complex problem. Action, not well-marketed paper plans full of sophisticated concepts, gets results (Gummer, 2000). Pfeffer and Sutton (1999) stated, "In a world where sounding smart has too often come to substitute for doing something smart, there is a tendency to let planning, decision making, meetings and talk come to substitute for implementation" (pp. 98-99). Gummer (2000) also points out the importance of leadership creating an environment in which:

- It is accepted that mistakes will be made in the process of learning;
- It is known that fear cripples action, so fear must be driven from the system;
- Collaboration is understood and demonstrated, fighting the problem, as opposed to others, in the open system;
- What matters is measured, thus reinforcing action and results;
- Leaders demonstrate what is important by how they spend their time and allocate resources.

While an open system exists in a different leadership model than many leaders have historically operated, the role of stakeholder leaders is even more important in California if it is ever going to truly move to a set of integrated solutions in time to have an impact on its STEM workforce crisis.

STEM Stakeholders' Focus

The next focus area for this literature review is a survey of the key stakeholders and the activities they are currently engaged in, as well as the challenges facing them. Analyzing the players is important, as this study is targeting an integration of these stakeholders as the critical element in developing the solutions necessary to address California's present workforce gap.

Industry. In a recent survey, a shortage of talent was identified by industry as the number one issue requiring focused attention, up from 22nd place in 2009, and overtaking financial stability concerns (Davis, 2012). The shortages exist, or are forecasted to exist, in both entry-level employees, and with incumbent workers.

Activities in the policy and education arenas must target both the entry-level and incumbent worker resource pool. As the skills required for the 21st century continue to evolve, industry must be clear about which skills are specifically required, and then policy makers and educators must establish programs that are tailored not only for entry level employees but also programs that enable the critical transitions required for the existing U.S. workforce. In addition to identifying strategic industry skills and forecasting volume and timing needs, industry also needs to look to its own internal policies supporting lifelong learning with tuition reimbursement programs.

One of the significant changes in today's workforce, as compared to the workforce 20 to 30 years ago, is the emphasis on the *knowledge worker*. Peter Drucker (1999), a renowned management consultant, originally coined the term in 1959. This shift from directive work to work that requires expertise and the application of knowledge has impacted both the white collar and blue-collar workforce. Both areas are more dependent than ever on information technology. This requires both new skills for the workforce and new ways to motivate and lead in this environment for managers. These knowledge workers at all levels often know more about their work than their boss, and therefore they must be given the freedom to use their knowledge and skills to make independent day to day decisions (Frick, 2011). Understanding how to influence productivity of the knowledge worker is in an emerging trend. Gummer (2000) summarizes the six factors that Drucker originally identified to determine knowledge worker productivity:

1. They must understand and identify the task they are to complete;
2. They must have autonomy to act in their environment;
3. Innovation must be a part of their work;
4. There must be an expectation of continuous learning and continuous teaching;
5. Output should be primarily assessed by quality not quantity;
6. They must be seen as assets to the organization as opposed to costs.

Women and minorities represent the second high opportunity target area. For a number of reasons, the STEM pipeline does not represent the diversity of the American labor force despite the fact that these disparities have long been acknowledged (Hira, 2010). The long term STEM shortage is unlikely to be sustainably addressed without taking much more aggressive, systemic action to turn this situation around, and industry will play a key role. It is more of a challenge for students to imagine themselves in fields that they have not been exposed to and where they do not see people who look like them, thriving.

To address student awareness, particularly in underserved populations, industry is engaged in several creative activities:

- Dean Kamen (2009) is an inventor, physicist and entrepreneur who established the FIRST program in 1992. This program took tenets from sports and entertainment and imported them into STEM learning through a robotics competition targeting underserved communities, as opposed to, just AP science students. This program has now reached over 195,000 children in 42 countries.
- NASA has an organization dedicated to education, as well as a multitude of programs that have been established for educators and students. Their mission is to inspire and motivate students, and to engage the public in sharing the experiences of exploration and discovery (NASA, n.d.).
- Raytheon has targeted middle school students with a program called Math Moves U. They believe tomorrow's innovators need to be excited about math and science, and have created a program that includes line resources, games, and classroom materials. Moreover, they have an actual simulation roller coaster ride call the Sum of All Thrills at EPCOT, and they sponsor a national math competition for middle school students called MATHCOUNTS extends to all 50 states. They also support other partnerships like FIRST, and a similar program called Team America that is a well-established student rocketry competition. Scholarship programs are another important component of their work.
- The BHEF (2012) has aggregated a team of industry CEOs and University presidents to create a think tank of strategies for the future. One of the recent outcomes of this community is a set of national and regional workforce

> solution projects targeting the next generation workforce. 12 projects were publically launched June 11, 2012 that are joint university and industry commitments to develop solutions to some of the country's most complex workforce problems in high demand areas such as cyber-security, big-data, life sciences, water, energy, engineering, and entrepreneurship. These commitments represent major financial and human capital commitments for all the parties involved, and will serve as a model for replication.

These programs help provide insight into the kinds of activities and resources industry is devoting to this national problem. They are only a small sample of the breadth of activities already in work. Industry must both provide insight into their needs and be willing to lend their expertise and resources as required. It is critical they partner with educators, but at the same time they must be deferential to educators' expertise. While educators are the experts relative to pedagogy, they can lag in the efficacy of their content. Therefore, educators must welcome participation from industry as they structure the content and focus of their respective curricula. Global engineering, technology and bioscience corporations are beginning to engage in STEM education as it is becoming increasingly apparent that, while the number of jobs in STEM fields are growing, the talent graduating from college is not prepared to meet these workforce needs. As a result, vanguard companies (broadly defined as forward-thinking, innovative, and socially responsible) often take the lead in public education reform as innovative leaders (Kanter, 2009).

The best value proposition in STEM exists in alignment and collaboration, which leads to scalability and sustainment across all of the core stakeholders. Raytheon, a leading aerospace and defense company, developed a systems engineering modeling tool that looks at the programmatic elements, focusing on areas such as mentoring, cohort strategies, teacher effectiveness, as well as the target populations for focus in K-5, middle school, high school, and the first 2 years of college. From this, they created a tool for strategists to be used to model where their efforts are going to yield the most effective results. This tool was donated to open source access through BHEF (2010), and is being further developed to increase its efficacy. It is through refining these kinds of tools, as well as incorporating measureable elements with objective results, that we will be able to understand where our efforts will yield the most success.

Educators. Educators clearly play one of the most vital roles in preparing the pipeline for the future. The STEM pipeline narrows significantly from 9th grade through college graduates. A study conducted by the National Science Board (2010) followed this pipeline over a span of 10-years. STEM engagement began with 3.8 million 9th graders in 1997, narrowing to 2.7 million high school graduates in 2001, and then to 1.7 million college freshmen, which resulted in a mere 233,000 STEM graduates in 2007. This report further notes that while we have seen some growth since the study was published, STEM degrees represent only 15.6% of the total number of bachelor degrees awarded in the U.S., compared to 46.7% in China, 37.8%, in South Korea, and 28.1% in Germany (BHEF, 2010).

Something is creating a significant drop off in the U.S. One theory is that certain mythologies have permeated the subconscious, such as the notion that, Asians are better at math than Americans, or who needs to know how to figure it out if you have a calculator or, most women can’t do math (Drew, 2011). Addressing some of these myths, Drew (2011) further notes that subject matter is generally approached in one of two ways. The first is relative to material that is deemed important to be understood by all students. For this material the challenge is creating methods to make this content available for all students. The second approach is for materials that are deemed accessible for only our best and brightest. Much of the STEM content has been identified in this second category however, considerably less focus has been placed on the methods to make these materials more accessible, such as hands-on project-based learning, as opposed to dry textbook and exercise approaches. For this very reason, teachers are a critical part of the process of making materials user-friendly and accessible to students.

Teacher quality and quantity have also been identified as a critical component of the solution system. A recent study by the BHEF (2007) identified critical facts that need to be understood in order to create focused solutions. These include:

- The quality of preschool-12th grade math and science teaching, which is the single most important factor driving improved math and science achievement;
- There are currently an insufficient number of highly skilled math and science teachers entering the profession or committing to long-term careers in education;
- The most significant shortage of these teachers is in high-minority and high-poverty classrooms;
- There is a critical shortage of minority teachers;
- Every day nearly 1,000 teachers leave the public schools and another 1,000 move to other schools;

- Replacing teachers costs a lot more than retaining them, and costs the U.S. $4.9 billion annually.

Given these facts, the recommendations provided by the study were three-fold. The first is to strengthen teacher recruitment policies in mathematics and science. Second, the retention of teachers must be dealt with, including addressing the factors that cause teacher dissatisfaction. Finally, all math and science teachers must participate in periodic renewal activities to ensure their sustained effectiveness in the classroom.

Underscoring the criticality of the current teacher resource gap, it is estimated that the U.S. will need a minimum of 280,000 new math and science teachers by 2015 (BHEF, 2007). Ensuring adequacy of skills and qualification for our existing and future teachers is important to addressing the current STEM student pipeline shortfall. According to Logsdon (2006), in 2000, teachers who neither majored in nor held a certification for physical sciences were teaching 93% of U.S. physical science students in grades five through nine. This is because there has been no requirement for skill demonstration as a prerequisite to teach these courses. We must address our expectations of and requirements for our STEM teachers. To that end, there has been research done about support mechanisms for teachers, such as the introduction of math coaches to provide professional development in the areas of content, curriculum, and pedagogy (Campbell & Malkus, 2011). Coaching roles have the potential to be effective across the base of STEM disciplines, but they must be implemented in a supportive and comprehensive manner.

In addition to supporting the continued development and recruitment of STEM teachers, educators are also being encouraged to play an increased leadership role both inside and outside of the classroom. Teachers have not necessarily seen themselves as leaders, particularly outside their classrooms, but this concept is consistent with the transition of the workforce from assembly to knowledge workers. Like knowledge workers, teachers have their fingers on the pulse of what works, what is needed, and what impedes their ability to thrive. However, if teachers feel they are not heard in the system, they are less capable of utilizing their knowledge to help with systemic reform. In a recent MetLife Survey, 69% of the teachers polled believe their voices are not being heard in the current education debate (Love, 2010). Teachers of the future should be recruited as leaders for the educational system, and the most desirable candidates should be those who desire autonomy, and in addition are constantly improving their subject matter skills, and are motivated by achievement. This will not only have payoffs in teachers taking greater ownership for outcomes (Helterbran, 2010), but these teachers will also help build student leadership efficacy.

Student leaders have the potential to strengthen peer-to-peer learning as well becoming future leaders upon their entry into the workforce (Hoffman, Rosenfield, Gilbert, & Oandasan, 2008). The challenges facing teachers, particularly in underserved communities, are daunting, and stakeholders spend unproductive time finding fault instead of being part of the solution. As forward-looking solutions continue to be developed, teachers must be featured as a resource to be enabled and empowered, rather than vilified (McKenzie & Scheurich, 2008). It will take the entire STEM stakeholder system working together in order to design executable solutions to advantageously reposition California for the future.

Finally, all levels of the educational system need to be assessed relative to their contributions to future solutions. Though the discussion of this research is focused primarily on the role of K through 12, of equally critical importance are California's community colleges, as well as public and private universities. These institutions of higher learning must continue to enhance their ability to adequately prepare the knowledge workers of the future.

Furthermore, STEM gaps are exacerbated in the first years across college systems, as STEM committed students migrate to other areas of focus. Currently, only 23% of students who enroll in college choose to major in STEM disciplines, and of those, only approximately 40% graduate with a STEM degree after 6 years (Snyder, Tan, & Hoffman, 2006). The system, then, is losing 60% of the student base that had initially self-identified as STEM. In order to adequately address this student base loss, the reasons causing it must be fully understood. This is particularly true with regards to women and minorities, who are even more severely under-represented in STEM.

Statistics released by Building Engineering and Science Talent, a public-private partnership that focuses on workforce diversity, issued a 2004 report that indicated the U.S. science and engineering workforce in 1999 was 80% white and 75% male (Dunn, 2005). Reason would dictate, then, that increasing the diversity of STEM practitioners, both women and minorities, would go a long way toward bridging this gap.

Policy. While focus on the educational component of the STEM challenge is vital, so too is the direction of policy decisions in California. Policy is a core enabler that ideally should translate vision into action. This would presume that the policy is consistent with the over-arching vision, and that stakeholders have aligned around this vision. So once again, we return to the critical nature of alignment in addressing the STEM challenge. The various stakeholders must be engaged in order to expend their efforts in designing a comprehensive, inclusive strategy focusing on moving stakeholder energy in a positive direction (Meadows, 2008).

When alignment is lacking across stakeholders, each uses their energy to promote their particular interests, which often comes at the expense of other critical pieces to the overall puzzle. Two examples of challenges that may impact key stakeholders differently include the adoption of common standards and teacher accountability for student outcomes. While industry strongly desires common standards that are driven by workforce needs, teachers have serious concerns for how success is defined, and what the appropriate standards will be in terms of assessing accountability. Therefore in order to ensure success and progress, common standards for content need to be agreed upon in a collaborative manner, so that industry is ensured it is in alignment with workforce needs. All agreed, for example, that teaching to tests has been a contributor to some negative aspects with regards to the present state of education, and that as a result, there needs to be additional embedded methodologies developed as a means of assessing in-process learning as a part of a more project-based learning approach.

This section will look at specific policy objectives critical to STEM that the stakeholder community needs to address and then fit, as desired, into an overall policy strategy. This strategy should include the following elements: resource allocation to schools; how to address the needs of the arts and STEM as a partnership; the direction of national policies that impact California; the focus and direction of after school programs in California; linking university funding to industry demands to ensure the educational system is effectively feeding the workforce; and finally, the need to address the shortfall of women and minorities in STEM across the board. Understanding the policy side of STEM will ultimately allow the respective stakeholders to dedicate their resources toward moving in complimentary directions.

