# Career and Technical Education (CTE) Directors' Experiences with CTE's Contributions to Science, Technology, Engineering, and Math (STEM) Education Implementation

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ABSTRACT

In spite of the large overlap in the goals of CTE and STEM education, there is little evidence of the role(s) CTE delivery systems, programs, curricula, or pedagogical strategies can play in advancing STEM education. Because of their responsibilities, especially for organizational and instructional leadership, school district CTE directors could illuminate our understanding of linkages between CTE and STEM education. The purpose of this study was to analyze the experiences of school district CTE directors to better understand these linkages.

The researcher used a qualitative research design to gain understanding of the local CTE directors' experiences. Data were collected using face-to-face semi-structured interviews with 13 participants. The data were analyzed using a continuous process of coding, recoding, memo-writing and making comparisons across the transcripts.

Among the results of the study were that definitions of STEM education were varied, but all had aspects of an integrated approach and using real world applications. The data revealed a number of contributions made by CTE to assist in STEM education implementation. They include context for learning, multiple pathways; platform for program delivery, and administrative leadership and framework. It was also found that strategies for increasing the visibility of CTE's contributions in the advancement of STEM education could include marketing CTE, demonstrating the value of CTE, enhancing curriculum and instruction, and rebranding CTE.

Conclusions made in the study include, but not limited to, the fact that there are tremendous reciprocal benefits that CTE and STEM education can provide for one another, given there are strong, mutual, and intended linkage of the two; and that establishing a state-level STEM education coordinator position would result in providing much needed leadership at the local and state levels.

Recommendations for practice that were made in the study include, but are not limited to, continuing to establish Virginia Governor's Academies throughout the Commonwealth of Virginia by aligning STEM education with CTE and continuing to support, at the highest level, intentional and mutual collaborative initiatives between STEM education and CTE. A recommendation for future research includes conducting a longitudinal study on the impact that Virginia Governor's Academies are having on student morale, growth, learning, and future endeavor.

## Dedication

I dedicate this work to my family. First, to my loving wife Roydah for the all-round support throughout the duration of my studies. My children, Chitatanga, Bubile, Kondwani, and Mwelwa, for being such a tower of strength and the dignity with which they conducted themselves to allow me focus on my studies. My late father Jona Kezi Langford Nkhata for insights that still shine in me today and my mother Catherine Bubile Mazunda for shepherding me this far. To my brothers and sisters—both living and those in eternal rest.

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## Abbreviations and Acronyms

| | |
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| ACTE | Association for Career and Technical Education |
| CTE | Career and Technical Education |
| NAEP | National Assessment of Education Progress |
| PISA | Program for International Student Assessment |
| SOL | Standards of Learning |
| STEM | Science, Technology, Engineering, and Mathematics |
| TDM | Tailor Designed Method |
| TIMSS | Trends in International Mathematics and Science Study |
| USDOE | United States Department of Education |
| VDOE | Virginia Department of Education |

# CHAPTER 1 INTRODUCTION

In 1983, the findings of the National Commission on Excellence in Education in the United States alerted the nation to the fact that America's once unchallenged preeminence in commerce, industry, science, and technological innovation was being overtaken by competitors throughout the world. The Commission, in what was considered to be a landmark report, said "Our Nation is at risk. . . . The educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people" (National Commission on Excellence in Education, 1983, n.p.). Indicators of the risk cited by the Commission included the fact that, (a) there had been a steady decline in science achievement scores of 17-year-olds as measured by national assessments of science in 1969, 1973, and 1977; and (b) business leaders complained that they were required to spend millions of dollars on remedial education and training programs in basic skills such as reading, writing, spelling, and computation.

Results from international tests, especially tests administered by Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA), triggered additional concerns about the quality of education in general, and the state of science, technology, engineering, and mathematics (STEM) education in particular. The results showed that U.S. students' STEM critical thinking skill scores were lower than students in other industrialized nations. The National Science Foundation (NSF) (2007) leaders observed that the United States possessed "the most innovative, technologically capable economy in the world" (p. 1), and yet its STEM education system was failing to ensure that *all* American students received the skills and knowledge required for success in the 21st century workforce. Ginsburg, Cooke, Leinwand, Noell, and Pollock (2005) conducted a study on behalf of the American Institutes of

Research aimed at making meaningful interpretations of U.S. performance in TIMSS and PISA tests relative to 12 other industrialized countries. This was in view of the variability of participating countries in TIMSS and PISA tests. Ginsburg et al. (2005) made a harsh observation saying that "the analysis of international performance among the 12 countries reveals consistently mediocre U.S. results" (p. 9). U.S. Department of Education (2010) leaders made the observation that "It is not that their students are smarter than ours. It is that these countries are being smarter about how to educate their students" (p. 1). This observation made by the U.S. Department of Education leaders clearly suggests that reform efforts were needed in STEM education.

Disparities in learning achievement among ethnic groups provide another reason to call for changes in the educational process. Authors of the U.S. Department of Education's report (2008), *A Nation Accountable: Twenty-five Years After a Nation at Risk,* said that the nation's performance at the high school level was as alarming as it had been at the time of *A Nation at Risk*, if not worse, and that:

> … the situation is even more troubling for minority students in inner cities. Half of them do not graduate from high school on time—a staggering fact. The on-time graduation rate for black students is only 53 percent, while for Hispanic students it is only 58 percent. This means that inner-city parents wake up every day knowing that there is about a 50-50 chance that their children will not graduate on time. (p. 11)

Toulmin and Groome (2007), in the document, *Building a Science, Technology, Engineering, and Math Agenda*, for the National Governors Association's "Innovation America" initiative, expressed a specific concern with regard to the lack of progress in learning achievement. Toulmin and Groome's concern was based on data from the National Assessment of Education Progress (NAEP) which revealed that there had been persistent mathematics and science achievement gaps among students relative to their race/ethnicity, gender, and socioeconomic status. Some STEM education pedagogies such as technological/engineering design could provide classroom experiences that accommodate a wide variety of cognitive skills because the design tasks allowed for varied levels of sophistication of solutions (DeLuca, 1991). Further, problem-solving in technology design activities allowed opportunities for students to practice and extend their mathematics and science skills in relevant real world problems.

Amid advocacy efforts to reform STEM education, simultaneously, reforms were taking place in CTE. Prior to the 1990s, the role of vocational education, later named CTE, was perceived to be only for preparing students to begin work immediately following high school, and these students were “mostly male, too often minorities, academically backward, and destined for dead-end jobs” (Gray, 2004, p. 129). Much of this image of CTE has changed since the 1990s for two reasons. First, in addition to completing a CTE concentration, most students also complete a traditional academic program (Gray, 2004). Second, CTE content areas were constantly evolving due to the changing global economy (Association for Career and Technical Education, 2012). Curricula in CTE content areas need to be tailored to meet the demands of the workplace - explaining a shift towards aims and objectives similar to postsecondary education aims and objectives (Pearson, Sawyer, Park, Sanatamaria, van der Mandele, Keene, & Taylor, 2010). These changes culminated into the re-conceptualization of what it meant to be “career ready”. The Association for Career and Technical Education (ACTE), America’s largest non-profit education association dedicated to the advancement of education that prepares youth and adults for successful careers conveyed the new conceptualization of CTE by stating that:

> Career readiness involves three major skill areas: *core academic skills* and the ability to apply those skills to concrete situations in order to function in the workplace and in routine daily activities; *employability skills* (such as critical thinking and responsibility) that are essential in any career area; and *technical, job-specific skills* related to a specific career pathway. (ACTE, 2011, p. 1)

The fact that students are now taking a CTE concentration while also completing a traditional academic program and the evolution of the global CTE curricula has also changed the role CTE plays in local schools across the U.S. The main focus for CTE to equip students with career readiness skills now means that CTE is two dimensional, that being to: (1) prepare students who intend to enter the workforce immediately after graduation with career readiness skills and (2) prepare students who intend to further their education in a post-secondary setting with career readiness skills.

The goal of CTE - to produce students who were career ready; and the goal of the STEM education reform - to produce a new workforce of problem solvers, innovators, and inventors; together provide opportunities for mutual leveraging between CTE and STEM education. For example, CTE teachers could provide their STEM education counterparts with authentic, problem-based activities through which students can apply academics in relevant ways (Pearson et al., 2010). Advocating for “STEM Education for *all* students” the National Governors’ Association said that the saturation of technology in most fields meant that *all* students—not just those who planned to pursue a STEM profession, needed a solid foundation in STEM to be productive members of the workforce (Toulmin & Groome, 2007).

At the federal government level, support for CTE is mainly by way of the Carl D. Perkins Career and Technical Education Improvement Act of 2006, also known as Perkins IV. The purpose of this Act was to develop more fully the academic, career, and technical skills of secondary and postsecondary education students who elect to enroll in CTE programs. The strategies designed to achieve this purpose included:

> (1) building on the efforts of states and localities to develop challenging academic and technical standards and to assist students in meeting such standards, …
>
> (2) promoting the development of services and activities that integrate rigorous and challenging academic and career and technical instruction, …
>
> (4) conducting and disseminating national research and disseminating information on best practices that improve career and technical education programs, services, and activities; and
>
> (5) providing technical assistance that promotes leadership, initial preparation, and professional development at the State and local levels. (U.S. Congress, 2006, p. 2)

To provide a basis for evaluation of whether or not objectives were being met, the Perkins IV Act established student performance measures for state educational agencies and local authorities. However, this Act provided broad flexibility on how states implemented the measures with one consequence being that "while this flexibility enables states to structure and evaluate their programs in ways that works best for them, it may hinder … ability to gain a broader perspective on the success of state CTE programs" (U.S. Government Accountability Office, 2009, p. 24). With specific reference to initiatives to explicitly integrate academics into CTE programs as required by Perkins IV, state and local CTE directors acknowledged that their efforts were sporadic and that "even in places where integration of academic content into CTE classes is systemic, integration of real world CTE content into the core academic classroom is almost nonexistent" (Meeder & Suddreth, 2012, p. 4). Meeder and Suddreth (2012) further noted that projects, which helped create integrated CTE/academics and cross-curricular connections, usually required core academic teachers and CTE teachers to review their respective content standards collectively, while looking for opportunities across the curricula to create alignments. However, this kind of collaboration rarely happened unless it was supported by administrators and principals. Additionally, Manley (2011) argued that state leadership and administration in any field of education supported sustainability and growth, and that if broad change occurred, it would happen through a broad power structure. In between state CTE leadership and school educators are school division directors of CTE, whose valuable insights link CTE, academics in general, and STEM education.

## Background to the Problem

The quest for relevance in STEM education curricula efforts, and the need to have all students graduate from high school with the essential STEM competencies necessary to succeed in postsecondary education and employment, suggests a need for greater synergies between STEM education and CTE efforts. On one hand, the Association for Career and Technical Education (ACTE), posits that "CTE programs offer an important instructional approach that strengthens students' understanding of STEM content and helps attract more individuals into STEM career pathways" (ACTE, 2009, p. 1). On the other hand, the STEM education movement (e.g. as represented by the US Congressional STEM Education Caucus) has been championing the case that STEM education should:

(a) produce scientists and engineers who will continue the research and development that is central to national economic growth;

(b) produce technologically proficient workers who are capable of dealing with the demands of a science based, high technology workforce; and

(c) develop scientifically literate voters and citizens who make intelligent decisions about public policy and who understand the world around them (STEM Education Caucus, 2011, n.p.).

Thus it seems to be evident that CTE is important in advancing STEM education efforts, and yet, there is still a lack of understanding of what exactly the role of CTE should be in STEM education. School district directors of CTE could provide valuable insights into the experiences, opportunities, and challenges of integrating CTE and STEM education because of their roles of having to provide instructional leadership, reorienting the district organizational structures and work practices, establishing policy coherence, and maintaining an equity focus with the view to raising the achievement for all students (Rorrer, Skrla, & Scheurich, 2008). To show that ‘good practice’ at school level was not a sufficient condition for sustainable change in educational practice, Kister (2001) stated that “there are good programs that happen locally, but you don’t make major change except through a broad power structure” (p. 6). School district administration is a ‘cornerstone’ of this broad power structure. According to the *School Leadership for the 21st Century Initiative’s* Task Force on School District Leadership, school district leadership is responsible for: (a) Organizational Leadership—being able to establish expectations or norms of teaching and learning for educators while building organizational systems to support them, and maintaining a professional climate; (b) Public Leadership—being aware of their spotlighted role because of the increasingly political nature of education and its highly visible profile as a national issue, i.e. school district leaders are expected to communicate effectively among stakeholders, manage media relations, and develop coalitions with community groups; and (c) Instructional Leadership—establishing a clear vision for teaching and learning by paying attention to issues such as equity and access for all students, creating safe and nurturing learning environments, providing educators with professional development opportunities as well as resources on effective curriculum and practice; making effective use of instructional technologies, and using accountability measures to foster student learning (Clark, Farmer, & Welch, 2010; Usdan, McCloud, Podmostko, & Cuban, 2001).

## Statement of the Problem

In spite of the large overlap in the goals of CTE and STEM education, there is little evidence of the role(s) CTE delivery systems, programs, curricula, or pedagogical strategies can play in advancing STEM education. As Meeder and Suddreth (2012) observed, the goal of ensuring that all students graduated from high school ready for college, careers and life had taken hold in every state across the U.S. and "yet all too often, the focus on 'college readiness' and 'career readiness' remains in two distinct silos" (p. 4). This is in spite of reform efforts to integrate academics and, at that time, vocational education going as far back to John Dewey early 20$^{th}$ century, who advocated for contextualize learning in America's high schools (Castellano, Stringfield, & Stone, 2003). Because of their responsibilities especially for organizational and instructional leadership, school district authorities, and of special interest to this researcher, local directors of CTE (Usdan, McCloud, Podmostko, & Cuban, 2001), could illuminate our understanding of linkages between CTE and STEM education. The problem is that we do not know enough about the experiences of local directors of CTE.

## Purpose of the Study

According to Leithwood, Louis, Anderson, and Wahlstrom (2004), even though there is diversity in approach, all school reform efforts aim to improve teaching and learning. For example, some reforms are focused on innovative curricula (e.g. in CTE and STEM education), typically addressing one part of a school's program and aim for widespread implementation.

Others might attempt innovative approaches to instruction (e.g. integrative teaching and learning between curriculum areas), hoping to change teachers' practices one teacher at a time. As different as these approaches to school reform might be, "the chance of any reform improving student learning is remote unless district and school leaders agree with its purposes and appreciate what is required to make it work" (Leithwood et al., 2004, p. 4). Because of the pivotal role of district leadership in education delivery, and an interest in CTE and its potential to contribute to STEM education implementation, the researcher has interest in the experiences of local directors of CTE. Hence, the purpose of this study is to analyze the experiences of school district directors of CTE to better understand the linkages between CTE and STEM education.

## Research Questions

The main question to be answered is: What have been the experiences of local directors of CTE with linkages between CTE programs and STEM education implementation? The study will be guided by the following sub questions:

1. How do CTE directors define STEM education?
2. What do directors consider to be the contributions of CTE programs to STEM education implementation?
3. What do directors describe as specific examples of CTE initiatives that have contributed to advancing STEM education at the school/district level?
4. How can the contributions of CTE in the advancement of STEM education be made more visible to and accepted both by CTE and STEM educators?
5. What are school division CTE directors recommendations concerning successful policy/curricula/pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education?

## Significance of the Study

CTE is a major component of education reform and improving student achievement. One of the major reform efforts is "to eliminate the dichotomous silos of academics and CTE and to reimagine their supporting infrastructures to meet economic, workforce and civic needs" (ACTE/NASDCTE/Partnership for 21st Century Skills, 2010, p. 33). Of interest to this study is the elimination of silos of CTE and STEM education. The strategies available to educators to achieve the reform objectives could include formulation of supportive policy guidelines for educators, identification of successful initiatives for replication, and support professional development and professional learning communities that foster collaboration between CTE and other educators, as well as administrators. The findings of this study could contribute information for use in formulation of policy and implementation guidelines—especially strategies for professional development in this area of education. Studies have found that sustained professional development is a requirement for successful curriculum integration (Pearson, Sawyer, Park, Sanatamaria, van der Mandele, Keene, & Taylor, 2010; Stone, Alfeld, Pearson, Lewis, & Jensen, 2006).

## Theoretical Framework

The theoretical framework for this study was based on the *social reconstructionist* theory of John Dewey. Arising from Dewey's conceptualization of education in general, and vocational education in particular, the following themes arise for further consideration: (a) career readiness – arising from Dewey's concern for vocational education to be more than trade-specific training, (b) integration of CTE and academics – arising from Dewey's belief in education through occupations, (c) linkages between CTE and STEM education – arising from his belief that acquisition of specialized skills should go together with industrial intelligence based on science,

(d) constructivism – arising from his advocacy for pedagogy that allowed students to be active learners, and (e) factors in sustaining change in curriculum practice – arising from what Dewey apparently *failed* to achieve, that is to define the shape and purpose of CTE in America in spite of promulgating visionary ideas. Of the factors in implementing system-wide sustainable change in education as conceptualized by Dewey, special attention was given to local directors because of their role in providing instructional, organizational, and political leadership to school systems (Leithwood et al., 2004). A more detailed discussion of the theoretical framework for this study is presented in Chapter 2.

## Overview of Research Design

A qualitative study design was used to answer the research questions for this study. Qualitative researchers are concerned with understanding and interpreting meanings people make of their lives and situations, which are the kinds of things that are important for the conduct of social action in a local community of social practice (Lapan, Quartaroli, & Riemer, 2012; Merriam, 2009). A combination of *convenience* sampling and *extreme deviant* sampling was used to choose participants for the study (Patton, 2002). Data were collected using semi-structured interviews, and analyzed using a process of constant comparative and content analysis to identify common themes (Creswell, 2013; Merriam, 2009; Patton, 2002).

## Delimitations

First, CTE and STEM education have numerous definitions. The researcher confined himself to the definition of CTE as provided for in the Carl D. Perkins Career and Technical Education Improvement Act of 2006, and the definition of STEM education as provided by the National High School Alliance (n.d.). Second, the study was restricted to a sample of school district CTE directors in Virginia even though it is acknowledged that each school division CTE director is unique and operates in a unique setting.

## Limitations

The main limitation for this study was that the researcher's experience with America was limited to the four years he was in graduate school. Thus, the researcher had limited experience with school curriculum issues in the U.S. Because of this, cultural competence could be a factor in the study. Mertens (2012) stated that "cultural competence is a critical disposition that is related to the researcher's or evaluator's ability to accurately represent reality in culturally communities" (p. 31). Even if Mertens' definition of cultural competence is more in respect to research related to cultural minorities, a researcher in a new culture can easily miss nuances in the research process.

Another limitation is that the study design was for one-on-one interviews with participants. However, in one large school district (with more than 20 high schools), the administrative structure is that there is a Director of the Office of Professional Life Skills (OPOLS) and also a CTE Coordinator. The CTE Coordinator reports directly to the Director OPOLS. For this reason, but also because the Director OPOLs was the immediate past CTE Coordinator, the two officers were of interest to the researcher. In the interest of time, the two were interviewed together.