One of the challenges facing California schools is the perpetual state budget shortfall. In the fall of 2012 voters were asked to vote on two different initiatives targeting additional monies for our schools. If California failed to support at least one of these initiatives, there would have been further cuts required to balance the state budget. With a barrage of commercials for and against both proposition 30 and proposition 38, these two propositions competed against each other for the taxpayer’s attention. Civic, business and education leaders had pro and con arguments that cancelled each other out in voter information guides (Bowen, 2012). There is no trust across the stakeholders that additional monies will be carefully managed by the legislature. There is a real shortage of funds in many California classrooms and there is clearly a lack of alignment around the path forward. Stakeholders in this example were actually pitted against each other despite the fact that there was alignment around the need for change. Proposition 30 did end up narrowly passing which prevented the current fiscal crisis but there is little harmony among the stakeholders about how the additional funds will be utilized. When an aligned policy implementation strategy is lacking, predictable forward progress is at a high risk of falling short.

Another intriguing stakeholder discussion was vetted during a panel at the first national STEM summit in Dallas (U.S. News & World Report, 2012). Actor Tim Daly, president of the Creative Coalition and one of the panel members, noted that the arts must play a prominent role in the discussion about STEM. In fact, Daly advocated changing the acronym from STEM to STEAM (the added “A” standing for “Arts”). As a result, the panel universally accepted the premise that innovation and creativity are highly dependent on the arts, and that, moreover, the arts are highly dependent on science and math. The more critical component of the discussion was not so much whether or not to change the acronym, but rather that supporting the arts is in direct alignment with existing STEM goals. One, therefore, cannot be eliminated to enhance the other.

The open forum discussion underscored the importance of the alignment of these efforts. Absent these kind of collaborative discussions, these two communities, both of whom focus on enrichment in current education programs, could find themselves competing instead of collaborating. The challenge, then, lies in creating an integrated strategy that meets the systems needs as opposed to those of individual constituents.

At the federal level, there have been a series of policy levers identified to positively impact the STEM workforce (Hira, 2010). The focus is being placed on the following areas:

- Increasing federal funding of basic research;
- Increasing access to both undergraduate and graduate scholarships, as well as loans for students targeting STEM studies;
- Creating demand for STEM labor through federal acquisition in areas such as green energy and other STEM-focused areas;
- Making lifelong learning more affordable for the workforce through strategic subsidies;

- Focusing on improving the representation of women and minorities in the STEM workforce;
- Looking at immigration policies that enable foreign worker access in critical STEM shortage areas;
- Broadening access to STEM careers as individuals transition from non-STEM fields into the STEM workforce;
- Providing better information about where the labor market is heading.

Hira (2010), further notes that despite the positive focus on the importance of addressing the national STEM crisis, there has not been sufficient focus on modeling these objectives and effects as related to specific policy focus. Lacking facts and data, decisions in both the private and public sectors are likely to be suboptimal, as the relationships across these policies are complex, and it is often unclear where the most effective actions are occurring.

In California, both K-8 and high school after school programs were studied, with an objective to discern policy recommendations in order to strengthen these funded programs (Huang, 2012; Huang & Matrundola, 2012). Utilizing the facts and data from studies such as these is critical to ensuring such programs meet their intended funding objectives. Too often in policy, at both the state and federal levels, there is insufficient definition around success expectations and measures of accountability. The money gets spent, but there is no improvement. In addition to utilizing facts and data, the recommendations provided by the studies point to the critical nature of partnerships across stakeholders in community, business, day school, and after school programs in order to ensure they are operating with a shared sense of purpose.

In addition to defining the areas of focus for policy, a compelling argument was made by Utah's Senator Howard Stephenson (2012), who proposed legislation that ensures students are made aware of the employment opportunities available by traversing certain educational pathways. Students, parents, and those presently in the workforce should have easy access to employment trends and salary projections. This information is critical to the decision making of students who are often disappointed by their employment prospects upon completion of education programs post-high school graduation. Stephenson, furthermore, advocates channeling funding to universities based on the degrees, licenses, and certifications that are related to present workforce demands, as opposed to financing all educational tracks equally. This direction is certainly controversial, and its merits must be debated across the stakeholder communities of each state. California stakeholders, for example, must determine the funding strategies for its community colleges, California State University (CSU), and University of California (UC) systems, and how those strategies will ultimately integrate with workforce gaps.

In a recent discussion with the CSU chancellor's office (C. Keith, personal communication, June 5, 2012), it was made apparent that California's present budget crisis has been challenging the system as it struggles meet all stakeholder needs in areas that extend beyond STEM. The assertion of this discussion was that the CSU system should be targeting degrees that lead to the fields that are congruent to the needs of the overall economy. Moreover, there was discussion about how to generate more qualified math and science teachers in K-12 classrooms. Keith's (personal communication, June 5, 2012) perspective is that this objective is best addressed by incentives, such as grants, that encourage students to seek credentials in these underserved areas, as opposed to offering higher pay to teachers with the desired STEM skill set. The debate between such pay differentials versus financial support for pursuers of STEM credentials, however, is not the issue. Rather, the issue pertains to the fact that there is a multitude of opinions related to solving the STEM gap, and these opinions translate to policy; therefore, these policy proposals need to be debated in a collaborative environment that is fed by facts and data so that aligned, measurable strategies can be put into place and evaluated. The current state of things sees policies not moving results in the right direction quickly enough, thus creating an environment in which one policy competes with another policy, the result of which is that the two may inadvertently cancel out one another.

Any policy strategy invoked in California must also address, as a given, the need to increase the number of women and minorities in STEM (Drew, 2011; Gonzalez, 2011; Hira, 2010; Logsdon, 2006; Singer, 2011). This deficit has already been thoroughly documented, both in this research, and in the literature at large. Strategically focusing modeling and subsequent policy on the actions that will move the needle, on both the representation gaps and the STEM shortfall gaps, can be a win-win for California.

Foundations and non-profits. Throughout this research, there has been a discussion about the importance of bringing the stakeholders together to create aligned, integrated strategies that address the STEM workforce challenge. Foundations and non-profits play critical roles in this stakeholder network. They can act as the source of funds and research pursuits for innovation and support of STEM-strategic objectives (Collins et al., 2009). Specific non-profits can also be well positioned to act as the connectors of complex networks (Casey, 2008), because there is no individual stakeholder positioned to play this integrative role. CA STEM Learning Network is identified as the California focal point for building the statewide network focused on transforming the state's approach to addressing the STEM workforce challenge.

In addition, without private sources of funding for critical research and other subsidies for budget shortfalls supplemented by foundations, California's STEM crisis would be even worse. The challenge is to be deliberate about making the best use of the resources across the funding sources. Integrative networks are required at all levels of the STEM network across California. The CSLNet is presently supporting the building of partnerships of key stakeholders across these levels as well. There are currently eight regional networks identified in California. The objective of these networks is to bring systemic change to the regions by creating joint strategies across the stakeholders, addressing the needs of students, employers, the workforce, and the communities in order to meet the state's current and future needs (California STEM Summit, n.d.). These connecting networks can also quickly rally stakeholders when needed.

At the California STEM Summit, Chris Roe (2012) discussed a current example of a quick response need. In an effort to help balance California's budget, governor Jerry Brown floated the idea of narrowing high school graduation requirements to only a single required year of science. Adopting this idea would cause California to have the lowest science graduation standards in the nation, which would only further exacerbate the state's workforce gap. The CSLNet organization was quickly able to create a petition and gather over 1,000 signatures across industry, academia, and community partners, and the result was the preservation of funding for a required second year of science.

The power of these connectors is to bring ideas and stakeholders together with the purpose of creating awareness, understanding, and alignment so that comprehensive integrated strategy, policy, and action are possible. The STEM Education Coalition (n.d.) and the BHEF (2012) are two examples of these connectors, on a national level, that are bringing together leaders from across the base of stakeholders. The STEM Education Coalition's main focus is informing policymakers on the critical nature of STEM education and its relationship to national competitiveness. It is an alliance of over 500 industry, foundation, non-profits, and education organizations, and it creates a powerful directional voice. The BHEF is one of the organizations that collaborates with the STEM Education Coalition. BHEF is a collaboration of executive leaders in industry and higher education who are committed to driving change real time. They engage in the development, adoption, and promotion of best practices across the industries and education institutions they lead on a local and national level. As such, they represent a powerful policy voice at local, state, and federal levels.

The existing foundations and non-profits are powerful, well-financed, and highly motivated; moreover, even more new networks are being formed at the state and national levels, whenever perceived gaps are identified. The challenge for foundations and non-profits of the STEM ecosystem is to create a deliberate, integrated design in this open system so that efforts across these networks are complimentary and agile. California is fortunate to have a large base of stakeholders willing to participate and contribute. The lack of a systems approach to the layers of networks and actors is resulting in great ideas that are unable to scale across the system. The good news is that this is now being recognized as a problem. The challenge, then, is aligning across the stakeholders at the various levels on what to do about it. The connectors in the system, foundations, and non-profits are critical to helping the rest of the stakeholders design system approaches going forward.

Media. The final stakeholder group that this review will examine is the role of media as a key player in creating STEM solutions. The entertainment and media industries are the experts in communications, which is one of the challenges facing STEM, as it works to win the hearts and minds of students and communities. Enlisting help from media networks would represent another powerful step in the right direction. The first national STEM summit came about because *U.S. News & World Report* (2012) used its networks and influence to create a buzz before, during, and after the event, resulting in a huge turnout and productive sharing of solution ideas.

Demonstrating the power of using what works in entertainment and the sports world, Dean Kamen (2009) designed the FIRST competition. FIRST is a renowned robotics competition that has been heralded as an unmitigated success. Kaman's thesis in creating the program was that it needed to be built upon principles that would attract his target audience; girls and boys of all backgrounds who may never have been exposed, in an engaging manner, to math and science concepts. This competition has been running for 21 years now, and it operates internationally, requiring over 120,000 volunteers, over 3,500 sponsors, and its upcoming 2013 competition has generated nearly $16 million in scholarships, impacting more than 300,000 students, who will be creating over 25,000 robots (FIRST, n.d.).

Another effort in which the media has played a critical role has been the attention paid toward creating a stronger focus on STEM female leaders. To this end, there was a recent publication of the 25 Female STEM Superheroes of Today (StaffWriters, 2012), celebrating such STEM stalwarts as Sally Ride, a former NASA astronaut; Maria Klawe, the president of Harvey Mudd College; and Sheryl Sandberg, COO of Facebook. Moreover, at the U.S. News STEM Summit, STEMconnector released a publication that celebrated 100 Women Leaders in STEM, highlighting a variety of careers and accomplishments, as well as sharing insights about the success traits and contributions of these women (STEMconnector, n.d.).

One of the strengths media experts bring is their ability to tell the stories that can reach the very populations STEM is endeavoring to attract. They help tell industry's stories about the problems they are trying to solve, and help non-traditional populations see themselves in exciting and rewarding roles they may not have previously been able to imagine for themselves.

Additionally, because they already have the attention of the coveted youth base, celebrities play influential roles in STEM recruitment. Basketball great Kareem Abdul-Jabbar, for example is an active participant in the FIRST program, and was recently named California's After-School STEM ambassador (California Department of Education, 2012a). Abdul-Jabbar has also written a children's book about African-American inventors that is full of stories intended to enable a generation of children to imagine new possibilities (Abdul-Jabbar & Obstfeld, 2012).

Will.i.am, from the popular band Black Eyed Peas, is also actively engaged in projects ranging from setting up a STEM school in his home town, to having one of his songs beamed back to Earth from the Mars Rover that landed on the Red Planet in August (Esero, 2012). These kinds of publicized efforts reach more children and young adults helping to make STEM more accessible and desirable. The media knows how to market to specific demographics, where to find them, and how to craft messages they will find appealing. Historically, under represented groups, such as women and minorities, struggle in the education settings that might have restricted their involvement in the past. However, when these under represented groups are both confident and able to feel a sense of belonging they are much more likely to engage and persevere (London, Rosenthal, Levy, & Lobel, 2011). The media can help to advance this sense of belonging.

Confirming this is a cross-national study demonstrating that when girls are encouraged, supported with tools, and exposed to female role models, they excel in mathematics (Else-Quest, Hyde, & Linn, 2010). The media can help to advance identity stories and opportunities for these populations as a key component of the STEM success strategy. Media leaders also have control over how they address negative stereotypical roles that serve to reinforce images such as math and science as being either uncool or not feminine. What's more, the media can help to neutralize stereotyped gender and race STEM roles by how such individuals are represented in popular entertainment (Myers et al., 2011). The media can help inspire and encourage the best and brightest under-represented students to think about STEM as a viable education and career path.

STEM Success Stories

The final segment of this literature review will illustrate examples of the many spots of success that have emerged in collaborative open environments. First, we have an example of a collaborative philosophy and systems environment created to support the design and manufacture of the Boeing 787 platform. Instead of defining all of the specifications for the parts that had to be provided by their suppliers, Boeing instead engaged the supply base to work with them in a virtual design environment creating the concepts for the its unique subsystems. Not only did this allow the potential manufactures to design products better suited for the manufacturing process, but Boeing was also able to engage its future manufacturers in an up front manner. This was made possible because Boeing created an open systems platform in which partners were provided joint access to the design data. This eliminated the previous, less productive iterative design process characterized by a disconnected environment that passed drawings back and forth. In this new environment, by contract, partners actively engaged in real time joint design, and the collaborations yielded significant time and cost savings revolutionizing how large design collaborations of the future will work (Tapscott & Williams, 2008).

Another powerful model of collaboration in an open environment can be found in the Stand Up To Cancer organization. This organization was put into place to accelerate the pace of making sure new treatments get to their intended patients as quickly as possible. The organization has created a unique model for funding, supported by major cancer researchers. This model encourages collaboration by creating multi-institutional grants to scientists so they are incentivized to work together to advance the research, and get life saving treatments into the hands of patients (Stand Up To Cancer, n.d.). The strength of the collaborative environment of this organization has also been demonstrated by an hour-long telethon during primetime on a Friday, in which, all of the major television networks twelve, additional cable channels, and several high-powered entertainment names were involved. This organization, which uses an open social network of collaboration, aligning around the strength of a powerful mission, is self-organizing, and works much more efficiently that the more traditional superstructure model (Perry, 2012).