## Definitions

**Career and Technical Education (CTE):** Organized educational activities that offer a sequence of courses that (i) provides individuals with coherent and rigorous content aligned with challenging academic standards and relevant technical knowledge and skills needed to prepare for further education and careers; and (ii) provides technical skill proficiency, an industry-recognized credential, a certificate, or an associate degree. CTE includes competency-based applied learning that contributes to the academic knowledge, higher-order reasoning and problem-solving skills, work attitudes, general employability skills, technical skills, and occupation-specific skills. (U.S. Congress, 2006)

**District CTE Director:** The administrator in a local school system that is responsible for providing leadership, supervision, and oversight of Career and Technical Education programs in that system (G. T. Willcox, Virginia Coordinator of CTE, personal communication, April 17, 2013)

**Curriculum Integration (of academics and CTE):** A relationship between academic and occupational or career-technical subject matter that goes beyond what would normally occur in the delivery of either the academic or occupational/career-technical subject matter alone (Johnson, Charner, & White, 2003).

**School Division:** A geographical area and school-age population in the state of Virginia—created by the General Assembly of the state to promote the realization of the prescribed standards of quality of education (Jamerson, 2011). (The National Center for Education Statistics [NCES] uses the term "School District", instead of School Division. *School District* is defined as "a geographic area within a state whereby a public school system operates as a governmental entity with responsibility for operating public schools in that geographic area. School districts may be wholly contained in one county or parts of many counties" [NCES, n.d.]).

**Science, Technology, Engineering and Mathematics (STEM) Education:** An interdisciplinary (or transdisciplinary) approach that integrates knowledge from diverse academic disciplines into authentic problem-/project-based learning experiences as related to instruction in STEM content areas. Each of these is embedded with the scientific method and engineering design processes, as well as 21st century skills (Basham, Israel, & Maynard, 2010, p. 11).

## Format of the Dissertation

Chapter 2 of this document presents a review of literature. It begins with a detailed discussion of the theoretical framework that guides the study; followed by a discussion of constructivism, a rationale for linkages between CTE and STEM education, factors in sustaining change in curriculum practice, and a summary of the chapter. Chapter 3 provides a discussion of the research process that was used in this study. The process has been presented in the headings of research design, choice of participants, number of participants, data gathering procedures, data analysis procedures, pilot study, and quality and rigor. Chapter 4 is a presentation of the results of the study. Chapter 5 provides a synthesis of lessons from the literature reviewed and the data analysis, and based on this synthesis, what the researcher concluded and recommended with respect to synergies between CTE and STEM education, and for further research.

## Summary

The background of the study is in the quest for relevance in STEM education curricula, and the need to have all students graduate from high school with the essential STEM competencies necessary to succeed in postsecondary education and employment. There is need for "STEM education for all" and simultaneously, there is need for all students to graduate from high school with the essential competencies necessary to succeed in postsecondary education and employment. This suggests that there is a need for greater synergies between STEM education and CTE. However, there is insufficient evidence of those synergies. At the heart of efforts for successful CTE, and inevitably, successful STEM education, are school district CTE directors. Thus, this researcher sought to analyze the experiences of school district directors of CTE to better understand the linkages between CTE and STEM education. A qualitative study design was used to achieve the purpose of the study. The findings of this study could contribute information for use in policy formulation and implementation guidelines.

# CHAPTER 2 REVIEW OF LITERATURE

## Theoretical Framework of the Study

The purpose of the study was to analyze the experiences of school district directors of CTE to better understand the linkages between CTE and STEM education. The study was guided by John Dewey's "social reconstructionist" philosophy. For Dewey, education was a process of formation of mind (Dewey, 1917). Dewey posited that:

> All education forms character, mental and moral, but formation consists in the selection and coordination of native activities so that they may utilize the subject matter of the social environment. Moreover, the formation is not only formation *of* native activities, but it takes place *through* them. It is a process of reconstruction, reorganization. (p. 84)

Making a case for democratic practices in education, Dewey (1917), called for equitable educational opportunities for all the members of a social group - saying that in the absence of free interchange of varying life-experiences, the educational experience of each social group was incomplete. He advocated for opportunities for members of diverse social groups to learn from each other, "otherwise, the influences which educate some into masters, educate others into slaves" (p. 98).

With specific reference to CTE, Dewey argued that a vocation needed to be conceptualized in a broader sense to include life activities that brought fulfillment to a person. In this respect, an occupation includes a wide range of endeavors such as the development of artistic capacity of any kind, special scientific ability, effective citizenship, or mechanical labor. Dewey made the point that we should not limit the conception of *vocation* to the occupations where there was immediate production of goods and services. He also argued against the notion that vocations were distributed in an exclusive way - one and only one to each person. To illustrate his argument against a narrow conception of vocational, or industrial education, Dewey gave the example of the automobile industry where, (a) both, the process of production and the product, i.e. the automobile, were complicated and yet ninety-five per cent of the labor of the workforce was unskilled, (b) there was rapid change of the manufacturing process by means of new inventions, and (c) there was high mobility within the manufacturing process requiring workers to move from one mode of machine to another. Dewey argued that under such circumstances, any trade-training needed to be part of a more general plan of industrial education. He advocated for an education whose chief purpose was to develop initiative and personal resourcefulness, otherwise "the same forces which have broken down the apprenticeship system render futile a scholastic imitation of it" (p. 56).

Dewey objected to conceptualizing vocational education in a narrow sense of training for a specific occupation which the student was destined for, and he also objected to a dual system of secondary school education in which one track was for those who inevitably had to have trades-training and those who needed general education. He made known his views on this matter as follows:

> I object to the identification of vocation with such trades as can be learned before the age of, say, eighteen or twenty; and to the identification of education with acquisition of specialized skill in the management of machines at the expense of an industrial intelligence based on science and knowledge of social problems and conditions. … a separation of trade education and general education of youth has the inevitable tendency to make both kinds of training narrower, less significant and less effective than schooling in which the material of traditional education is reorganized to utilize the industrial subject matter—active, scientific and social … (Dewey, 1977, p. 38)

Dewey envisioned an education system that would combine democratic and humanistic values with science and industry (Wirth, 1974). With specific reference to the wider case of the integration of academics and CTE, Dewey (1917) argued for curricula that enabled students to be educated *through* the occupations rather than *for* the occupations, and that education through occupations was more conducive to learning than any other method. Dewey believed that occupational contexts provided rich avenues through which students could effectively learn important concepts in traditional academic subjects (Pearson, Sawyer, Park, Sanatamaria, van Mandele, Keene, & Taylor, 2010). He advocated the use of activity methods in classrooms, where students could move about, discus, experiment, work on communal projects, and pursue research (Phillips, 1995). Thus Dewey's view of learning could be called a "social constructionist" view of learning.

**Constructivism**

*Social constructionism* is one of the numerous versions of constructivism. For example, Phillips (1995) placed the versions of constructivism on three different continuums. One continuum ranged from a consideration of constructivism as being about individual psychology, i.e. how individuals learn, whereas on the other end of the continuum, constructivism is considered; to be a public discipline, i.e. an interest in how humans build communally held knowledge. The second continuum, in Phillips' categorization, was in a belief in knowledge to be a creation of the human mind, in contract with humans discovering pre-existing knowledge. The third continuum contrasted knowledge construction as being attributed to individual cognition, or to social and/or political factors. According to Phillips, "good" constructivism placed emphasis on "active participation by the learner, together with the recognition … of the social nature of learning" (Phillips, 1995, p. 11). Dewey was identified with social constructivism because of his interest in the educational process of constructing knowledge, individual empowerment and social progress (Hyslop-Margison & Sears, 2006). Additionally, Hyslop-Margison and Sears (2006) said that Dewey's model of constructivism situated the teacher as a facilitator to help students pursue objectives based on their own experiences, interests and concerns—to nurture democratic ideals of students in which the learning path was not predetermined, but rather, responded to students' personal priorities.

According to Doolittle and Camp (2009), learning should take place in authentic and real-world environments. Experience, both socially oriented and object oriented, is a primary catalyst of knowledge construction. Experience provides the activity upon which the mind operates. In addition, knowledge construction is enhanced when the experience is authentic. For the social constructivists, authentic experiences are important so the individual may construct mental structures that are viable in meaningful situations. Doolittle and Camp (2009) illustrated the meaning of authentic learning experience using the example of an automotive technology student learning how to operate a micrometer. If the student learnt about micrometers in the course of solving a real life problem such as constructing a solar-powered car, the resulting knowledge constructed would be more accurate and viable than if the student merely practiced using the micrometer in isolation. Such a vision of learning about the vocations; and science, technology, engineering, and math can be achieved through the integration of CTE and STEM education.

Drake and Burns (2004) identify three approaches to curriculum integration, namely multidisciplinary, interdisciplinary, and trans-disciplinary. In the multidisciplinary approach, the disciplines are distinct but they are linked to a uniting theme. The thematic approach to teaching and learning implied in multidisciplinary integration provides a context for disciplinary knowledge (Drake & Burns, 2004). This form of integration takes away one major impediment to students' learning, "Why do we have to learn this?" The interdisciplinary approach to integration focuses the teaching and learning around common lessons across the disciplines. For example, a fish-farming lesson in agriculture can be extended to explore biology, or math, or technology standards embedded in the topic. Organizing a curriculum around common learning points across disciplines enriches understanding because students meet the same concepts from multiple perspectives. Drake and Burns (2004) stated that in trans-disciplinary integration, the curriculum was organized around student questions and concerns. The strength of this approach to curriculum integration was that it was responsive to students' needs and interests and hence, students were more likely to have the motivation to learn. Desire to learn is an essential ingredient in intentional integrative learning.

The educational ideals encapsulated in Dewey's vision for education and in constructivist thinking were now taking root in the American classroom. Wells (2008) observed that translating the goals for improved student content knowledge and understanding of STEM took some clear direction for change through the efforts of the American Association for the Advancement of Science's (AAAS) curriculum documents *Science for All Americans* (1989), and the *Benchmarks for Science Literacy* (1993). Wells stated that these documents provided the rationale and conceptual structure needed to improve student interest and proficiency in science, math and technology – calling for "teaching of these content areas as an integrative endeavor" (Wells, 2008, p. 3). Additionally, wide disparities continued between the nation's call for change in STEM education practice and the ability of America's educational system to implement that change, and that evidence was pointing to "business as usual". Wells further noted that there was concern for the lack of relevance in STEM education curricula at all levels of education. There was a lack of practices that promoted student understanding of the interconnectedness of content, concepts, and processes across STEM disciplines. These concerns were "providing impetus for collaboration among STEM fields for preparing the workforce for tomorrow. Needed is a workforce whose knowledge base must be more than a superficial understanding of isolated facts" (Wells, 2008, p. 10).

## Rationale for Linkages between CTE and STEM Education

It has been stated earlier that CTE programs offer an important instructional approach to strengthen students' understanding of STEM content and to help attract more individuals into STEM career pathways (ACTE, 2009). It is necessary to explore these two curriculum concepts further.

### Career and Technical Education (CTE)

CTE receives fiscal and directional support from the federal government through the Carl D. Perkins Career and Technical Education Improvement Act of 2006. The current reauthorization of the Act is also known as Perkins IV. Of significance to this study, the Act provides a definition for CTE, as follows:

> Organized educational activities that offer a sequence of courses that (i) provides individuals with coherent and rigorous content aligned with challenging academic standards and relevant technical knowledge and skills needed to prepare for further education and careers; and (ii) provides technical skill proficiency, an industry-recognized credential, a certificate, or an associate degree. CTE includes competency-based applied learning that contributes to the academic knowledge, higher-order reasoning and problem-solving skills, work attitudes, general employability skills, technical skills, and occupation-specific skills. (U.S. Congress, 2006, p. 1)

The fact that aspects of the Act provides mandates and spells out aspects of direct relevance to instructional practice is important for common interpretations, even if implementation might still vary.

**STEM Education**

Different scholars have defined STEM education differently. For example, Tsupros, Kohler, and Hallinen (2013) defined STEM education as follows:

> … is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (N. Tsupros, N. Kohler, R., & J. Hallinen, personal communication, September 13, 2013)

This is a comprehensive definition touching on many aspects necessary to guide educators' actions. Additional information about the definition is that it was developed with the participation of active educators through focus groups and surveys (Tsupros, Kohler, & Hallinen, 2008). Motivation for coming up with a definition was the fact that teachers, administrators and decision makers were finding the term confusing and were unsure of its meaning and implications for teaching and learning (Tsupros et al., 2008). Having educators develop it could make the definition resonate more with peers. However, including 'STEM literacy' in the definition introduces a major concept that itself needs defining.

In the report of the National Science and Technology Council Committee on STEM Education (CoSTEM), *The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio*, STEM education is "formal or informal (in school or out) education that is primarily focused on physical and natural sciences, technology, engineering, and mathematics disciplines, topics, or issues (including environmental science education or environmental stewardship)" (CoSTEM, 2011, p. 5). This definition was made in the context of the need to report details of Federal STEM education investments. Thus, for purposes of teaching, there might be insufficient guidance from this definition. Of significance and equally true about education-focused definitions, "the label 'STEM education' encompasses an enormous multidimensional landscape covering many different audiences, objectives, STEM fields, educational products, geographical regions, and funding sources" (CoSTEM, 2011, p. xii).

Basham, Israel, and Maynard (2010), defined STEM education as follows:

> An interdisciplinary (or transdisciplinary) approach that integrates knowledge from diverse academic disciplines into authentic problem-/project-based learning experiences as related to instruction in STEM content areas. Each of these is embedded with the scientific method and engineering design processes, as well as 21st century skills. (p. 11)

This definition relates to the aspect of instructional practice, and to career development. Instructional practice, and career development are fundamental concepts in both STEM education, and career and technical education. A closely related concept, *Integrative* STEM Education (Wells & Ernst, 2012) is for later consideration.

Factors for seeking greater synergies between CTE and STEM education include the following:

**STEM Education for All**

Stone (2011a) posits that all CTE programs, to varying degrees, address some aspects of science, mathematics, and technology – even if all might not be focused on engineering-related jobs. Based on this premise, STEM-focused education can be incorporated into any CTE delivery system, or curricular and pedagogic approach. Additionally, the Forum of representatives of business, education, government and civil society held in 2006 on developing a national action plan to address the 'T&E' of STEM stated in its report, *Preparing for the Perfect Storm*, that the national security and competitiveness of the U.S. rested on skills developed through STEM education. Additionally, the report stated that all students need to be innovators equipped with a good understanding of technological design and the design process, to ensure that sufficiently large percentages of young people will be entering the 21$^{st}$ century workforce (Coppola & Malyn-Smith, 2006). Advocating for "STEM Education for *all* students", members of the National Governors' Association (NGA) said that the saturation of technology in most fields in life meant that all students – not just those aspiring for STEM professions, need a substantial grounding in STEM to be productive members of the workforce (Toulmin & Groome, 2007).

**Demands of the New Global Economy**

Closely linked to the need for STEM education for all is the fact that to remain competitive in the new global economy requires a workforce of problem solvers, innovators, and inventors. A key to developing such a workforce lies in enabling every K–12 student to acquire the necessary STEM competencies (Toulmin & Groome, 2007). In addition to the need for America to remain competitive in the global economy, the demands of the workplace were continually changing to the point that workplace demands had now become increasingly similar to the objectives and aims of postsecondary education (Pearson, Sawyer, Park, Sanatamaria, van der Mandele, Keene, & Taylor, 2010). Thus, for schools, preparing students for postsecondary education and the workforce were no longer mutually exclusive goals. Many high-skilled trades now require some form of postsecondary training. Pearson et al. argued that meeting these needs and supporting high academic standards required procedural and academic rigor in the career and technical curriculum (Pearson et al., 2010).

**Building Academic Skills in Context**

Stone, Alfeld, Pearson, Lewis, and Jensen (2006) carried out a study to test whether a new pedagogy combined with professional development designed to enhance mathematics instruction in different occupational contexts would influence student performance on standardized tests of mathematics. The aim of the study was to help CTE teachers make the mathematics already embedded in the occupational curriculum more explicit as a necessary tool for solving workplace problems and then help reinforce students' mathematics understanding both in and out of that context. The findings of the study were that enhancing instruction in the mathematics that was inherent in the curricula of five diverse occupational areas improved the performance of students on standardized measures of mathematical achievement, and it did so without negatively affecting the acquisition of occupational skills and knowledge. Further, Stone et al. identified five core principles that were necessary for the ongoing mathematical enhancement to become the norm. These principles were as follows: (1) develop and sustain a community of practice among the teachers; (2) begin with the CTE curriculum and not the math curriculum; (3) understand that math is an essential workplace skill; (4) maximize the math in the CTE curriculum; and (5) recognize that CTE teachers are teachers of math-in-CTE, and not math teachers.

With specific reference to community of practice, Stones et al. said that the necessary condition for successful replication of the NRCCTE Math-in-CTE model was a group of CTE teachers from single occupational foci and their math-teacher partners working together in a community of practice to identify the math inherent in unique occupational curricula. Stone et al.

(2006) emphasized that communities of practice were critical to replication success. It was suggested that at least 10 CTE teachers, each with a math partner, was a minimum size needed to build the kind of relationships needed to be successful in this type of venture.

Lewis and Pearson (2007) carried out a follow-up study to the *Math-in-CTE* study with the view to determining the extent to which the teachers in the experimental group had continued to use the instructional method and lessons developed for the experiment, and the extent to which teachers in the control group had adopted any of the lessons. Lewis and Pearson found that the control CTE teachers who taught the math-enhanced lessons after the experiment had difficulty understanding the math, much less being able to teach it. These teachers had not experienced the professional development that the experimental CTE teachers had found to be essential to understanding both the math concepts and the structured, contextual approach for teaching them. Lewis and Pearson (2007) suggested that simply disseminating the lesson plans developed for the *Math-in-CTE* study would not replicate its results. An essential aspect to the success of the intervention was extensive professional development through which a community of practice focused on the improvement of instruction emerged.

**Building on Existing Foundation**

The quest for relevance in STEM education curricula, and the need to have all students graduate from high school with the essential STEM competencies necessary to succeed in postsecondary education and work, suggests a need for greater synergies between STEM education and CTE. According to the Association for Career and Technical Education (ACTE), CTE programs offered an important instructional approach that strengthened students' understanding of STEM content and helped attract more individuals into STEM career pathways.

Expanding and strengthening CTE programs were critical parts of the solution to the STEM challenge (ACTE, 2009).

From a CTE perspective, Stone (2011b) identified four categories of intersections between STEM education and CTE, namely:

- delivery systems, e.g. regional shared-time centers, CTE high schools, and CTE offered within traditional comprehensive high schools,
- programs: e.g. Career Academies, Tech Prep, and Programs of Study,
- curriculum: e.g. Project Lead the Way, and contextualizing math and science in CTE, and
- pedagogies, e.g. project-based learning, work-based learning, and problem-based learning.

Table 2.1 shows the illustration Stone (2011b) gave to show the linkages between CTE and STEM education.

Table 2.1.

*Linkages between CTE and STEM education*

| | STEM Education Goals<br>Developing STEM Intellectual Capital | | |
|---|---|---|---|
| | Developing Scientists & Engineers | Developing Technologically Proficient Workers | Developing Scientifically Literate Voters |
| CTE Schools | | √ | |
| CTE Programs | | √ | |
| CTE Curriculum | √ | √ | |
| CTE Pedagogies | | √ | |

*Note:* How CTE schools, programs, curriculum, and pedagogies intersect with goals of STEM education. Source: Stone (2011b, p. 5), used under fair use, 2013.