Finally, there is the example of a public school charter system embedded in both South and East Los Angeles, which is demonstrating exemplary results in underserved, traditionally underperforming neighborhoods. The Knowledge is Power Program (KIPP) is a system that exists across the U.S., with a strong track record of student achievement. As a charter program, KIPP has been able to establish ground rules that center on high expectation for all its students. Parents, students and the educators must make a commitment to the program up front as a condition for their acceptance into the program. Nationwide, 89% of KIPP students have gone on to college. KIPP's Los Angeles affiliates are presently partnering with Google's Computers for Youth to provide access to computers in the schools and homes of all its sixth grade families (KIPP: LA Schools, 2011).

KIPP also partners with other organizations such as GreatSchools, which offers online workshops to parents as a way to productively enhance their involvement and focus on college readiness. The bottom line is the program works. KIPP's Los Angles Prep is the top performing middle school in the Los Angeles School District (LAUSD). 100% of the schools eighth graders score at the advanced level in science, and 98% of its kindergarteners consistently outperform the national average in math and reading. KIPP, however, faces some difficult challenges, due to the fact that it depends on 26% of its financing from private sources, which means it must remain focused on fundraising, which moreover, constrains its ability to grow rapidly, even with its record of success (KIPP: LA Schools, 2011). However, KIPP demonstrates that the STEM gap with regards to the underserved populations is driven more by a lack of focus and resources than it is by a lack of capability in its representative student communities. This should serve as significant motivating factor as solutions are modeled to robustly address the California STEM workforce gap.

All three of the above examples are exemplary illustrations of the power and speed of open system collaborations. They also illustrated how important it is to have clarity of purpose as a starting place for uniting a coalition of willing stakeholders.

Chapter Summary

The focus of this literature review has been to explore elements that are critical to developing a systemic approach to more efficiently and effectively design timely, scalable solutions to the California STEM crisis. The current state of STEM, and why addressing this issue is important to California, was briefly surveyed in order to establish the case for action. Next, the study explored the potential of addressing the creation of solutions in an open systems framework, applying well-vetted industry modeling tools to the STEM challenge. Another critical area explored was the importance of clarity related to the goals and roles of each of the respective stakeholders in the system.

Other key characteristics, including sustainability, scalability, alignment, collaboration, partnership, and the role of leaders in a systems design were explored. This was done as a means to understanding how each element comes into play when designing a systems approach. The study then targeted specific perspectives across the broad stakeholder base of STEM, including industry, educators, policy makers, non-profits, and the media. Finally this review concluded with specific stories that incorporated collaborative systems approaches as models for the potential value proposition.

Clearly, in our fast paced global world, the solutions of the past are no longer keeping pace with the current workforce challenges. The knowledge base established by this literature review will be extended to ascertain the current state of alignment across California's critical stakeholder community with respect to their roles in this open system. It will also seek to determine how close the current system is to an aligned statement of purpose, as this is critical to moving the state of California in the direction of an efficient and effective open systems approach to solving this complex challenge.

Chapter 3: Methodology

Introduction

The purpose of this research is to explore the current level of alignment around the discrete goals addressing California's STEM workforce challenges. Additionally, the study assessed the level of alignment related to stakeholder leaders within the STEM system relative to their respective roles in working towards solutions. The purpose of focusing on the roles is to understand the level of alignment existing amongst the stakeholders, as well as to gain a better understanding as to who should be doing what.

Central Research Questions

1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?
3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?

Research Methodology

The research utilized a quantitative approach (Bryman, 2008; Creswell, 2009). Quantitative methods begin with a theory and then design an approach to test the theory. This method was chosen as an effective way to test the theory of current state alignment of goals and roles across California. As evidenced in the literature review, there is a great deal of discussion about the importance of alignment when establishing a systemic strategic plan. While this is a recurring theme in the literature and at various cross stakeholder events such as the California STEM Summit, there is little quantitative objective data about the current state condition in California. A quantitative survey was administered to a purposefully selected sample of stakeholders to provide data to document this condition. This data were then used to assist in defining next steps for California STEM stakeholder leaders ideally utilizing the open systems approach discussed in the literature review section. The value of quantitative survey data is that it provides a measurement device to objectively determine perceived distinctions and to show relationships across and within groups based on the answers from respondents (Bryman, 2008).

The framework of complex open systems design thinking is the theoretical perspective driving this research. A quantitative methods approach was selected because of the importance of establishing actual measureable stakeholder data that helps to illuminate a potential cause for the lack of progress to closure of the STEM workforce gap in California. The quantitative output was used to establish the stakeholder alignment baseline relative to goals, roles, and the current state of collaboration. The results of this portion were analyzed to understand if in fact a lack of alignment of stakeholder perceptions of focus and purpose could be an inhibitor to purposeful solution designs. Open collaborative systems have an established track record in the business world as an enabler of rapid, robust problem solving, demonstrated through projects like the Human Genome Project or the phenomenon of Wikipedia. The Human Genome Project is a collaborative effort of several pharmaceutical firms who abandoned their individual proprietary pursuits at DNA sequencing and instead joined this collaborative effort in which basic research is being shared; the results have been reduced product development costs, shorter development cycle times, enhanced share holder value, and ultimate benefit to society. Likewise, Wikipedia created a fundamentally new model of open source knowledge development and sharing, opening the traditionally centrally controlled encyclopedia generating progress to the public, and in so doing changing the way knowledge is compiled and distributed. Wikipedia, with only a handful of employees, has ten times as much information as a traditional encyclopedia, and is competitive with the traditional encyclopedia with respect to its accuracy despite the fact that its content is self-managed by the open system (Tapscott & Williams, 2008).

These examples demonstrate the power of an open systems environment when properly targeted for an aligned purpose. The theory this study is attempting to advance is that absent a clear and aligned purpose across the stakeholders, results would be suboptimal. In such a situation, stakeholders may not be aiming at the same target, and may, in fact, be inadvertently working against each other. In addition to the systems frameworks and modeling tools, the importance of evaluating potential scalability and sustainment of proposed solutions was also a key element explored in the literature review. With an open systems design framework as the backdrop, this quantitative survey queried two of the five identified California populations of stakeholders to test for alignment in the areas of goals and roles across the respective communities.

Design of the Study

The literature review discussed five discrete categories of stakeholders when examining the STEM workforce gap. This study focused on two of these groups to test for alignment across a subset of the broader STEM community to illustrate whether alignment should be an area of concern when determining strategies for action in California. The purpose of the quantitative research study was to understand the current state of alignment around what California leaders are focusing on to address the workforce gap as well as who these leaders believe should be focusing on what to get to solutions. By selecting education leaders and industry leaders the data demonstrated if alignment is an issue that should be addressed. State and local government leaders, non-profits and foundations and the community are also important stakeholders who need to be a part of future goal and role planning but they were not included as a part of this study's quantitative analysis. Demonstration of the level of alignment across the two stakeholder leader groups chosen is sufficient to demonstrate whether this is an issue that should be addressed as solutions are defined for California.

The variables for this study were: independent (the two respondent stakeholder groups), and dependent (the various role and goal choices). Each independent variable was evaluated against the identified dependent variables, first within the respondent stakeholder group and then across the two respondent groups. This allowed for a determination of statistically significant alignment within the educator leaders and within the industry leaders. It also assessed whether alignment existed in perception of the survey questions across the two surveyed respondent groups. The first portion of the survey attempted to ascertain the level of alignment within and across education and industry leaders related to nine specific goal statements that were derived from the literature and from non-profits that have been actively engaged in STEM. Pearson correlations were used to compare the stakeholder group (educator versus industry) for each of the nine goal ratings at the $p = .05$ level. If significant differences were found about the importance of goals either within and or across respondent groups, this would generate quantitative data that shows while California leaders are aligned about the importance of working the STEM workforce gap problem; they are not aligned about the specific goals of the improvement efforts.

The second question asked the respondents to select across three stakeholder groups (industry, academia, and government) who they believe should be doing what on specific task statements. This question focused on understanding if there is alignment relative to stakeholder roles in California. Respondents could select some, all, or none all of the three groups. Pearson correlations were used to establish at the alpha set at $p = .05$ alpha level, the relationship between a series of yes/no questions. This series of questions attempted to ascertain whom the respondent stakeholders believed should be doing what. A lack of statistically significant alignment would show that well intended stakeholders are likely not optimizing their collective resources.

Finally, there was a series of questions investigating surveyed stakeholders' perspectives on the current state of collaboration and integration across California stakeholders. As with the first question, Pearson correlations were used to compare the stakeholder group (educators versus industry leaders) with respect to the level of collaboration and integration across stakeholder leaders in California all evaluated at the $p = .05$ level. Once again, statistically significant differences would illustrate that the surveyed respondents would likely benefit from taking the time to strategize up front about their collective focus, investments, and roles prior to embarking on action.

If the survey did quantitatively show the lack of alignment in any or all of the three areas of goals, roles, and or collaboration and integration sections, this would help to show that part of the reason California is not making progress towards closing the gap despite interest and investment is that stakeholders are moving to action without an integrated strategic plan that focuses collective stakeholder efforts around aligned objectives and measures as required by a systems approach.

Analysis Unit

For this study the analysis unit was the stakeholder leader being surveyed. A series of education leaders associated with K-12 students and a series of industry leaders who are currently engaged in STEM activities in California were the targeted population. These leaders were the focus of interest for purposes of this research as the objective was to understand the current level of alignment across these thought and action leaders as they participate in decisions that set the direction for how California responds to the STEM workforce shortage going forward into the future. The analysis explored individual responses within their group and across the two groups being surveyed to identify any appropriate generalizations that could be made about the population with which they are affiliated (Crossman, 2012).

Population Data Sources

This quantitative study utilized a purposive sample of two of the five stakeholder groups in California, industry and education, who are currently actively engaged in the STEM workforce challenge:

- The first group was a purposefully selected segment of the K-12 education leadership community. The survey targeted approximately 50 superintendents, principals, as well as community college, CSU, and UC leaders. The Department of Education was utilized as the source for appropriate contact information for these leaders in education.

- The second group was comprised of industry leaders actively engaged in STEM activities in California today. Leader companies who have been identified in the literature as active participants, companies that have been identified by other non-profit integrators, and leaders who have participated in recent California conferences were targeted as candidates for the survey. The survey targeted about 50 of these individuals.
- Sample Size = 100: 50 Industry leaders, 50 education leaders
- Population = 250: 100 Active Industry Leaders (California Department of Education, 2012c; STEMconnector, 2011), 150 Superintendents, Community College, UC and Cal State Leaders (California Department of Education, 2012b)
- 95% confidence level

Data Collection Tool (Survey)

One of the challenges inherent in this research is that it is targeting leaders in education and in industry. The education leaders may be expected to have a vested interest in the STEM challenge in California and the industry leaders targeted are only those whose companies are already active in STEM concerns, they are still leaders who can be difficult to reach and who may not find the time to participate in the survey. To address this concern, the first step in the process was to canvas the respondent targets through a pre-survey introduction to the research. This introduction explained the objective of the research, the anonymity the survey afforded the respondents, the minimal level of effort that was required to fill out the survey, an offer to share the findings at the conclusion if the respondent was interested, and finally a request for them to indicate their interest in participating. The introduction to the research also gave the leader the option to provide 2-3 other leader names at his/her institution or company to whom they would like the survey directed. While the sample was designed to be 50 education leaders and 50 industry leaders, the pre-survey was sent to the total population as derived from the Department of Education listing and from all the industry targets identified. This approach reduced risk in a few ways. First, the researcher gained a better sense of the likelihood of response prior to issuing the survey. It also allowed the researcher to oversample the targeted respondent group populations to reduce the risk of insufficient data to draw meaningful conclusions.

Once the respondents confirmed interest in participating, they received the actual survey through SurveyMonkey (2012), an on-line survey tool that enables the collection and analysis of the data as well as protection of respondents' identity. The actual survey results were accessible only by the researcher and a statistical advisor. The survey tool was configured such that the results would not be accessible to the public. The researcher is the sole owner of the SurveyMonkey data, including email information and survey responses. E-mail information was not saved once a respondent completed the survey: an embedded SurveyMonkey capability. If a respondent asked to be withdrawn at any point in the process he/she could be removed from the survey list by contacting the researcher via an email address provided in the cover letter. All information was handled as private information and as governed with SSL security. A link was provided to the privacy and security policies of SurveyMonkey in the introductory letter. Before beginning the survey the respondents were presented with a brief overview of the survey objective and content and asked if they consented to proceed (Appendix A).

The survey was open for 3 weeks. SurveyMonkey (2012) allowed the researcher to send reminders to those who had not responded, which was done at the end of weeks 1 and 2. Figure 2 describes the data collection and analysis process the researcher followed.

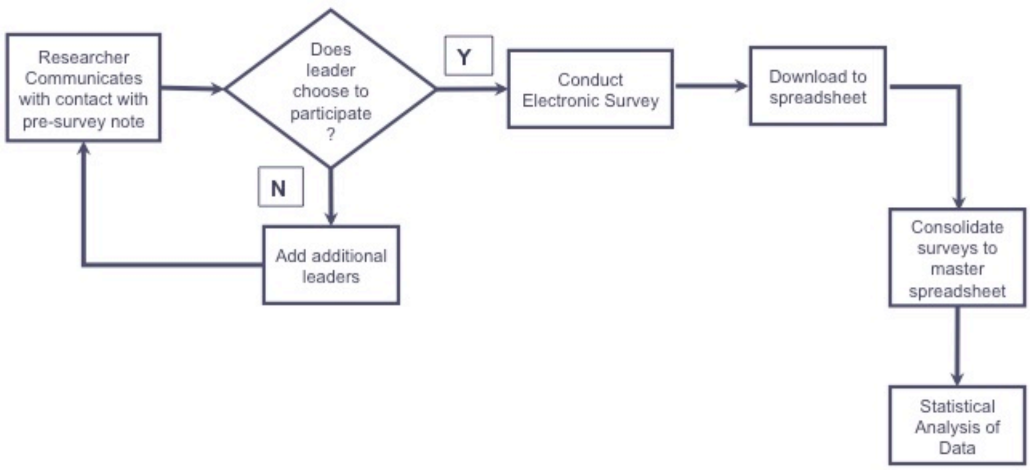

Figure 2. Data collection and analysis process.

The instrument itself was a 30-question, three-section, self-constructed survey utilizing Likert scale and self-selection items to identify respondents' perspectives toward specific statements about STEM goals and the roles of various stakeholders. Additionally, there was a series of informational questions investigating the surveyed respondents' perspectives relative to the current state of California's collaboration and integration.

The opening section of the survey collected demographic information about the stakeholder groups, including whether the respondent was in industry or education and their role in their field. The first research section identified a selection of discrete goals of California's STEM program for the surveyed stakeholders to rate relative to importance. The second section asked the surveyed industry and education leaders to assign ownership across three of the five core stakeholder groups – industry leaders, education leaders, or government leaders –to a series of identified STEM tasks. This was done in order to better understand, from the respondents' perspective, which stakeholder should be focusing on what activities within the STEM ecosystem. The final section was established to understand the surveyed stakeholders' perspective on the present state of collaboration and integration across STEM programs in California.

The goal, role, and collaboration selections in the survey were developed based on findings in the literature review as well as published STEM research study summaries conducted by organizations such as:

- STEMconnector (2011)
- BHEF (2007, 2010)
- California STEM Learning Network (n.d.)

These selections are not intended to be comprehensive, but rather representative of the consistent themes recurring in stakeholder discussions related to STEM literature. Table 1 shows the source of each question.

Study Design

The questions were organized into three sections in the survey to support the three research questions. If the answers from the respondents showed statistically significant differences in the section about Goals, that would demonstrate alignment across the two respondent leader groups surveyed, which is the focus of research question one. The second section of the survey asked the respondents to define who they think should be executing which tasks on behalf of STEM to test for alignment regarding roles from the perspective of the two respondent leader groups. Finally, the third section asked respondents to indicate whether they believe California stakeholders are current exhibiting collaboration and integration while addressing the STEM workforce gap problem.

Table 1

Research Questions, Data Source, Researcher, and Study Analysis Matrix

Research Questions	Data source	By Whom	Statistics or study analysis
1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?	Goals were selected based on areas of focus identified in the literature. Appendix B identifies the references for the goals selected. Survey Questions 1-10	Researcher	Pearson correlations will be used to compare stakeholder groups to understand whether there is statistically significant alignment within and or across the two respondent stakeholder groups, educator leaders and industry leaders relative to their perceptions of the importance of each goal.
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?	Tasks were identified based on the work of STEM identified in the literature. Appendix B identifies the references for the tasks selected. Survey Questions 11-25	Researcher	The two respondent groups will determine who they believe should execute each identified task. Pearson correlations will be used to see if there is any statistically significant alignment for each task with and or across the educator/industry leaders relative to who should be doing what with the STEM tasks.
3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?	Survey based upon leadership concepts, technical skills and interpersonal skills found in literature search. Appendix B identifies the references for collaborations and integration. Survey Questions 26-30	Researcher	Pearson correlations will be used to compare stakeholder groups to understand whether there is statistically significant alignment within and or across the two respondent stakeholder groups, educator leaders and industry leaders relative to their perceptions of current level of collaboration and integration across California stakeholder leaders

If educator leaders all found a goal *very important* and industry leaders found the same goal *not important*, this would demonstrate a lack of alignment across the two stakeholder groups. The same could be observed with the group of educator leaders where they may have been divided on the importance of a goal or who should be executing a particular task for STEM, or even the current state of collaboration and integration across stakeholder leaders in California. The objective of the survey was to explore the three research questions to ascertain whether the communities working to solve the STEM workforce gap see their goals and roles in a similar fashion, a requirement for designing a systemic solution, or whether they are plunging forward with solutions before there is alignment across the community on what the goals and measures of this acknowledged STEM issue should be.

Validity

Content validity was established by using a subject matter expert group that served as a judge panel in order to preview the content and ensure it covered a sufficient spectrum of STEM goals and roles (Bryman, 2008). The expert group was made up of a few leaders from CSLNet as well as a few industry leaders. These leaders were asked to validate that the content was sufficiently representative of the goals, roles, and indicators of collaboration for California STEM. Any significant areas of concern were addressed prior to the pilot administration of the survey.

Reliability

Reliability of the survey addresses the consistency of the survey instrument (Bryman, 2008). To ensure reliability, a pilot survey was administered to a small sample of the intended population. A small subset of the respondents (two to three each) from both industry and education who agreed to participate were asked to participate in a pilot to ensure the questions were clear and unambiguous before administering it to the total respondent population. Pilot candidates were asked to provide suggestions for clarity if a question was unclear. Updates were made as appropriate.

Survey Data Collection Approach

The survey was administered asynchronously using the online survey software, SurveyMonkey (2012), which delivered a questionnaire (Appendix C) electronically to the identified stakeholder populations. The initial invitation to participate preceded the survey itself, explaining its purpose and requesting their consent to participate. Because this survey targeted leaders in education and industry, there was a potential risk in respondents taking the time to respond. To reduce this risk, the initial invitation asked whether they would participate and if not, if they knew someone to whom they would like to delegate the survey (Appendices D & E). The first step of the data collection process was obtaining electronic access to the various stakeholder groups. As previously discussed, the two groups targeted for the survey were education and industry leaders. These leaders were asked for their perspectives about California STEM goals as well as their perspectives related to the role focus of their groups, and those of the other three core stakeholder groups that were addressed in this study. These include:

- Non-profits and foundations: organizations such as the California STEM Learning Network, STEMconnector, Innovate + Educate, Bill and Melinda Gates Foundation, Bechtal Foundation, ASTRA, STEM Collaborative Action Plan Group, and the California STEM Task Force which has been commissioned by the Department of Education;
- Government leaders: this group is made up of policy leaders in the legislature, the governor's office, as well as regional government leaders such as mayors;

- Community leaders: this group includes members of organizations such as the California PTA network, as well as regional chamber of commerce leaders.

All five of these groups were defined in the body of the questionnaire to ensure a common understanding of the stakeholder groups related to the questions.

Another risk for the two leader respondent groups was the timeliness of response. The survey was limited to a 3-week period for response. Weekly reminders were sent to those surveyed to encourage returns (Appendix F).

Data Analysis

Each of the research questions was explored through the survey questions in order to test for current levels of alignment related to the questions' focus both within and across the stakeholder groups. Table 2 describes the analysis approach that was applied to the quantitative portion of this mixed methods research:

Table 2

Quantitative Analysis Approach

Research Question	Related Null Hypothesis	Survey Items	Statistical Approach
1. Are the perceptions of the two respondent stakeholder leader groups aligned relative to 9 identified California STEM goals?	None of 9 perception ratings will be significantly different between the 2 respondent groups Alternative: At least 1 of the 9 will be significantly different	1. 9 discrete goal statements 2. 2 respondent groups: 3. Industry versus Education 3. Pick top 3 priorities Items 1-10	Pearson correlation coefficients with alpha level set at $p = .05$
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?	None of the role assignments will be related to respondent group leaders' affiliation Alternative: At least one of the role assignments will be related to the respondent group across the stakeholder groups.	15 discrete tasks will be assigned Yes or No designation across 3 of the stakeholder groups: Education, Industry, Government resulting in 45 Yes/No questions compared across the 2 respondent groups. Items 11-25	Pearson correlation coefficients with alpha level set at $p = .05$

(continued)

	Research Question	Related Null Hypothesis	Survey Items	Statistical Approach
3.	What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?	No difference in perception of the degree of collaboration across the CA stakeholders Alternative: At least one of the respondent groups will be significantly different	5 discrete activities assigned levels by 2 stakeholder groups, Items 26-30	Pearson correlation coefficients with alpha level set a $p = .05$

Plans for IRB

This research project was submitted to IRB utilizing an exempt application. The category proposed for this research was 45 CFR 46.101(b)(2). The proposed research involved interviews with an adult population that is not part of a protected group. The questions and information posed none to minimal risk to the participants. SurveyMonkey was the tool being used. On the introduction to the survey, a description of privacy practices was provided to the respondents. The researcher utilized best practice data gathering and privacy practices. Areas covered included:

- A description of the demographic information being collected and how it would be utilized,
- The purpose of the responses and how they would be used,
- The fact that responses would be quantitatively assessed within and across the stakeholder groups and would not be identified to any individual respondent in the analysis,
- Acknowledgement that all responses would be managed on an encrypted survey link as well as providing respondents with access to the privacy and security policies of SurveyMonkey,
- E-mail addresses would not be saved once a respondent submits their survey, so all responses will be anonymous, and
- How respondents could contact the researcher (SurveyMonkey, 2012).

The actual survey results were be accessible by the researcher and a statistical advisor, and the survey tool was configured such that the results would not be accessible to the public. The researcher is the sole owner of the SurveyMonkey data, including email information and responses. E-mail information was not saved once a respondent completed the survey: an embedded capability of SurveyMonkey. If a respondent asked to be withdrawn at any point in the process he/she was could be removed by contacting the researcher via an e-mail address provided in the cover letter. All information was handled as private information and was governed with SSL security. The researcher validated that SurveyMonkey was an appropriate vehicle on which to host the survey and also to publish subsequent results, as long as the SurveyMonkey policies regarding data and services were upheld (Appendix G). Approval to proceed with the survey from the IRB is documented in Appendix H.

Summary

A quantitative approach was chosen given the lack of measured data about stakeholder alignment in the current literature. The CA STEM workforce gap is not closing and fiscal resources available to California educators are challenged as well. The results of this quantitative research, understood in the context of an open systems design, may hold the missing link that will enable a more focused strategic plan for California stakeholder leaders as they design and invest in STEM solution approaches in the future. The irony is that the fields of science, technology, engineering, and math are based on systematic, quantifiable, systems-oriented frameworks taught in academic environments and practiced in industry environments. Despite the practice of these systems frameworks in both industry and education, these same stakeholders are not applying these systems problem-solving techniques to the challenge of solving the shortage of STEM capable workers in California. This quantitative research hopes to ascertain whether the alignment gap is a fundamental missing element critical to solving the California workforce gap utilizing a systems based approach.

Chapter 4: Presentation and Analysis of Research Results

The purpose of this study was to explore the current level of alignment around the discrete goals addressing California's STEM workforce challenges. Additionally, the study assessed the level of alignment related to stakeholder leaders within the STEM system relative to their respective roles in working towards solutions. The purpose of focusing on the roles was to understand the level of alignment among the stakeholders, as well as to gain a better understanding of who should be engaged in which specific tasks. Lastly the study looked at the current state of collaboration across the stakeholders groups in California.

The central research questions were:

1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?
3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?

Table 3 displays the frequency counts for the selected variables. There was a fairly even balance of educators and industry respondents. A total of 82 individuals from industry and education participated in this study. The educators in this study made up 53.7% of the respondents. Twenty-nine percent (24) came from K-12 with the balance, five coming from community colleges (6.1%), 10 from the California State system (12.2%), and five other educators (6.1%). The respondents also characterized themselves relative to their respective roles in education. Educator superintendents (five) and college and university leaders (three) made up 6.1% and 3.7% of the respondents respectively. The majority of the educator respondents (22.0%) identified themselves as teachers or professors (18), followed by administrators and program directors comprising 15.9% of the educator group (13).

Table 3

Frequency Counts for Selected Demographic Variables

Variable	Category	*n*	%
Leader Designation	Education K-12	24	29.3
	Education Community College	5	6.1
	Education CA State	10	12.2
	Education Other	5	6.1
	Industry High Tech	29	35.4
	Industry Other	9	11.0
Professional Grouping	Education	44	53.7
	Industry	38	46.3
Leader Role	Education Superintendent	3	3.7
	Education College/University Leader	5	6.1
	Education Professor/Teacher	18	22.0
	Education Other	13	15.9
	Industry Executive	18	22.0
	Industry Manager/Supervisor	16	19.5
	Industry Other	9	11.0

Note. $N = 82$

Industry represented 46.4% (38) of the respondents with the majority (35.4%) identifying themselves as high technology industry (29) and the balance (11%) identifying themselves as other (9). The industry leaders were comprised of 18 executives (22.0%) and 16 managers and supervisors (19.5%). The balance of the industry respondents (9) identified themselves as other (11.0%).

Central Research Questions

Research Question One asked, Are the perceptions of the two respondent stakeholder groups aligned relative to the nine identified California STEM goals? To answer this question, Pearson correlations were used to compare the stakeholder group (educator versus industry leader) for each of the nine ratings. None of the nine correlations were statistically significant at the $p < .05$ level. There was no significant difference between how educators and industry leaders responded relative to the perceived importance of the goal.

Table 4 shows that the majority of the population of aligned respondents believed that Goal 4h, "Increase STEM interest, capabilities and engagement among all P-14 California students (with an emphasis on critical thinking, innovation, and use of information technologies)" with a mean of 4.41 (out of a possible 5.00) and a standard deviation of 0.77 was the most important. This was followed Goal 4a, "Strengthen and expand access to STEM teaching and learning in schools, colleges and communities" with a mean of 4.34 (*SD* = 0.82). The goals with the lowest scores were Goal 4d, "Increase STEM certificate and degree completions from women and minorities" with a mean of 3.93 (*SD* = 1.14, and Goal 4i, "Adopt next generation science standards and implement common core state standards" with a mean of 3.76 (*SD* = 1.15).