From a STEM education perspective, the following intersections between CTE and STEM education are apparent:

- Delivery systems, e.g. elite or selective STEM-focused schools, inclusive STEM-focused schools, STEM-focused career and technical education (CTE) schools, and comprehensive schools that are not STEM focused (Beatty, 2011).
- Programs, e.g. agricultural sciences, business and information technology, health and medical science education, and technology education.
- Curriculum, e.g. Project Lead the Way; Engineering by Design, Engineering is Elementary (EiE); Invention, Innovation and Inquiry; Virginia's Children's Engineering Council, and TSM materials
- Pedagogies, e.g. Integrative STEM Education; Technology/Engineering Design-Based Learning; Scientific Inquiry-Based Learning.

Beatty (2011) provided the framework below for understanding what constitutes success in K-12 STEM education. The framework is shown in Figure 2.1.

Explaining the framework, Beatty said that it depicted the factors that influenced the effectiveness of STEM education. The context in which education took place (the upper-most box) determined the curriculum, the resources, the priorities, and students' expectations and motivation. The program's specific goals, e.g. to prepare top students for advanced study and challenging careers, and reducing achievement gaps would then dictate the standards by which the program would be judged. The different school structures and the specific conditions and practices within programs needed to be taken into account. Ultimately, 'successful' STEM education needs to be determined by outcomes and indicators. In the case of CTE, for example,

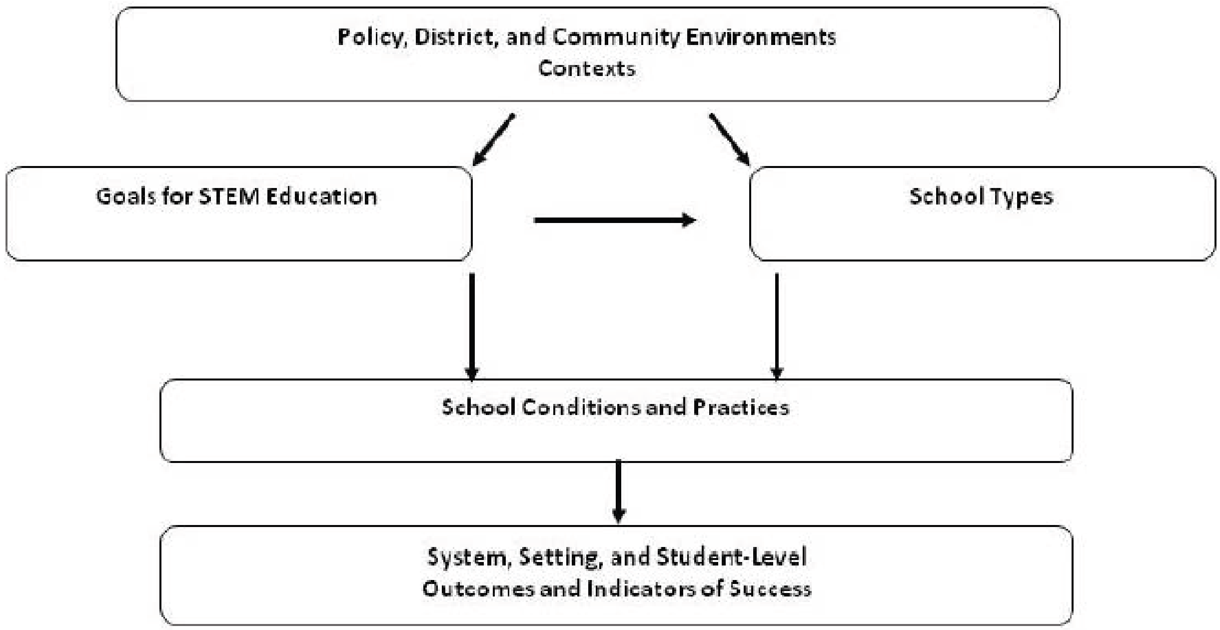


*Figure 2.1*. Framework showing linkages among implementation context, goals for STEM education, school types, school context, and indicators of success. Source: Beatty (2011, p. 6), used under fair use, 2013.

some of the performance measures specified by the Perkins IV Act are academic attainment in reading and math, secondary school completion, and technical skill attainment (U.S. Government Accountability Office, 2009). Considered together, Stone's (2011b) outline of intersections between CTE and STEM education, and Beatty's (2011), it is evident that CTE provides a foundation on which to contribute to advance the goals of STEM education.

**Legislative Requirements**

The Carl D. Perkins Vocational and Applied Technology Act of 1990 (PL 101-392) also known as Perkins II, was grounded in the notion that the U.S. was falling behind other nations in its ability to compete in the global marketplace. The focus of Perkins II was intended to strengthen the workforce preparation process. This included integration of academics and vocational education (Threeton, 2007).

Another significant piece of federal legislation concerned with the economy of the U.S. was the School-to-Work Opportunities Act of 1994 (PL 103-239). The purpose of this act was to address America's skills deficit by providing a comprehensive system to assist students in acquiring knowledge, skills and abilities in order to successfully transition from school to career-oriented work or further education. The main components of this legislation included: integration of academics and occupational learning, work experience, structured training, career guidance and a variety of work-based learning activities. Funding for the School-to-Work Act ceased in October of 2001 due to a termination clause incorporated into the 1994 legislation.

The Carl D. Perkins Act of 1998, also known as Perkins III, called for a state performance accountability system in which the objective was to promote academic and technical performance, integration of academics in vocational education, as well as postsecondary placement of students. The Carl D. Perkins CTE Improvement Act of 2006 (Perkins IV) placed greater accountability on integration of academic standards. The Act ultimately intended to strengthen the focus on responsiveness to the economy; while tightening up the accountability statement in regards to the integration of academics and technical standards (Threeton, 2007). Perkins IV requires "the integration of coherent and rigorous academic content standards and career and technical education curricula, including opportunities for the appropriate academic and career and technical education teachers to jointly develop and implement curricula and pedagogical standards and professional development that is high quality, sustained, intensive and increases academic knowledge" (U.S. Congress, 2006, p. 36).

## Teacher Capacity

McDiarmid and Clevenger-Bright (2008) argued that learning to teach was a life-long process which begins with 'apprentice observation' in elementary school classrooms through pre-service teacher education, and continuing professional development. Consequently, *teacher capacity* needed to be understood in terms of potential for teachers to develop in their knowledge, skills, and dispositions. Additionally, because expectations for teachers were continually increasing due to policy initiatives, growth of knowledge, technology, changing demographics, etc., a need emerged to conceptualize teacher education as enhancing teacher capacity along a learning continuum (McDiarmid & Clevenger-Bright, 2008). Expressing the idea that teachers can never learn enough, Ball and Cohen (1999) stated that “teaching occurs in particulars—particular students interacting with particular teachers over particular ideas in particular circumstances.… No amount of knowledge can fully prescribe appropriate or wise practice” (p. 10).

**Teacher Knowledge**

Interest in the connections between CTE and STEM education is a result of educators’ desire to foster students’ meaningful learning by enhancing authenticity and relevance of lessons. But an equally important factor in fostering students’ learning is teacher knowledge because making content accessible to learners requires teachers to have both the understanding of subject matter, and appreciation for how students learn this subject matter (Bransford, Darling-Hammond, & LePage, 2005; Shulman, 2005a). Shulman (1986, 1987) posited that at the very least, teacher knowledge could be placed into the following seven categories: content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts; and knowledge of educational ends, purposes, and values. Of these categories, Shulman (1986, 1987) stated that *pedagogical content knowledge* was of special interest because “it represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). Although pedagogical content knowledge is necessary for fostering students' learning, it is inadequate to produce an 'accomplished teacher'—one who can "teach in theory-rich, open-ended, content-intensive classrooms" (Shulman & Shulman, 2004, p. 259). An accomplished teacher is one who possesses a vision for teaching, is self-motivated, had pedagogical content knowledge, was a reflective practitioner, and was a member of a professional community (Shulman & Shulman, 2004). Of these attributes, Shulman and Shulman (2004) identified 'community' as the most important because in a community there is deliberation, collaboration, reciprocal scaffolding, and distributed expertise. Additionally, teacher communities allow for shared visions, community commitments, shared knowledge base, and a community of practice through which to enhance the development of particular accomplishments. Successful integration of CTE and STEM education needs such teacher communities. However, for teaching communities to thrive, there is need for a supportive policy framework such as school schedules, and teacher workloads (McDiarmid & Clevenger-Bright, 2008). Formulation and implementation of a supportive policy environment is within the realm of responsibility of local directors of CTE (Usdan, McCloud, Podmostko, & Cuban, 2001).

**Teacher Beliefs**

Beliefs teachers hold about knowledge, teaching, and learning play a pivotal role in how they interpret pedagogical knowledge, conceptualize teaching tasks, and subsequently enact their teaching decisions (Bryan, 2003, Nespor, 1987). According to Bryan (2003), belief systems are more influential than content knowledge in with regards to teachers' instruction. Thus, to understand why teachers conduct classrooms as they do, there is need to pay attention to the goals they pursue—taking into account the goals might be nebulous, conflicting, and not necessarily focused on enhancing student's learning. Additionally, Nespor (1987) argued that educational contexts were ill-defined because of the multiple goals, lack of clarity of problems being addressed such that alternative courses of action at different points of the problem-solving process were equally not clearly-defined. Integration of CTE and STEM education could be one such educational experience that could unsettle teachers. Nespor argued that when people encountered such ill-structured problems, many standard cognitive processing strategies were no longer viable. Because of uncertainties about how to deal in an adaptive manner in such instances, belief systems provide a 'comfort zone' because belief systems were non-consensually held, and an individual teacher can safely apply the same beliefs to a variety of teaching (Nespor, 1987). Bryan (2003) also stated that studies had shown that the educational beliefs of teachers played a vital role in how they interpreted pedagogical knowledge, conceptualized teaching tasks, and level of instruction.