Table 4

Ranking of the Importance of STEM Goals Sorted by Highest Mean

Goals	*M*	*SD*
4h. Increase STEM interest, capabilities and engagement among all P-14 California students (with an emphasis on critical thinking, innovation, and use of information technologies	4.41	0.77
4a. Strengthen and expand access to STEM teaching and learning in schools, colleges and communities	4.34	0.82
4c. Increase the number of students who pursue STEM-related credentials, degrees and careers	4.28	1.02
4e. Increase the number of STEM teachers with STEM degrees and credentials for K-12	4.22	0.98
4f. Ensure California has an aligned set of goals for K-12 student outcomes agreed to by education, industry and the community	4.09	0.88
4g. Ensure that expenditures for STEM programs are coordinated and tied to outcomes	3.95	0.96
4b. Close the workforce capability gap in California as measured by employers	3.94	1.05
4d. Increase STEM certificate and degree completions from women and minorities	3.93	1.14
4i. Adopt next generation science standards and implement common core state standards	3.76	1.15

Note. N = 82. Ratings based on a 5-point metric: 1 = *Not important* to 5 = *Critically important.*

Respondents were also asked to rate their top three of the nine goals listed. Table 5 shows the frequencies from highest to lowest of the top three responses for all nine goals from the aggregated responses of educator and industry leaders. The top three were: (a) item 5c, “Increase the number of students who pursue STEM-related credentials, degrees and careers” (50.0%); (b) item 5a, “Strengthen and expand access to STEM teaching and learning in schools, colleges and communities" (46.3%); and (c) item 5e, "Increase the number of STEM teachers with STEM degrees and credentials for K-12" (43.9%).

Table 5

Frequency Counts for Top Three Goals Sorted by Highest Frequency

Goal	*n*	%
5c. Increase the number of students who pursue STEM-related credentials, degrees and careers	41	50.0
5a. Strengthen and expand access to STEM teaching and learning in schools, colleges and communities	38	46.3
5e. Increase the number of STEM teachers with STEM degrees and credentials for K-12	36	43.9
5h. Increase STEM interest, capabilities and engagement among all P-14 California students (with an emphasis on critical thinking, innovation, and use of information technologies)	31	37.8
5b. Close the workforce capability gap in California as measured by employers	16	19.5
5f. Ensure California has an aligned set of goals for K-12 student outcomes agreed to by education, industry and the community	15	18.3
5d. Increase STEM certificate and degree completions from women and minorities	15	18.3
5i. Adopt next generation science standards and implement common core state standards	14	17.1
5g. Ensure that expenditures for STEM programs are coordinated and tied to outcomes	10	12.2

Note. $N = 82$

Research Question Two asked, Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation? The respondents were asked to identify whether Education, Industry, and or Government should be focusing on the tasks. They were to endorse all stakeholders that applied per task; if they believed no one should take on the identified task they were requested to leave all the boxes for that task blank. Pearson correlations with an alpha level set at $p = .05$ were used as tests of significance. Each of the 15 tasks was evaluated for statistical significance across potential endorsements of responsibility for education, industry, and government. Across all 45 combinations (15 task ratings and three stakeholder groups), only two showed a statistically significant correlation. Specifically, educators were more likely to endorse that task 6i was the responsibility of education, ‘Facilitate collaboration within and across the various regional stakeholders as educator respondents’ ($r = -.26$, $p = .02$) as well as task 6o, “Provide scholarships/internships and employment opportunities for STEM students as educator respondents” ($r = -.24$, $p = .04$). As with STEM goal responses, both educators and industry leaders were aligned around whom should be focusing on what across the tasks identified for 43 of 45 task-stakeholder responsibilities.

Table 6 identifies the frequency of responses assigned by the respondents to educator leaders sorted by the highest frequency. The top tasks assigned to educators were task 6j, “Heighten student and community awareness and excitement about STEM opportunities” (86.6%) and task 6k, “Create an integrated master plan for California including metrics” (82.9%). The least frequently targeted tasks for educators were task 6o, “Provide scholarship/internships and employment opportunities for STEM students” (32.9%), and task 6m, “Provide employment projections” (7.3%).

Table 6

Frequency Counts for Tasks Assigned to Educator Leaders by the Respondents Sorted by Highest Frequency

Goal	*n*	%
6j. Heighten student and community awareness and excitement about STEM opportunities	71	86.6
6k. Create an integrated master plan for California including metrics	68	82.9
6b. Define the goals for California STEM education that address workforce gaps	65	79.3
6d. Make recommendations for alternative STEM education approaches	65	79.3
6c. Identify redundancies and duplication in current STEM initiatives	64	78.1
6i. Facilitate collaboration within and across the various regional stakeholders	56	68.3
6h. Provide people, capital and facilities to support STEM education needs	54	65.3
6g. Identify community gaps and needs	50	61.0
6e. Coordinate STEM policy across the stakeholders	47	57.3
6f. Publish regular measures of progress against agreed to STEM Goals at defined levels (State, Regional, District)	41	50.0
6l. Carefully coordinate STEM investments across regions	39	47.6
6n. Define workforce education and training related needs	35	42.7
6a. Define the skills required for the 21st Century workforce in California	34	41.5
6o. Provide scholarships/internships and employment opportunities for STEM students	27	32.9
6m. Provide employment projections	6	7.3

Note. $N = 82$

Table 7 identifies the frequency of responses assigned to industry leaders sorted by the highest frequency. The top tasks assigned to industry were 6o, “Provide scholarships/internships and employment opportunities for STEM students” (92.7%) and task 6n, “Define workforce education and training related needs” (91.5%). The least frequently identified tasks for industry focus were identified as task 6c, “Identify redundancies and duplication in current STEM initiatives” (28,1%) and task 6f, “Publish regular measures of progress against agreed to STEM Goals at defined levels (State, Regional, District)” (19.5%).

Table 7

Frequency Counts for Tasks Assigned to Industry Leaders by the Respondents Sorted by Highest Frequency

Goal	*n*	%
6o. Provide scholarships/internships and employment opportunities for STEM students	76	92.7
6n. Define workforce education and training related needs	75	91.5
6a. Define the skills required for the 21st Century workforce in California	74	90.2
6m. Provide employment projections	72	87.8
6j. Heighten student and community awareness and excitement about STEM opportunities	63	76.8
6h. Provide people, capital and facilities to support STEM education needs	62	75.6
6g. Identify community gaps and needs	56	68.3
6b. Define the goals for California STEM education that address workforce gaps	56	68.3
6d. Make recommendations for alternative STEM education approaches	54	65.9
6i. Facilitate collaboration within and across the various regional stakeholders	52	63.4
6k. Create an integrated master plan for California including metrics	44	53.7
6l. Carefully coordinate STEM investments across regions	37	45.1
6e. Coordinate STEM policy across the stakeholders	36	43.9
6c. Identify redundancies and duplication in current STEM initiatives	23	28.1
6f. Publish regular measures of progress against agreed to STEM Goals at defined levels (State, Regional, District)	16	19.5

Note. $N = 82$

Table 8 identifies the frequency of responses assigned by the respondents to government leaders sorted by the highest frequency. The top tasks assigned to government were task 6e, “Coordinate STEM policy across the stakeholders” (80.1%) and task 6l, “Carefully coordinate STEM investments across regions” (78.1%). The least frequently identified tasks for government were task 6b, “Define the goals for California STEM education that address workforce gaps” (32.9%) and task 6n, “Define workforce education and training related needs” (32.9%).

Table 8

Frequency Counts for Tasks Assigned to Government Leaders by the Respondents Sorted by Highest Frequency

Goal	*n*	%
6e. Coordinate STEM policy across the stakeholders	66	80.5
6l. Carefully coordinate STEM investments across regions	64	78.1
6h. Provide people, capital and facilities to support STEM education needs	64	78.1
6f. Publish regular measures of progress against agreed to STEM Goals at defined levels (State, Regional, District)	61	74.4
6i. Facilitate collaboration within and across the various regional stakeholders	54	65.9
6o. Provide scholarships/internships and employment opportunities for STEM students	53	64.6
6k. Create an integrated master plan for California including metrics	52	63.4
6m. Provide employment projections	46	56.1
6g. Identify community gaps and needs	45	54.9
6j. Heighten student and community awareness and excitement about STEM	35	42.7
6c. Identify redundancies and duplication in current STEM initiatives	35	42.7
6a. Define the skills required for the 21st Century workforce in California	30	36.6
6d. Make recommendations for alternative STEM education approaches	28	34.2
6b. Define the goals for California STEM education that address workforce gaps	27	32.9
6n. Define workforce education and training related needs	27	32.9

Note. $N = 82$

Table 9 is the final table derived from survey data collected for Research Question Two, and displays the aggregated frequency responsibility data with all three executors (education, industry, and government), and the associated collective position on who should be engaged in that particular task. The data is considered to be meaningful wherever there is a difference of 20% or more between executors. For task 6m, “Provide employment projections," 7.3% of the respondents identified this as the responsibility of education while 87.8% of the respondents identified the responsibility as belonging to industry. For task 6o, "Provide scholarships/ internships and employment opportunities for STEM students," 32.9% of the respondents identified the responsibility as belonging to educators while at the same time, 92.7% of the respondents believed the responsibility belonged to industry.

Table 9

Aggregated Frequency Responsibility Data by Executor (Education, Industry, Government) by Task

Task	Ed %	Ind %	Gov %
6a. Define the skills required for the 21st Century workforce in California	41.5	90.2	36.6
6b. Define the goals for California STEM education that address workforce gaps	79.3	68.3	32.9
6c. Identify redundancies and duplication in current STEM initiatives	78.0	28.0	42.7
6d. Make recommendations for alternative STEM education approaches	79.3	65.9	34.1
6e. Coordinate STEM policy across stakeholders	57.3	43.9	80.5
6f. Publish regular measures of progress against agreed to STEM Goals at defined levels (State, Regional, District)	50.0	19.5	74.4
6g. Identify community gaps and needs	61.0	68.3	54.9
6h. Provide people, capital and facilities to support STEM education needs	65.9	75.6	78.0
6i. Facilitate collaboration within and across the various regional stakeholders	68.3	63.4	65.9
6j. Heighten student and community awareness and excitement about STEM opportunities	86.6	76.8	42.7
6k. Create an integrated master plan for California including metrics	82.9	53.7	63.4
6l. Carefully coordinate STEM investments across regions	47.6	45.1	78.0
6m. Provide employment projections	7.3	87.8	56.1
6n. Define workforce education and training related needs	42.7	91.5	32.9
6o. Provide scholarships/internships and employment opportunities for STEM students	32.9	92.7	64.6

Note. $N = 82$. Ed = Education, Ind = Industry, Gov = Government

Research Question Three asked, What is the current state of collaboration in California based on the perception of the two respondent groups' leaders? To answer this question, Pearson correlations were used to compare the stakeholder group (educators versus industry leaders) with the level of collaboration and integration across stakeholder leaders in California. None of the five collaboration/ integration statements was significant at the p value < .05 level. Table 10 shows the current ranked level of collaboration statements across California stakeholder leaders sorted by the highest mean. These ratings were based on a 5-point metric (1 = *Never* to 5 = *Very Common*). The highest level of collaboration was found for task 7a, "A regional STEM agenda exists with support from key stakeholder leaders in education, industry, the community and local government" (M = 2.88) while the least common task was 7b, "Success measures have been defined at the regional level and accountabilities are shared across the stakeholder leaders" (M = 2.51).

Table 10

Ratings of Collaboration/Integration Across the California Stakeholder Community Sorted by the Highest Mean

Collaboration Statement	*M*	*SD*
7a. A regional STEM agenda exists with support from key stakeholder leaders in education, industry, the community and local government	2.88	0.84
7c. Regional stakeholder leaders work together to strategize and collaborate on investments	2.76	0.81
7e. Barriers to collaboration are identified and addressed by the stakeholder leaders	2.55	0.97
7d. A regional implementation and communications plan has been created by the impacted stakeholder leaders	2.52	0.86
7b. Success measures have been defined at the regional level and accountabilities are shared across the stakeholder leaders	2.51	0.77

Note. N = 82. Ratings were based on a 5-point metric: 1 = *Never* to 5 = *Very Common.*

In conclusion, this study explored the current level of alignment around the discrete goals and roles of California stakeholder leaders as well as assessing the current level of collaboration across these stakeholders. This was accomplished by analyzing the perceptions of 44 educators and 38 industry leaders. In the final chapter, these findings will be compared to the literature, conclusions and implications will be drawn, and a series of recommendations will be suggested.

Chapter 5: Summary, Conclusions and Recommendations

Summary of the Results

This chapter will summarize the results of the quantitative research study as well as advocate for the application of a systems approach to addressing the California STEM crisis as discussed in the literature review chapter. The literature will be compared to the research study findings to identify consistencies and challenges and any new contributions not found in the reviewed literature. The literature examination will be followed by a discussion of conclusions and implications for the STEM-focused community as well as recommendations for future research. The chapter will conclude with overall perspectives of the research and thoughts about next steps and action recommendations.

This dissertation utilized two core methodologies to approach understanding and addressing the California STEM workforce gap. The first was an exploration of a systems approach as a critical enabler to addressing a complex social problem through the literature reviewed in Chapter 2. The second was a quantitative study of the current state of alignment of California stakeholders relative to the specific goals of the STEM program as well as their perspectives about roles, who should be executing what STEM tasks. The quantitative research also sought to understand the current level of collaboration and integration across stakeholder leaders in California.

The purpose of the research study was to explore the current level of alignment around the discrete goals addressing California's STEM workforce challenges. Additionally, the study assessed the level of alignment related to stakeholder leaders within the STEM system relative to their respective roles in working towards solutions. The purpose of focusing on the roles was to understand the level of alignment existing among the stakeholders, as well as to gain a better understanding as to who should be doing what. The research was also looking to quantify the current state of collaboration across key stakeholder leaders in California.

The central research questions were:

1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?
3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?

The survey research sought to understand the current level of alignment around the discrete goals and roles of California stakeholder leaders as well as assess the current level of collaboration across these stakeholders. This was accomplished by analyzing the perceptions of 44 educators and 38 industry leaders.

Three key findings were:

1. There were no significant differences between educators and industry leaders about the importance of the surveyed STEM goals that were identified as a part of the literature review.
2. There were no significant differences between educators and industry leaders about who (i.e., which roles) should be focusing on what key tasks across educators, industry and government. Additionally, meaningful differences

consistently identified by the respondents were across the tasks, indicating alignment about who should be executing these tasks across educators and industry leaders

3. There was no significant difference between educators and industry's perceptions relative to the current state of alignment and collaboration in the state of California.

As stated previously, *none* of the three central research questions was supported by quantitative Pearson correlations with a p value < .05 that showed a statistically significant difference in the response provided by educator leaders versus industry leaders. Had the data shown a statistically significant difference between these stakeholder leader respondent groups there would be quantitative data showing that part of the potential problem with closing the California STEM workforce gap may be found in this stakeholder misalignment.

The first research question, "Are the perceptions of two respondent stakeholder leaders groups aligned relative to nine identified California STEM goals?" was explored by surveying educator and industry stakeholder leaders about the relative importance of the nine core goals of STEM which was the focus of research question number one pulled from the literature review covered under the first section of the research survey. None of the correlations run showed a p value of less than .05. Instead of finding misalignment the data showed alignment about the importance of the surveyed goals as shown in Table 4 where responses ranged from 4.41 (out of a possible 5.00) at the high end to a low of 3.76 with 3.00 indicating important and 5.00 indicating critically important across the educator and industry leaders. Additionally, Table 5 provided insight into where these stakeholder leaders would collectively place their focus as they selected their top three goals as identified by the top three goals selected from the list of nine provided for rating. Instead of showing where these leaders needed to work to gain alignment, the data reinforces that this alignment is already in place.

Likewise, this result repeated itself with the survey questions that were asked to address the second research question, "Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leader's affiliation?" The Pearson correlations again showed no statistical significance at the $p < .05$ level across educators and industry leaders about their perceptions of whether the STEM tasks listed should be executed by education, industry or government. Once again the surveyed stakeholder leaders showed alignment around who should be focusing on what. Tables 6, 7, and 8 analyzed the frequency data that identified the tasks from highest alignment to lowest across the stakeholders characterizing the aligned positions regarding what educators, industry and government should be focusing on respectively. While the research data did not provide support for the STEM gap challenge being created by a misalignment of roles across the stakeholder leaders, it instead once again provided data that showed the surveyed respondents share a common perspective that creates a potential opportunity to build from. Another perspective is shown in Table 9 that showed the frequency data associated with the entire array of respondent role identifications. Where the frequencies had differences of 20 or more percentage points the data is being considered as meaningful. In these instances stakeholders not only were aligned, but also demonstrated collective clarity around what tasks specific stakeholder leaders should be focusing on. A few examples from the data are:

- 90.2% of the respondents believe industry should be defining the skills required for the 21st Century workforce with only 41.5% identifying this as a role for educators and 36.6% as a role for government.
- 78.0% of the respondents believe that educators should be identifying redundancies and duplication in the current STEM initiatives with only 28.0 identifying this as a role for industry and only 42.7% as a role for government.
- 74.4% of the respondents believe that government should be publishing regular measures of progress against agreed to STEM goals at defined levels (State, Regional, District), with 50.0% identifying this as a role for educators and only 19.5% identifying this as a role for industry.
- Alternatively, several goals showed little to no spread across educators, industry and government indicating that all three play a role in executing that task.

Finally, the third research question, "What is the current state of collaboration in California based on the perceptions of the two respondent group's leaders?" once again showed no statistical significance at the $p < .05$ level. Educator and industry leaders were aligned about California's current state. While Table 10 shows there was alignment demonstrated across the leaders, the results indicate low levels of current state collaboration with the lowest collaboration score identified as 2.51 and the highest at 2.88 on a scale of 1 to 5 with 1 identified as *Never* and 3 as *Uncommon*. A score of 5 was identified as an environment where collaboration was *Very Common.* These results indicate alignment in the stakeholder's perception that the level of current state collaboration across the key stakeholder leaders in California is happening at a *Very*

Uncommon (2) to *Uncommon* (3) Level. While there is alignment, this question may point to a gap that is inhibiting California in closing the STEM workforce gap. Table 9 shows alignment about who should be executing specific tasks in California and in many instances it shows several stakeholder leaders as responsible for executing the stated task. If the leaders acknowledge that the current state of collaboration falls between very uncommon and uncommon it is unlikely the leaders are consistently working together on a plan to close the California STEM workforce gap. Again the stakeholders are aligned, but they are aligned about a current state that is not ideal. With this low level of alignment it is unlikely that these stakeholder leaders are strategizing together to address the STEM workforce gap across the state with discussion about *how* they should collectively approach recommended improvements as well as, *what* the measures of success should be.

One of the goals of this dissertation was to quantitatively explore the current state level of alignment across key stakeholder leaders relative to the central research questions. While stakeholder leaders demonstrate alignment around the importance of the STEM workforce goals as indicated by the quantitative survey, the results of the literature review indicate the outcomes are not improving. This research sought to understand if this lack of workforce gap closure was the result of a lack of alignment across key stakeholder leaders or perhaps due to something else. The results of this research study would not support a lack of alignment as being a likely cause of the current STEM workforce shortfall.

Another one of the goals of this study was to explore whether the application of a systems approach could be beneficial to addressing the California STEM workforce gap.

The quantitative portion of the study indicated that alignment generally exists across educator and industry stakeholder leaders. It appears that alignment alone is insufficient to solve the STEM problem. By combining the results of the research with the literature review findings that discuss the importance of approaching large complex problems systematically, this study may have identified a critical approach gap to the STEM workforce challenge in California. The questions in the third section of the research survey associated with research question three identified in Question 7 of Appendix D show that a missing link to the current state approach is the lack of a robust systems design at an agreed to implementation level, i.e., state, regional or district level to guide subsequent action plans.

Literature Review Analysis

This section will summarize the opportunities to apply approaches from the literature review that are consistent with the findings of the research conducted. It will review the effectiveness of systems approaches to address social problems, pointing to an opportunity for application to the California STEM workforce gap crisis (Brafman & Beskstrom, 2006; Hanna, 1997; von Bertalanffy, 1950; Wheatley & Kellner-Rogers, 1999). Next the discussion will cover challenges presented by the literature review and research results. The section will conclude with a synthesis of the literature review and its relevance to recommendations for this study.

The literature strongly supports the gravity of the national STEM workforce gap as identified in Chapter 1, with findings such as those by a U.S. Department of Commerce (2012) study that noted the U.S. has made no progress in its competitiveness since 1999, and is beginning to lose ground to other countries that are actively building their scientific and technological infrastructures. Additionally, while the U.S. is dealing with high levels of unemployment, there is a projected shortfall of over 35 million skilled workers over the next 30 years (Bozell & Goldberg, 2009). Supporting the existence of this shortfall is a finding that indicates the current number one issue facing industry is a shortage of talent, rising from 22nd place in 2009, overtaking concerns over stability in financial market factors (Davis, 2012).

There is also alignment in the literature about the importance of addressing the STEM workforce gap. The STEM workforce is critical to the U.S., impacting the standard of living as well as national security in areas such as international competiveness, combating terrorism, and addressing global warming, to name just a few (Hira, 2010). Despite basic alignment around the importance of addressing the STEM shortfall in the U.S. over the last 30 years, necessary improvements in workforce availability and competency have not been achieved (Axelrod, 2010; Camp, 1997; Haney et al., 2004).

Systems Thinking, Modeling, and Human Systems Literature Alignment

The support for a systems approach to a problem such as the California STEM workforce gap was documented in Chapter 1 by the challenges identified in the America COMPETES Act of 2007 and echoed in other studies (Council on Competitiveness, 2005; National Academies, 2007), which pointed to the need for increased research investment, strengthened educational opportunities from kindergarten through graduate school, and the development of an innovation infrastructure. These challenges require the creation of a systemic, integrated approach that will involve educators, as well as the collective brainpower and financial support of the public and private sectors (Thomas &

Williams, 2010). Additionally, leaders in systems thinking, point to the importance of first adequately understanding the problem before attempting to solve it. This philosophy was proffered by Rubenstein (1986), a noted systems thinker and problem solver, who stated; “A problem well understood and well stated is often half solved” (p. 6).

Several approaches to systems thinking were explored in Chapter 2. The open systems model appears to be particularly relevant to the unique challenges of the California STEM workforce gap. Open systems are essentially leaderless systems, at least as defined by traditional organizational design models. The STEM challenge exists in an environment of multiple stakeholders and organizational structures. The final research question addressed by the survey (Appendix D, Question 7) showed a very low level of collaboration currently occurring across California stakeholder leaders despite an aligned concern about the importance of the California STEM workforce gap. It is not clear who has been charged with resolving the overall problem and what the mechanisms should be for creating and measuring the results of a more collaborative systems design.

Another important finding in the literature was the nuance of developing a systems design in a CAS environment. In a CAS environment, elements of the system are highly dependent upon one another. If one element within this type of system changes, other elements are subject to failure (N. Johnson, 2009; Miller & Page, 2007). Because of this characteristic the introduction of change needs to be carefully assessed to try to minimize unintended consequences. An example of unintended consequences can be seen when an incentive system is introduced without examining what other unintended behaviors may be incentivized. For example, an organization wants to reduce injuries in the workplace and so it offers free pizza lunch to the team with the least reported injuries.

Mary’s team has not had a reported injury in over 200 days and is destined to win this period’s pizza lunch when Mary begins to feel ever-worsening pain in her wrist from all her computer data entry activity. She chooses not to report her pain, as she does not want to let her team down. They do in fact win the pizza, but Mary’s wrist worsens to the point that she can no longer perform her work without surgery and 2 months off work, costing her employer significantly more in worker’s compensation than a little physical therapy or adjustment to her workspace would have cost initially.

To combat unintended consequences that are the result of discrete metrics chosen as success measures such as the example above, much work has been done to create modeling tools in an attempt to predict outcomes in complex situations in a simulated environment. These models allow stakeholder problem solvers the ability to look at the many levels involved in addressing the California STEM workforce challenge at the national, state, and regional levels from the vantage point of educators, businesspersons, communities, government, and non-profits. In the STEM space there needs to be consistency and alignment at the local level before aggregating at the district or regional level, and ultimately moving to the state and federal levels (Collins et al., 2009; Kim, 2000). In order to get to the root of the problem and define system models that will impact the major leverage points in a system, the system must consider the goals and needs of all levels and stakeholders. If the systems design team does not exist or does not possess an adequate characterization of the problem, the team will not be able to set up accurate models to simulate options.

The power of a good model should not be underrated, particularly in a landscape currently peppered with significant activity and investments but disappointing results.

Strategic policy decisions in STEM can be significantly improved by addressing the workforce problem as a CAS with many feedback loops and the need to be adaptive (Hira, 2010). The objective of exploring systems thinking and modeling is to arm decision makers with new tools that will improve the outcomes of social systems problems (Miller & Page, 2007; Subotnik et al., 2010) such as the STEM workforce challenge.

Finally, there was considerable alignment in the literature around the human element of open CASs. An example discussed in Chapter 2 illustrates the importance of the human factor in strategy and design models; 85% of business acquisitions fall short of their projected goals because they have not adequately prepared for the social side of a business acquisition as an element that must be dealt with (Chatzkel & Saint-Onge, 2007). A critical human factor in the STEM challenge lies with the behavior of the stakeholder leaders. Leader behaviors are key to the successful resolution of the STEM workforce challenge. There will likely be issues of trust even when all parties accept the premise that unity throughout the stakeholder leader community is vital to addressing the STEM gap. These trust issues may arise because of varied interests and a basic lack of understanding of respective stakeholder leader languages, challenges, and objectives.

Challenges Identified In the Literature

The interesting paradox presented by the California STEM workforce gap challenge is that there is considerable alignment in the literature about the criticality of the problem and the lack of progress, despite what appears to be alignment of general purpose and quite a bit of activity and investment occurring across the stakeholders in industry, education, government, non-profits, and the community (Davis, 2012; Elrod, 2006; STEMconnector, 2011). There is also alignment in the literature that a systems approach is a good fit for solving a complex social problem such as the California STEM workforce gap. (Brafman & Beskstrom, 2006; Hanna, 1997; von Bertalanffy, 1950; Wheatley & Kellner-Rogers, 1999). Stakeholders agree that alignment and collaboration are critical to resolving this issue and they also agree that despite sporadic success stories, solutions have lacked scalability and sustainability at the level required to close the STEM gap in the critical time window required.

The survey results discussed in this chapter indicate that California's STEM workforce gap is not the result of a lack of alignment across the surveyed stakeholder leaders. The results shown in Table 10 do indicate that despite educator and industry goal and role alignment, California stakeholder leaders are not currently working collaboratively. If stakeholder leaders continue to approach the California STEM workforce gap crisis in silos without a holistic collaborative plan, the status quo is likely to remain. There are so many other challenges that thoughtful individuals would never attempt to approach without an overall master plan, such as building a house, playing a baseball game, or hosting a wedding. Yet, currently stakeholders leaders are attempting to solve the California STEM workforce gap with each stakeholder group individually embarking on their own path with the best of intentions. The next section will summarize some of the literature findings about the challenges that must be addressed as the field migrates towards a deliberate integrated systems approach.

The stakeholder leaders required to collaborate on designing solutions to the California STEM challenge each exist in their own silos. Industry exists in a different environment than education or government. Each of these groups typically lives inside its own world. They speak with different acronyms, are governed by different policies, and are motivated by different incentives. One of the first challenges they must address collectively is to begin to learn each other's languages and challenges, which are vital to creating an environment in which ecosystem-appropriate solutions are discovered and nurtured (Kerzner, 1979). Creating forums where these discussions happen is a challenge in and of itself. Other than working on local projects, educators, industry, and government do not regularly gather.