Meeder and Suddreth (2012), in their study to determine how state education agencies were including CTE leaders in Common Core State Standards (CCSS) implementation, found the following to be among the common issues that often made integration of the CCSS into CTE a challenge: (a) Teachers traditionally were responsible solely for the delivery of their content and had limited experience enhancing their subject through cross-disciplinary integration with other content areas; (b) There were few innovative models of how to systematically integrate real-world CTE examples into academics, and where models did exist, they were mostly at the local level and often difficult to replicate without significant resources or planning time set aside for educators to collaborate on integration strategies and materials. With respect to linkages between CTE and STEM education, a compounding challenge could be that the phenomenon of STEM education is itself a work-in-progress—for example, the on-going work on strategies for incorporating engineering and technological design processes into the regular teaching of science and math (Wells, 2010). These challenges might be ameliorated with a ‘signature pedagogy’ that links CTE and STEM education, and with both initial teacher education and continuing professional development.

**Signature pedagogy.** Shulman (1993) stated that one of the fundamental wrongs of teaching was pedagogical solitude. One consequence of pedagogical solitude in teaching was that it lowered the status of teaching (Shulman, 1993). Another consequence was that engaging and effective teaching that makes a difference in students’ learning achievement was perceived as an individual trait of a teacher rather than being as a professional norm that could be attained by all teachers (Elmore, 1996). Elevating engaging and effective teaching to be a professional norm in educational practice requires what Shulman (2005b) called a ‘signature pedagogy’. A *signature pedagogy* is “a systematic, shared set of practices that distinguishes the preparation programs in a given profession” (Viadero, 2005, p. 1). Shulman (2005a) outlined three characteristics of a signature pedagogy of a profession. The first characteristic was that the pedagogy was pervasive and routine, meaning that it cuts across courses, programs, and training institutions. The second characteristic of the pedagogy was that public student performance is always part of the curriculum. This enables students to be active and interactive learners. was pervasive within the curriculum. The third feature was that it involves risk taking and managing uncertain situations—noting that some level of emotional investment was necessary intellectual growth and professional formation. was pervasiveness—cutting across courses, individual practitioners, and institutions. Other descriptors Shulman used for signature pedagogies were that they were habitual, routine, visible, accountable, interdependent, collaborative, emotional, unpredictable, and affect-laden (Shulman, 2005a). For teaching, a signature pedagogy could ensure that beginning teachers, no matter where they are prepared, have been exposed to some practices that experts agree are beneficial to student learning (Viadero, 2005).

Signature pedagogies make a difference, “they form habits of the mind, habits of the heart, and habits of the hand” (Shulman, 2005a, p. 59). Thus, the lack of a signature pedagogy—one on which CTE and STEM education might unite could be a vital missing link in taking to scale and sustaining integrative teaching of CTE and STEM. In the context of STEM education reform, ‘Integrative STEM Education’ is being popularized.

**Integrative STEM Education.** *Integrative STEM education* is founded on premises of integration among STEM disciplines being intentional, systematic, and persistent - rather than sporadic integration across a selection of curriculum units among STEM constituent disciplines (Wells & Ernst, 2012). Integrative STEM education is a pedagogy through which students might acquire the ability to transform knowledge into personally useful strategies (Wells, 2010). Wells and Ernst (2012) defined integrative STEM education as:

> The application of technological/engineering design based pedagogical approaches to *intentionally* teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels. (n.p.)

Integrative STEM education, as conceptualized by Wells and Ernst (2012) is of interest to an integrative approach to the teaching of CTE and STEM education in many respects that are fundamental to successful achievement of the goals of both CTE and STEM education. The following factors are noted about Integrative STEM education:

- It is grounded in major national curriculum documents, including those of the American Association for the Advancement of Science (AAAS) – a international non-profit organization dedicated to advancing science, technology and innovation internationally, namely *Science for all Americans* and *Benchmarks for science literacy*.
- It is grounded in the constructivist theory of knowledge and learning.
- It focusses in ability to apply knowledge to a variety of contexts.
- It focusses on intentional teaching of two or more disciplines.
- It is premised on teachers collaborating in multidisciplinary teams (Sanders, 2009; Wells, 2010).

A signature pedagogy linking CTE and STEM education could be built on the principles of Integrative STEM education in which the application of content, context, and pedagogical approaches of CTE could be used to *intentionally* teach content and processes of STEM education. But, as Wells noted, "instructional design and classroom practices of this caliber will challenge even the most seasoned educator (Wells, 2008, p. 12). The concept, and practice would require to be embedded in teacher education, both at the pre-service, and at the continuing professional development levels.

**Teacher Education**

The core purpose of formal education is to enable the development of *all* children to take their place in adult society with the competencies to be positively contributing members to the society (Dewey, 1917; Hansen, 2008; Horowitz, Darling-Hammond, & Bransford, 2005, p. 125). Expressing a similar view, Symonds, Schwartz, and Ferguson (2011) stated that the education system should take into account multiple pathways to prosperity bearing in mind widely diverse needs, interests and abilities of students. According to Darling-Hammond and Hammerness (2005) responding to this challenge requires teacher education programs that have coherent visions of teaching and learning, and integrate related strategies across courses. Teacher education programs should produce effective teachers—ones who are "deeply engaged with their students and their subjects, and be able to weave an intricate web of connections among themselves, their subjects, and their students, so that students can learn to weave a world for themselves" (Palmer, 1998, p. 10).

Darling-Hammond and Hammerness (2005) posit that, (a) learning about teaching develops through participation in a community of learners where content is encountered in contexts in which it can be applied, and (b) this learning is strengthened when it is embedded within a community of practitioners. One implication of this is that preservice teacher education should be seen only as a step in a lifelong process of teacher development (OECD, 2011). Another implication is that preservice teacher education should transition seamlessly into well structured programs for supporting new teachers, continuing professional development that involve teachers in learning activities that are similar to those they will use with their students, encouraging the development of teachers' learning communities, and linking teacher development needs to the wider goals of school and system development (OECD, 2011).

The changes needed to teacher preparation programs would be to define signature pedagogy for (a) teacher preparation, and (b) the teaching of CTE – of which intentional integration of CTE and STEM education would be a part. Defining signature pedagogies for either teacher preparation or teaching has been problematic so far (Viadero, 2005) because of, first, the complexity of the teaching endeavor. For example, approaches to the teaching of a particular piece of content needs to be related to the topic itself and to the abilities and experience of both teachers and pupils. Because of differences of personality and circumstance, methods which may be extremely successful with one teacher and one group of pupils will not necessarily be suitable for use by another teacher or with a different group of pupils (Cockcroft, 1982). Additionally, unlike other professions, teacher education exists in a more politicized regulatory environment in which key professional matters are to a large extent governed by political entities rather than by the profession itself (Darling-Hammond, Pacheco, Michelli, LePage, Hammerness, 2005). Thus, because of the responsibilities school district leadership have to provide local level organizational, political, and instructional leadership (Usdan, McCloud, Podmostko, & Cuban, 2001), local directors of CTE have a major role to play in teacher education.

To achieve the vision of teaching which can bring about learning as envisioned by Dewey, preservice teacher education, and continuing professional development need to help teachers move beyond management and discipline concerns so that they can spend their energy reflecting on their beliefs and practice (Bryan, 2003). Additionally, teachers would benefit from more opportunities to practice their growing conceptions of teaching with resources to help them think through tensions and uncertainties. For example, in communities of practice, teachers could examine their own videotaped lessons, and confront their beliefs. Local directors of CTE could play a role in creating an enabling environment by making resources and time available for teachers to do this.

## Role of School Division Directors in Educational Reform

McLaughlin and Talbert (2003) observed that school districts have participated in numerous types of education reform initiatives in the past few decades. The reform initiatives have varied origin - federal, state, and local levels and they have varied in nature, e,g.

restructuring the school day, holding students and teachers accountable to more rigorous standards, and installing new curricula and instructional practices. However, McLaughlin and Talbert (2003) reported that the wide array of reform initiatives have not achieved a noticeable impact on the quality of students' learning, and even when success could be claimed, the success was often short-lived, localized, and near impossible to scale up.

In the context of educational reform efforts, a district might be conceptualized as an institutional actor in systemic reform, which working together with schools, develops and implements solutions to identified problems (Rorrer, Skrla, & Scheurich, 2008). Rorrer et al. (2008) studied extant literature on district-level leaders to contribute to successful systemic educational reform. Their synthesis of the literature formed a basis for a theory that explained how districts operated as institutional actors in systemic reform - with the goals of the reforms being to raise students' achievement and, concurrently, advancing equity. This theory is built around four roles that districts could utilize to implement reform. The four roles are (a) providing instructional leadership, (b) reorienting the organization, (c) establishing policy coherence, (d) maintaining an equity focus" (p. 335). Figure 2.2 illustrates the theory of systemic reform and how the roles relate to each other.

According to Rorrer et al. (2008), in the role of providing instructional leadership, district directors are expected to galvanize the will for educators to embrace reforms and to build capacity for implementation. When reorienting the organization, directors need to refine organizational structures such as creating time and opportunities for teachers to operate in communities of practice. This might also require encouraging a work culture in which reform efforts might thrive.