Non-profits have become instrumental in creating forums at the national, state, and regional level to start moving this conversation forward. An example of this occurred with the third annual California STEM Summit 2013 hosted by CSLNet, which gathered over 300 individuals from government, education, non-profits, and the community. These events are beginning to foster the creation of a common language and an understanding of the need for collaboration. They help to illuminate the stakeholders' varied issues and perspectives. At the highest level, stakeholders are aligned around the necessity of addressing workforce needs and ensuring that education can meet the needs of the 21st century student. The challenge is to translate these higher-level goals into specific methodologies that can be executed and provide clarity about specific roles of stakeholders to ensure that solutions are sustainable (Gambert, 2010).

Additionally, challenges exist within industry and education. Industry is pre-programmed to compete with its rivals. STEM solutions will require fundamentally different behaviors. There is significant redundancy across industry in its approach to addressing the STEM workforce gap. Industry rivals are often competing to have the best programs to market to show their differentiation as employers or as corporate citizens.

Some collaboration has begun with programs such as FIRST created in 1992 (Kamen, 2009), and these collaborative efforts have been adopted by many businesses. There are also collaborations between industry and higher education like the BHEF that are focusing on a variety of important and aligned initiatives. However, there are also gaps in communication and strategy between K-12, afterschool programs, community colleges, and universities that make handoffs of and investments in students often less than optimal. These gaps must be strategically addressed and measured if they are to be moved towards minimization or ideally closed. This will require all participants in the stakeholder leadership community to understand the win-win proposition so they will act accordingly. Many of these stakeholder leaders have been so historically competitive or siloed, that collaboration of STEM efforts may not necessarily be natural or intuitive.

Another interesting challenge is adopting the widely accepted practices of systems thinking that are regularly applied in industry project management and engineering practices to complex social problems. Universities teach these skills and industry consistently applies systems engineering approaches to their complex product development projects. The challenge is helping these leaders to make the logical step to applying these same approaches to challenges like the California STEM workforce gap. Some successful models have been developed that explore systems approaches to social problems such as human resource systems (Weston et al., 2001) and restructuring a family business (Lazarus & Davis, 2006). Raytheon, a leading aerospace and defense firm, developed and donated a systems engineering model that was designed to determine the most effective actions that would double the number of STEM college graduates by 2015. The objective was to inform decision makers as they determined the effectiveness of various policy alternatives related to STEM outcomes. Secondarily, they wished to share this model with the academic and industry community to further develop the tool as an open source enabler to be enhanced and used throughout the STEM community (BHEF, 2010; Wells et al., 2009). Unfortunately, these are examples of successful spot successes, not widely adopted practices used to develop collaborative STEM master plans at the national, state, regional, and community levels. These systems modeling practices are not widely understood, available, and enabled to ensure regular adoption as an approach.

Literature Review Synthesis

The California STEM workforce gap paradox requires a fundamentally different approach than what is being practiced to date. The paradox is exemplified by a high degree of alignment across the stakeholder leader community about the nature and importance of the problem, juxtaposed across an environment of random, well-intentioned action that will not systematically or sustainably resolve the crisis. The current state approach must be reformed. Non-profits have bridged the absence of infrastructure within government, industry, and education to consistently and robustly approach the national and statewide crisis. While this is helping to move the conversation forward, this approach is not systemically designed to create integrated sustainable statewide solutions. There needs to be an institutionalization of this collaboration across California that does not ultimately rely on non-profits to take the lead.

The conclusions drawn as a result of both the literature review and the quantitative survey were drawn from evidence of a great deal of alignment across the respondent California stakeholder leaders. The challenge appears to be the lack of robust, sustainable collaboration mechanisms required by a systems approach to enable the development of a focused plan with measureable results that can be monitored to ensure California is strategically poised to bridge the critical STEM workforce gap. This research contributed to the literature by quantifying the actual current state of alignment across stakeholder leaders. Likewise, while the literature is full of relevant discussion about the value of systems approaches to social problems as well as considerable discussion about current STEM gaps and isolated successes, the literature is lacking in discussions about approaching the critically identified national, state, and regional STEM problem with an actual systems strategy.

The surveyed literature emphasized that the strength of the strategy will ultimately lie in aligned and shared objectives and that the strongest collaborations are tied to those whose stakeholders share common goals (Alexander et al., 2008). Large, complex collaborations require flexible and innovative approaches. They need to share ideas about appropriate policy and values, and be open to fundamentally new research and ideas that can then be translated to actionable plans (Boyer et al., 2010). In the STEM space, there needs to be consistency and alignment at the local level before aggregating at the district or regional level, ultimately moving to the state, and them finally to the federal level (Collins et al., 2009). In order to get to the root of the problems and define systems models that will impact the major leverage points in a system, the system must consider the goals and needs of all levels and stakeholders. If the systems design team does not possess an adequate characterization of the problem they will not be able to set up accurate models to simulate options. At the highest level, it is typically easier to align on noble goals such as education that is aligned with workforce needs, or that meets the needs of 21st century students. The challenge is to then translate these higher-level goals into specific methodologies that can be both skillfully executed and provide clarity to the specific roles of individual stakeholders (Gambert, 2010).

Conclusions and Implications

The results of this quantitative study are positive with respect to opportunities for a fundamental change in approach to the STEM workforce gap problem. The results demonstrate that the key stakeholder leaders are aligned relative to the importance of the problem. They are aligned about the key areas of focus (i.e., goals) as defined in the literature. They are even aligned around which stakeholder group should take the lead (i.e., roles) relative to key STEM tasks surveyed. This alignment presents a huge opportunity, as many social problems lack this fundamental alignment, and finding points of alignment is generally the first step towards addressing a problem. A current example of a lack of stakeholder alignment can be seen in the contentious discussions around which key goals need to be addressed in solving pressing national and state economic problems.

While there was alignment around goals and roles among the stakeholder leader respondents, the survey also showed a large gap in the area of systemic collaboration across these same groups. The potential importance of this finding is that it provides information about what is missing in the current approach to solving the STEM workforce gap. Alignment while necessary is insufficient to close the California STEM gap. The literature review provided significant support for the value of systems approaches to social problems. Exploration of open systems, parallel systems, and CASs provides insight into the challenges and opportunities inherent in thinking about the

STEM challenge from a systems perspective. The value of this perspective is, ideally, to derive solution-based approaches that might help to ameliorate the problem.

An examination of the literature relative to systems thinking, systems modeling, and human systems design indicates considerable potential for successful application to the STEM workforce challenge facing California. The open system STEM environment requires leaders to exhibit new behaviors. The most important attribute leaders must bring to the CA STEM challenge is a sense of urgency with a bias towards action. This is a highly complex problem. While open systems exist in a different leadership model than many leaders have historically followed, the roles and behaviors of stakeholder leaders in this open systems environment is even more important in California if it is ever going to truly adopt a set of integrated solutions in time to have an impact on its STEM workforce crisis.

Recommendations for Future Research

This research provided quantitative information about two of the key stakeholder leaders groups: educator and industry leaders. Future areas of research include: (a) the expansion of this research to include government, non-profit and community leaders; (b) qualitative discussions with leaders in these stakeholder groups about what is inhibiting collaboration in California; and (c) deeper research into specific open systems models and methods to provide actionable tools for stakeholder groups who are attempting to collaborate. California has already organized eight regional groupings across the state that account for approximately 80% of the affected population. Developing specific methodologies and tools with the help of non-profits such as the California STEM Learning Network has the potential to ensure guided collaborations applying systems approaches with measureable objectives and defined stakeholder leader accountabilities. This is ultimately a problem that California can solve, but it must fundamentally change its approach. The final area of additional research recommended is: (d) how to best institutionalize this systems collaboration in California so it is enabled by groups like non-profits but is designed into the state's formal government, education, and industry goals and roles in the future.

Final Summary

Both the nation and California are faced with a critical threat to their long-term strength and welfare due to an acknowledged deficit in STEM-ready students and workers as the 21st century progresses. The STEM workforce gap requires integrated conversations and solutions as it impacts multiple stakeholder groups that do not necessarily fully comprehend each other's needs and challenges. There is a broad consensus that increasing the STEM workforce is critical to the U.S., impacting standard of living, as well as national security in areas such as international competitiveness, combating terrorism, and addressing global warming, to name just a few (Hira, 2010). Historically, the world has looked to the U.S. as the globe's preeminent source of innovation. However, critical indicators have caused industry, educators, policy makers, and communities to take a deeper look at some alarming trends. For example, a U.S. Department of Commerce (2012) study noted that the U.S. has made no progress in its scientific and technological competiveness since 1999, and is beginning to lose ground to other countries that are actively building their infrastructures.

This dissertation utilized the literature review to explore and advocate the power of applying systems thinking to this complex social problem. In addition, the quantitative study demonstrated the current state of alignment in California across two key stakeholder groups' leaders – industry and education – by exploring the following areas:

1. Are the perceptions of two respondent stakeholder leader groups aligned relative to nine identified California STEM goals?
2. Are the perceptions of the assignment of roles across the California STEM stakeholders related to the two respondent group leaders' affiliation?
3. What is the current state of collaboration in California based on the perceptions of the two respondent groups' leaders?

The quantitative research demonstrated alignment of the key stakeholder leaders around what is important relative to the goals of California's STEM workforce gap as well as around which stakeholder leaders should be executing specific tasks. Additionally, the research also underscored the current lack of collaboration that exists across stakeholder leaders in California. This collaboration gap has many causes, not the least of which is a lack of: common language, natural intersection, and organizational purpose. The literature review pointed to the power of open systems approaches in enabling large complex social problems that could be utilized as a powerful tool to bridge the current language, access, and purpose gaps. The deliberate application of systems thinking and tools to the California STEM problem has the potential to yield specific strategies with measurable objectives to allow California stakeholder leaders the ability to develop and manage meaningful roadmaps focused on closing the workforce gap in the near term.

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APPENDIX A

Survey Introduction Consent

The purpose of this research project is to study the level of alignment of California stakeholder leaders around where the focus should be placed when addressing the workforce gaps that exist in preparing our students for the Science, Technology, Engineering and Math (STEM) needs of the 21st Century. This project is being conducted as dissertation research towards Pepperdine University's Organizational Leadership doctorate degree. You have been invited to participate in this research project because you represent education and or industry's perspective on STEM directions in California. Your participation in this research study is voluntary. You may choose not to participate and may withdraw at any time.

The survey itself will take approximately 20 minutes. Your responses will be anonymous. We do not collect identifying information such as your name, email address or IP address. As soon as the respondent either agrees to continue and submits the survey or disagrees and decides not to complete the survey the response is electronically disconnected from the respondent. The survey questions will address three areas related to STEM: goal focus importance, role focus of the various stakeholders i.e. who should be doing what, and finally a few questions about the current state of collaboration and integration across stakeholder leaders in California. All data is stored in a password protected electronic format. The survey questions do not contain information that will personally identify you. The results of this study will be used for scholarly purposes only and may be shared with Pepperdine University representatives.

If you have any questions or concerns about the research study, please contact dawngarrett77@gmail.com. If you have further questions about this study you may contact my dissertation chairperson, Dr. James Rocco DellaNeve, at Pepperdine University, Graduate School of Education and Psychology, 6100 Center Drive, Los Angeles, CA 90045.

If you have further questions about your rights as a study participant, you may contact Doug Leigh, Ph.D, and chair of the Graduate and Professional Schools Institutional Review Board, Pepperdine University, 6100 Center Drive, Los Angeles, CA 90045. This research has been reviewed according to Pepperdine's IRB procedures for research involving human subjects.

APPENDIX B

Sources for Goals, Roles, Collaboration and Integration Questions

Goals	Source
1. Strengthen and expand access to STEM teaching and learning in schools, colleges and communities	CA STEM Learning Network Goal
2. Close the workforce capability gap in California as measured by employers	Davis, 2012
3. Increase the number of students who pursue STEM-related credentials, degrees and careers	CA STEM Learning Network Goal
4. Increase STEM certificate and degree completions from women and minorities	Drew, 2011;BHEF 2007
5. Increase the number of STEM teachers with STEM degrees and credentials for K-12	Logsdon, 2006; BHEF 2007
6. Ensure California has an aligned set of goals for K-12 Student outcomes agreed to by education, industry and the community	Dissertation research question
7. Ensure that expenditures for STEM programs are coordinated and tied to outcomes	Kerzner, 1979
8. Increase STEM interest, capabilities and engagement among all P-14 California students (with an emphasis on critical thinking, innovation, and use of information technologies)	CA STEM Learning Network Goal
9. Adopt next generation science standards and implement common core state standards	CA STEM Learning Network policy and advocacy priorities
10. Identify top 3 goals from above list: __e.g. 1,5, 7________________	N/A
Role	**Source**
11. Define the skills required for the 21st Century workforce in California	Frick,2011; Gummer, 2000; Drucker, 1999
12. Define the goals for California STEM education that address workforce gaps	Rubenstein, 1986; Meadows, 2008
13. Identify redundancies and duplication in current STEM initiatives	Casey, 2008
14. Make recommendations for alternative STEM education approaches	BHEF, 2007; CA Stem Learning Network; National Academies, 2007
15. Coordinate STEM policy across the stakeholders	Casey, 2008; BHEF, 2007; CA STEM Learning Network; STEM Ed Coalition,

16. Publish regular measures of progress against agreed to STEM goals at defined levels (State, Regional, District)	BHEF, 2007; Miller & Page, 2007; STEMconnector, 2011
17. Identify community gaps and needs	Drew, 2011; CA STEM Learning Network; Hira, 2010
18. Provide people, capital and facilities to support STEM educator needs	Researcher question
19. Facilitate collaboration within and across the various regional stakeholders	BHEF, 2007; CA STEM Learning Network; Casey, 2008; Collins et al., 2009
20. Heighten student and community awareness and excitement about STEM opportunities	Drew, 2011; Hira, 2010, Myers et al., 2011
21. Create an integrated master plan for CA including metrics	Rubenstein, 1986; Meadows, 2008
22. Carefully coordinate STEM investments across regions	Researcher question
23. Provide employment projections	Davis, 2012
24. Define workforce education and training related needs	BHEF, 2012; Kanter, 2009
25. Provide scholarships/internships and employment opportunities for STEM students	Hira, 2010; BHEF, 2012
Collaboration Current State	Sources
26. A regional STEM agenda exists with support from key stakeholder leaders in education, industry, and the community and local government	CA STEM Learning Network Draft Work Plan
27. Success measures have been defined at the regional level and accountabilities are shared across the stakeholder leaders	CA STEM Learning Network Draft Work Plan
28. Regional stakeholder leaders work together to strategize and collaborate on investments	CA STEM Learning Network Draft Work Plan
29. A regional implementation and communications plan has been created by the impacted stakeholder leaders	CA STEM Learning Network Draft Work Plan
30. Barriers to collaboration are identified and addressed by the stakeholder leaders	Researcher question

APPENDIX C

Quantitative Survey Questions

Demographics

*

1. ELECTRONIC CONSENT: Please select your choice below.

Clicking on the "agree" button below indicates that:

• You have read the above information
• You voluntarily agree to participate
• You are at least 18 years of age

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

- Agree
- Disagree

2. I am a leader in:

- a. Education – L-14
- b. Education = Community college
- c. Education – CS System
- d. Education – UC System
- e. Education – Other
- f. Industry – High technology
- g. Industry – Other

3. My role in my organization is:

- a. Education-Superintendent
- b. Education-College / University leader
- c. Education-Professor/teacher/instructor
- d. Education-Other role
- e. Industry-Executive
- f. Industry-Manager/Supervisor
- g. Industry-Other role

Goals of California's STEM focus:

4. Please rate the importance of the goals listed below relative to their ability to impact the current California STEM workforce gap from your perspective as a leader.