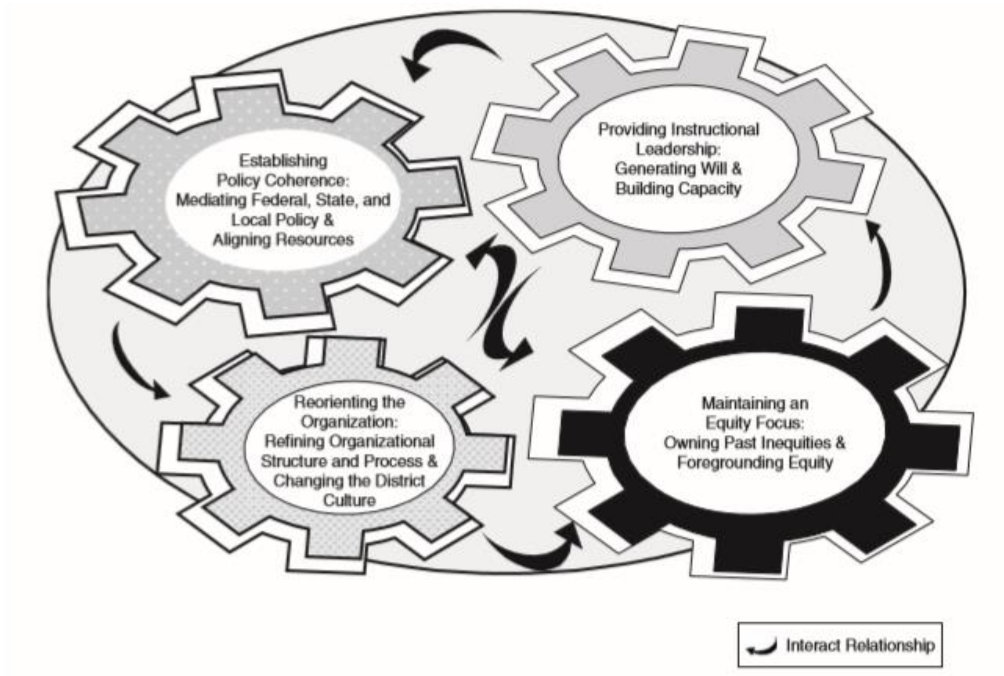


*Figure 2.2*. Framework for understanding how districts serve as institutional actors in improving achievement and advancing equity. Source: Rorrer, Skrla, and Scheurich (2008, p. 335), used under fair use, 2013.

The role of establishing coherent policy might mean harmonizing federal, state, and local requirements. In the model, the role of maintaining an equitable focus has been emphasized mostly to highlight what could be the biggest challenge in the reform efforts—raising the achievement for *all*. Not only is there concern for American students' under-achievement in STEM fields, but there are serious demographic disparities within that under-achievement. Thus in educational reform effort, "equity becomes both a defining explicit value and a desired outcome" (Rorrer et al., 2008, p. 334).

Elmore (1996) addressed the question of why innovations that require large changes in the "core of educational practice" hardly ever go beyond pockets of excellence to reach a much greater proportion of students and educators, and for a sustained period of time. By *core of educational practice*, Elmore meant "how teachers understand the nature of knowledge and the student’s role in learning, and how these ideas about knowledge and learning are manifested in teaching and classwork” (Elmore, 1996, p. 2). One problem Elmore explained as the reason for the lack of large scale sustained change of core educational practices is what Shulman (1993) called ‘pedagogical solitude’, whereby teachers are typically solo practitioners. He argued that the private nature of teaching not only lowered its status, it eroded its effectiveness. According to Shulman (1993), strategies to get out of this malaise included having teachers operate in communities of practice, making teaching visible through artifacts that reflected the richness and complexity, and have teacher-peer reviews. For Elmore (1996), the effect of pedagogical solitude was that inspirational and engaging teaching becomes noticed as an individual trait of a teacher rather than being an attainable professional. To make systemic and sustained change in educational practice, Elmore (1996) suggested four broad principles: (a) create strong professional and social normative structures for good teaching practice that are external to the individual teachers and their immediate working environment; (b) develop organizational structures that intensify and focus intrinsic motivation, and at the same time, influence peers to engage in challenging practice; (c) create intentional processes for reproduction of successes, rather than assume that success will invariably breed its own success; and (d) create structures that promote learning of new practices, and incentive systems that support the learning. Additionally, Elmore (1996) stated that in the absence of such explicit strategies for scaling up change, it is unlikely that teachers or schools will respond to the emergence of new practices any differently than they have in the past.

Ryndak, Reardon, Benner, and Ward’s (2007) findings from a 7-year study indicated that the efforts of a school district leadership attempting for five years to systematically change the inclusive nature of the special education program at the district level were that success was due to seven influential variables. The seven variables were as follows: (a) participants needed to share a common vision of the outcomes they desired, (b) participants needed to have a common understanding of the change process, (c) district and school personnel both needed to have a sense of ownership of change efforts, (d) varied efforts were required concurrently at the school and the district levels, (e) efforts needed to involve all types of constituents e.g. teachers, parents, and administrators; (f) a process of communication was needed among individuals in each constituency; and (g) the district and the school personnel needed 'critical friends' to provide feedback and input into the strategic planning process. Additionally, and of special interest to this study, Ryndak et al. (2007) reported that one of the lessons learned from this reform effort was the need to ensure that there was one district level person who had both the authority and responsibility to coordinate, facilitate, and monitor the systemic change efforts. To achieve this, this person "must have the ability to perceive the status of understanding and implementation of the desired changes at all levels (i.e., district, school, education teams) and consistently provide concurrent, yet different, support across personnel" (Ryndak et al., 2007, p. 244). For example, in the *Administrative Planning Guide for CTE in Michigan*, the roles of school district CTE directors were placed in five categories as follows: (a) program review/planning and development – to assure that the district's CTE delivery system is based upon goals and objectives in accordance with state program standards and guidelines, and provide leadership and direction for program evaluation and improvement; (b) program management – to assure that appropriately certified or approved personnel are employed in all positions requiring such qualifications, facilitate the acquisition of appropriate instructional equipment, and oversee the district's budget for CTE programs; (c) professional development – to be responsible for promoting CTE in-service activities for personnel in the district; (d) collaboration and coordination – to encourage program coordination and curriculum articulation with postsecondary agencies and local educational agencies; and (e) program marketing – to plan and lead marketing activities, and to create increased understanding and awareness of CTE programs, needs, and successes (Michigan Department of Education, 2011).

Smith and O'Day (1990) explained their support for the importance of district-level leadership in educational reform by noting that even though school-based initiatives might be more likely to produce significant changes in classroom practice than have edicts from above, it was still difficult for a strictly school-by-school approach to grow from the small number of initially active schools to a large number of institutions in a school district. Sanders (2012) noted that district leaders' intent, knowledge and skills, and access to key stakeholders enabled them to forge positive working relationships with key individuals and groups in their respective districts and that this factor was critical to scaling up and sustaining educational reforms. Several other researchers have confirmed the important role of district leadership in sustaining educational reforms (Datnow, 2005; McLaughlin & Talbert, 2003; Sanders, 2012; Sindelar, Shearer, Yendol-Hoppey & Liebert, 2006).

Meeder and Suddreth (2012) conducted a survey study to determine how state education agencies were including CTE leaders, as stakeholders, in the *Common Core State Standards* (CCSS) implementation. Meeder and Suddreth reported that both state and local CTE directors acknowledged that success to integrate academics in the CTE classroom had been sporadic, and that even in places where integration of academic content into CTE classes is systemic, integration of real-world CTE content into the academic classrooms was almost nonexistent. One challenge Meeder and Suddreth (2012) stated that one of the reasons for inadequate success in integrating academic and CTE was that, while legislation (e.g. successive the Perkins Acts) required CTE educators to integrate academics into CTE, there was no similar policy requirement to integrate real-world relevance into the teaching of academics. Additionally, CCSS had implications for instructional materials, curricula, professional development and assessment—all these being aspects of education in which CTE educators can share their expertise on curriculum integration. The fact that nearly half of responding states had no CTE representation on their CCSS implementation teams could be a reflection of a lingering belief among educators that common core state standards were a preserve of academics (Meeder & Suddreth, 2012). This makes it all the more worthwhile to study the experiences of local directors of CTE in view of their responsibilities for organizational, instructional, and political leadership of CTE educators.

## Summary

This literature review has been built on the foundation of John Dewey's "social reconstructionist" philosophy in which education is more than the acquisition of academic knowledge and narrowly defined occupational skills. To enable students to graduate from high school STEM career-ready, i.e. for either post secondary education or work, there is need for sustained systemic reform in CTE and STEM education. Education, especially through the occupations, was about formation of character. The literature indicated that district-level leaders are important to successful systemic educational reform. Rorrer, Skrla, and Scheurich (2008) proposed a theory of districts as institutional actors in improving achievement and advancing equity. The theory is built around four roles, which were to provide instructional leadership, reorient the organization to a productive work culture, establish policy coherence, and maintain an equity focus. The work of Ryndak, Reardon, Benner, and Ward (2007) on characteristics of school districts which had been successful in affecting systemic changes formed a basis for further thoughts on sustaining education reform. These thoughts included teacher beliefs, teacher knowledge, teacher education, and signature pedagogy. What this researcher did not find was literature on the experiences of school district directors of CTE with the integration of CTE and STEM education. This study is designed for the purpose of describing those experiences of local directors.

# CHAPTER 3 METHODOLOGY

Chapter 3 provides a detailed presentation of the research design beginning with the purpose of the study, statement of the problem, and research questions. The remaining parts of the chapter include a presentation of participant selection, data collection and data analysis procedures, indicators of quality and rigor, and the chapter summary.

## Statement of the Problem

In spite of the large overlap in the goals of CTE and STEM education, there is little evidence of the role(s) CTE delivery systems, programs, curricula, or pedagogical strategies can play in advancing STEM education. Local directors of CTE have responsibilities for organizational and instructional leadership in school districts (Usdan, McCloud, Podmostko, & Cuban, 2001) and, therefore, could illuminate our understanding of linkages between CTE and STEM education implementation. The problem is that we do not know enough about the experiences of local directors of CTE with respect to CTE-STEM education linkages.

## Purpose of the Study

The purpose of this study was to analyze the experiences of school district directors of CTE to better understand the linkages between CTE and STEM education.