	1 - Not Important	2 - Somewhat Important	3 - Important	4 - Very Important	5 - Critically Important
a. Strengthen and expand access to STEM teaching and learning in schools, colleges and communities	○	○	○	○	○
b. Close the workforce capability gap in California as measured by employers	○	○	○	○	○
c. Increase the number of students who pursue STEM-related credentials, degrees and careers	○	○	○	○	○
d. Increase STEM certificate and degree completions from women and minorities	○	○	○	○	○
e. Increase the number of STEM teachers with STEM degrees and credentials for K-12	○	○	○	○	○
f. Ensure California has an aligned set of goals for K-12 student outcomes agreed to by education, industry and the community	○	○	○	○	○
g. Ensure that expenditures for STEM programs are coordinated and tied to outcomes	○	○	○	○	○
h. Increase STEM interest, capabilities and engagement among all P-14 California students (with an emphasis on critical thinking, innovation, and use of information technologies)	○	○	○	○	○
i. Adopt next generation science standards and implement common core state standards	○	○	○	○	○

5. Identify top 3 goals from above list (e.g. a, b, c)

Roles of Stakeholders:

6. Please identify whether you believe Education, Industry and or Government should be focusing on the tasks listed below. Check all that apply per task meaning that if you believe that all three (education, industry, and government) should be focusing on that task, then check all three options. If you do not believe any stakeholder should be focused on the listed task, leave the boxes blank for all three groups.

	Education	Industry	Government
a. Define the skills required for the 21st Century workforce in California	☐	☐	☐
b. Define the goals for California STEM education that address workforce gaps	☐	☐	☐
c. Identify redundancies and duplication in current STEM initiatives	☐	☐	☐
d. Make recommendations for alternative STEM education approaches	☐	☐	☐
e. Coordinate STEM policy across the stakeholders	☐	☐	☐
f. Publish regular measures of progress against agreed to STEM Goals at defined levels (State, Regional, District)	☐	☐	☐
g. Identify community gaps and needs	☐	☐	☐
h. Provide people, capital and facilities to support STEM education needs	☐	☐	☐
i. Facilitate collaboration within and across the various regional stakeholders	☐	☐	☐
j. Heighten student and community awareness and excitement about STEM opportunities	☐	☐	☐
k. Create an integrated master plan for California including metrics	☐	☐	☐
l. Carefully coordinate STEM investments across regions	☐	☐	☐
m. Provide employment projections	☐	☐	☐
n. Define workforce education and training related needs	☐	☐	☐
o. Provide scholarships/internships and employment opportunities for STEM students	☐	☐	☐

Level of Current State of Collaboration / Integration across Stakeholders in California:

7. Please rate the current level of collaboration and integration (percentage of the time) across the following key stakeholder groups at the regional or state level in CA:

Industry – California businesses impacted by state and regional education and economic policy decisions
Education – Policy and curriculum leaders in Pre-school through undergraduate at the local, regional and or state level
Non-Profits and Foundations – Outside business or education leaders acting as investors, integrators and policy advisors in addressing the California STEM workforce shortage
Government – Local, regional and state policy makers in areas deciding education and workforce policies
Community – Local and regional voices such as PTA and chamber of commerce leaders

	Never (0%)	Very Uncommon (1-29%)	Uncommon (30-49%)	Common (50-79%)	Very Common (80-100%)	Unknown
a. A regional STEM agenda exists with support from key stakeholder leaders in education, industry, the community and local government	○	○	○	○	○	○
b. Success measures have been defined at the regional level and accountabilities are shared across the stakeholder leaders	○	○	○	○	○	○
c. Regional stakeholder leaders work together to strategize and collaborate on investments	○	○	○	○	○	○
d. A regional implementation and communications plan has been created by the impacted stakeholder leaders	○	○	○	○	○	○
e. Barriers to collaboration are identified and addressed by the stakeholder leaders	○	○	○	○	○	○

APPENDIX D

Pre-Survey Letter and Consent Agreement for Prospective Industry Leader Respondents:

California Industry STEM Leader:

I am a 3rd year doctoral student working on my dissertation in Organizational Leadership at Pepperdine University. The subject is "A Systems Study of STEM Goal and Role Alignment Across Stakeholder Leaders in California". The purpose of the dissertation is two-fold. The first is to explore the value of applying proven systems methodologies to this important social problem through an examination of the literature on system approaches to problem solving. The second is to conduct a survey across current California Industry and Education leaders to quantitatively document the current level of alignment that exists relative to what the goals of California's STEM focus should be and who should be doing what across the stakeholders to move towards closing the growing workforce gap.

The importance of the study is that despite considerable stakeholder interest and investment over almost three decades, very little progress is being made in closing the STEM workforce shortage. California educates one in eight students in America and is home to leading edge innovators. The significance of this study is that current stakeholder leaders may benefit from applying systems thinking approaches to this complex social problem, ideally resulting in large-scale improvement ideas.

Your business has been identified as a current leader in STEM awareness in California. I am seeking your willingness to participate in a brief 30 question anonymous survey that will be sent to approximately 50 STEM involved California businesses and 100 Superintendents, Community College, UC and California State College leaders.

Participation is entirely voluntary. If you consent to participate, please provide the email contacts of 2-3 STEM thought leaders in your company including yourself if desired. I will then be sending the survey to those individuals in early February.

The survey will be administered electronically through SurveyMonkey. SurveyMonkey has robust privacy and security protections in place and survey results are only accessible by the researcher. (http://www.surveymonkey.com/mp/policy/privacy-policy/), No e-mail addresses will be saved once the survey has been submitted and respondents can ask the researcher to remove them from the survey at any time. No specific businesses or educational institutions will be identified in the results. The results will characterize similarities and differences within and across the respondents in a summary fashion to illuminate the current level of alignment that exists across leaders in California.

Your responses will be invaluable, helping to characterize the importance of clear focus and goals with an aligned understanding of accountabilities, to help California systematically address our educational and workforce crisis in STEM. I have been inspired by the enthusiasm and interest of stakeholders across the state.

Please reply below relative to your willingness to participate by January 11th:

☐ Yes, my organization would be willing to participate. Please send surveys to the following e-mail addresses within my company:

1. ____
2. ____
3. ____

☐ No, our company is not willing to participate in this study

☐ Please send me the results of your survey findings upon completion (May/June 2013)

I have been inspired by both the stakeholder interest and the magnitude of the California STEM challenge having worked in Aerospace for the past 30 years. We are fortunate to have a state rich in both resources and innovators. Learning to systemically focus our energies and resources on integrated solutions across stakeholder leaders is a challenge we are fully capable of addressing.

Thanks for your acknowledged interest and for your consideration.

Respectfully submitted

Dawn Garrett
EDOL Doctoral Candidate
XXXXXXXXXX

APPENDIX E

Pre-Survey Letter and Consent Agreement for Prospective Education Leader Respondents:

California Education Leader;

I am a 3rd year doctoral student working on my dissertation in Organizational Leadership at Pepperdine University. The subject is "A Systems Study of STEM Goal and Role Alignment Across Stakeholder Leaders in California". The purpose of the dissertation is two-fold. The first is to explore the value of applying proven systems methodologies to this important social problem through an examination of the literature on system approaches to problem solving. The second is to conduct a survey across current California Industry and Education leaders to quantitatively document the current level of alignment that exists relative to what the goals of California's STEM focus should be and who should be doing what across the stakeholders to move towards closing the growing workforce gap.

The importance of the study is that despite considerable stakeholder interest and investment over almost three decades, very little progress is being made in closing the STEM workforce shortage. California educates one in eight students in America and is home to leading edge innovators. The significance of this study is that current stakeholder leaders may benefit from applying systems thinking approaches to this complex social problem, ideally resulting in large-scale improvement ideas.

All California Superintendents, Community College, UC and Cal State Presidents are being asked to respond as primary STEM methodology and policy drivers in our state. I am seeking your willingness to participate in a brief 30 question anonymous survey that is also being sent to approximately 50 STEM involved California business leaders and their teams.

Participation is voluntary. If you consent to participate, please provide the email contacts of 2-3 STEM thought leaders in your company including yourself if desired. I will then be sending the survey to those individuals in early February.

The survey will be administered electronically through SurveyMonkey. SurveyMonkey has robust privacy and security protections in place and survey results are only accessible by the researcher. (http://www.surveymonkey.com/mp/policy/privacy-policy/), No e-mail addresses will be saved once the survey has been submitted and respondents can ask the researcher to remove them from the survey at any time. No specific businesses or educational institutions will be identified in the results. The results will characterize similarities and differences within and across the respondents in a summary fashion to illuminate the current level of alignment that exists across leaders in California.

Your responses will be invaluable, helping characterize the importance of clear focus and goals with an aligned understanding of accountabilities, to help California systematically address our educational and workforce crisis in STEM. I have been inspired by the enthusiasm and interest of stakeholders across the state.

Please reply below relative to your willingness to participate by January 11th:

☐ Yes, my organization would be willing to participate. Please send surveys to the following e-mail addresses:

1. ____
2. ____
3. ____

☐ No, our company is not willing to participate in this study

☐ Please send me the results of your survey findings upon completion (May/June 2013)

I have been inspired by both the stakeholder interest and the magnitude of the California STEM challenge having worked in Aerospace for the past 30 years. We are fortunate to have a state rich in both resources and innovators. Learning to systemically focus our energies and resources on integrated solutions across stakeholder leaders is a challenge we are fully capable of addressing.

Thanks for your acknowledged interest and for your consideration.

Respectfully submitted

Dawn Garrett
EDOL Doctoral Candidate
XXXXXXXXXX

APPENDIX F

Reminder Letter to Respondents to Complete Survey

Thanks for your willingness to participate in this California STEM research study. The survey should take no more than 15-20 minutes to complete. If you have any questions please don't hesitate to contact me by e-mail or phone. Your support is most appreciated.

Dawn Garrett
EDOL Doctoral Candidate
XXXXXXXX
XXXXXXX

APPENDIX G

Question Addressed to Jean Kang, Pepperdine Focal Point for IRB Submissions

12/8/12:

One of my committee members asked whether Pepperdine requires me to get proof of permission to use a website like survey monkey. It looks like from the response below, the data collected from Survey Monkey is solely mine to be accountable for and to use to publish. Please advise as to whether I need to get additional external permissions to publish data collected from Survey Monkey.

Response from Jean 12/10/12:

You usually do not have to get permission from them, however, you do need to abide by their use policies regarding data and services.

Jean

APPENDIX H

IRB Approval

PEPPERDINE UNIVERSITY

Graduate & Professional Schools Institutional Review Board

February 7, 2013

Patricia Dawn Garrett

Protocol #: E0113D16
Project Title: A Systems Study of STEM Goal and Role Alignment Across California

Dear Ms. Garrett,

Thank you for submitting the revisions requested by Pepperdine University's Graduate and Professional Schools IRB (GPS IRB) for your study, *A Systems Study of STEM Goal and Role Alignment Across California*. The IRB has reviewed your revisions and found them acceptable. You may proceed with your study. The IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations 45 CFR 46 - http://www.nihtraining.com/ohsrsite/guidelines/45cfr46.html that govern the protections of human subjects. Specifically, section 45 CFR 46.101(b)(2) states:

> (b) Unless otherwise required by Department or Agency heads, research activities in which the only involvement of human subjects will be in one or more of the following categories are exempt from this policy:
>
> **Category (2) of 45 CFR 46.101**, research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: a) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and b) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit a **Request for Modification Form** to the GPS IRB. Because your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the GPS IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite our best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the GPS IRB as soon as possible. We will ask for a complete explanation of the event and your response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the GPS IRB and the appropriate form to be used to report this information can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* (see link to "policy material" at http://www.pepperdine.edu/irb/graduate/).

Please refer to the protocol number denoted above in all further communication or correspondence related to this approval. Should you have additional questions, please contact me. On behalf of the GPS IRB, I wish you success in this scholarly pursuit.

Sincerely,

6100 Center Drive, Los Angeles, California 90045 ▪ 310-568-5600

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F: 310-568-5755

cc: Dr. Lee Kats, Vice Provost for Research and Strategic Initiatives
Ms. Alexandra Roosa, Director Research and Sponsored Programs
Dr. James DellaNeve, Graduate School of Education and Psychology

APPENDIX I

Permission to Adapt Figure 1

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