## Research Questions

The main question the researcher was seeking to answer was as follows: What have been the experiences of local directors of CTE with linkages between CTE programs and STEM education implementation? The study was guided by the following sub questions:

1. How do CTE directors define STEM education?
2. What do directors consider to be the contributions of CTE programs to STEM education implementation?

3. What do directors describe as specific examples of CTE initiatives that have contributed to advancing STEM education at the school/district level?
4. How can the contributions of CTE in the advancement of STEM education be made more visible to and accepted both by CTE and STEM educators.
5. What are school division CTE directors recommendations concerning successful policy/curricula/pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education.

## Research Design

A qualitative study design was used to answer the research questions. Qualitative researchers are concerned with understanding and interpreting meanings people make of their lives and situations—the kinds of things that are important for the conduct of social action in a local community of social practice (Lapan, Quartaroli, & Riemer, 2012; Merriam, 2009). This study focused on the experiences of school district directors of CTE with regards to the contributions CTE programs have made to STEM education implementation. A combination of *convenience* sampling and *extreme deviant* sampling was used to choose participants for the study (Patton, 2002). Data were collected using semi-structured interviews, and analyzed using a process of constant comparative and content analysis to develop common themes (Creswell, 2013; Merriam, 2009; Patton, 2002).

## Selection of Participants

Rossman and Rallis (2012) noted that historically, the individuals who took part in a research study were referred to as subjects, respondents, and informants. However, qualitative researchers use the term ‘participant’ to imply a more inclusive and democratic process.

The choice of participants is based on criteria that served the purpose of the study in terms of providing relevant information (Lincoln & Guba, 1985; Merriam, 2009). According to Patton (2002), qualitative inquiry typically focused in depth on relatively small samples selected *purposefully*. The essence of purposeful sampling is having information-rich cases rather than in the size of the sample (Patton, 2002). Strategies for achieving purposeful sampling include the following: (a) extreme deviant sampling whereby the richness of information arises from the cases being unusual or special in some way—they could be outstanding successes or notable failures; (b) intensity sampling whereby the richness of information arises from the cases manifesting the phenomenon under study; (c) homogeneous sampling – the richness being in the focus on a subgroup; (d) typical case sampling – the strength lies in highlighting what could be considered average case; (e) stratified purposeful sampling from which the strength lies in focusing on subgroups from which comparisons  can then follow; and (f) convenience sampling in which the main advantage is the relative ease of access to the participants, although taking into account a risk of some loss of richness of information (Patton, 2002). For this study, the researcher used a combination of extreme deviant sampling and convenience sampling to select participants.

Virginia is divided into eight education regions as shown in Figure 3.1. All school systems in Virginia have a CTE director and each region has one director serving as a regional CTE coordinator. The regional coordinator is responsible for coordinating regional activities (i.e. regional director's meetings). The researcher obtained names and contact information for the regional coordinators from the Virginia Association of Career and Technical Education Administrators (VACTEA) website (VACTEA, 2013). The regional coordinators were contacted by email to introduce the study and the researcher, and to ask them to give brief descriptions of

CTE programs in their regions that were involved in integration with STEM education (see Appendix A). However, this process did not yield desired results. No regional coordinator supplied the information asked for.

The researcher contacted the regional coordinators again this time, not asking for information on CTE/STEM education programs, but for their participation as interviewees. Further email invitations for participation were sent to local directors of CTE based mostly on geographical proximity, but also paying attention to having a mix of city, suburban, town and rural school districts included. The invitation to local CTE directors also stated the purpose of the study, the issues they would be asked about, and the significance of the study (see Appendix B). Invitations were sent out together with an informed consent form and a demographics questionnaire. The informed consent form stated the purpose of the study, procedures, risks, benefits, confidentiality, freedom to withdraw, the lack of compensation, responsibilities, and contact details for research-related issues. Commitments to participate and scheduling of interviews was done by telephone.


*Figure 3.1.* Map of Virginia public schools by region. Source: Virginia Department of EducationVirginia web site. http://www.doe.virginia.gov/directories/schools/school_info_by_regions.shtml, used under fair use, 2013.

## Number of Participants

According to Patton (2002), there are no rules for sample size in qualitative inquiry. The purpose of the study guides the sample size by determining what will be useful and have credibility, and what can be done with available time and resources. Seidman (2013) said that there were two criteria for 'enough participants'. The first of these was 'sufficiency'. The *sufficiency* criterion entails taking into consideration whether or not the numbers reflect the range of participants and sites that made the population so that those who are outside the sample might be able to connect to the experiences of those in the sample. The second criterion was 'saturation' of information. *Saturation* is attained when the interviewer does not hear new information from participants. Lincoln and Guba (1985) used the term 'redundancy' and stated that sampling is terminated when no new information was forthcoming from participants. In view of the openness of the sample size in qualitative research, Patton (2002) recommends that there at least be a minimum sample based on "reasonable coverage of phenomenon given the purpose of the study and stakeholder interests … The design should be understood to be flexible and emergent" (p. 246). In this study, the researcher interviewed 13 participants were to be interviewed, subject to saturation occurring.

## Data Gathering Procedures

In most forms of qualitative research, data are collected through interviews (Merriam, 2009; Rossman & Rallis, 2012; Seidman, 2013). Interviews were the principal means of gathering data for this study. In addition, a brief questionnaire was used to gather demographic data of the participants, and teacher statistics on the school district. Field notes were taken during school visits and interviews, and a personal journal was also maintained. Email communication was used to clarify issues arising from interviews.

## Interviews

Merriam categorized interviews on a continuum of structure ranging from highly structured, semi-structured, and unstructured. Characteristics of the three categories include the following: (a) highly structured, whereby wording, and order of questions are predetermined; and the interview is based on a written survey; (b) semi-structured, whereby the interview guide has a mix of more and less structured questions; all questions are used with flexibility; usually specific data is required from all participants; and most of the interview is guided by issues to be explored; and (c) unstructured, whereby the interview is more like a conversation; used when the researcher does not know much about the phenomenon to be able to ask relevant questions, and the motivation is to learn from the interview to formulate questions for later use.

In this study, the researcher used face-to-face semi-structured interviews. All the interviews were conducted at the offices of participants. All interviews were one-on-one except for one school district where the Director of CTE and her immediate supervisor, previously Director of CTE for the same district, were interviewed together. Semi-structured interviews allowed raising the same issues with all the participants and yet keeping the questions open enough for the participants to speak about many aspects of the topics. Probing questions were asked and varied according to the case circumstances. Specifically, the following issues were raised with each director: (a) Description of the responsibilities of a school district CTEs; (b) Description of experiences regarding synergies between CTE and STEM education in the school division; (c) Description of successful efforts at the school/district level to integrate CTE and STEM education; (d) Description of unsuccessful efforts at integrating CTE and STEM education; (e) Thoughts on how the contributions of CTE towards the advancement of STEM education could be made more visible to and accepted by both CTE and STEM education personnel; and (f) Recommendations concerning successful policy/curricula/pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education (see Appendix C for the interview protocol).

Each interview lasted about 30 minutes. The researcher had intended to have all the interviews audio recorded to ensure that everything said during the interviews was available for analysis. However, one participant consented to the interview but not to audio recording. The researcher took more detailed notes during this interview than in the other interviews. Where the interviews were recorded, two digital voice recorders were used. This paid dividend because at two interviews, one of the recorders malfunctioned and nothing was recorded on it.

**Questionnaire**

A questionnaire was used to collect demographic information for purposes of describing the sample, and putting a context to their narratives. The questionnaire was also used to get the numbers of teachers of CTE, and non CTE. Information on teacher supply in a school system was useful for understanding participants' experiences with CTE-STEM education linkages. Knowing the numbers of teachers was also important background information for understanding factors that shaped the Directors' experiences. As stated earlier, Stone, Alfeld, Pearson, Lewis, and Jensen (2006) found that the success of a new Math-in-CTE pedagogy depended on a group of CTE teachers from a single occupational focus and their math-teacher partners working together in a community of practice. Stone et al. suggested at least 10 CTE teachers, each with a math partner, was a minimum size needed to build the kind of relationships. A follow-up study on Math-in-CTE confirmed the requirement for extensive professional development and fostering a community of practice (Lewis & Pearson, 2007). Thus, it was of interest whether numbers of teachers in each district would be sufficient to make a community of practice viable.

The questionnaire (in Appendix D), together with the informed consent form (in Appendix E), were e-mailed to participants in advance for collection during the interviews. In some cases, these documents had not been downloaded ahead of the interview and copies brought by the researcher were used.  Confidentiality and the option not to respond to any question were reiterated. With respect to numbers of teachers in the school district, most directors had at least the approximate number of CTE teachers available but not numbers of non-CTE teachers. Where not provided, numbers for non CTE teachers were obtained from a website Eladrel Technologies, LLC (2011).

**Field Notes**

Field notes are a systematic record of the researcher's impressions and insights during the data gathering process. Rossman and Rallis (2012) suggested two categories of field notes: (a) Running record describing what has been observed or noticed in the context of the interviews; and (b) Observer comments capturing the researcher's reactions to events, insights, and thoughts for follow-up action. Running records and observer comments were taken during the interviews in the form of quick notes, being mindful to give the participant maximum attention, and not to lose non-verbal communication. For example, one of the participants was explaining how the latest 'thing' in his school district was the setting up of "partnerships between business and industry, community colleges, and four year universities, making career pathways—STEM type initiative" and was making inverted commas with fingers when saying "STEM-type initiatives". It required a focus on the participant, rather than on note-taking to capture such nuances.

## Data Analysis Procedures

The first step in data analysis was to ensure accuracy of interview transcripts and familiarization with the data.

### Transcribing the Interviews

The researcher personally transcribed the interviews. Transcriptions were done in Excel to take advantage of the capabilities not known by the researcher to be available in Word. For example, having all the transcripts as different sheets of the same Excel workbook made it easier to switch between the transcripts and instead of leaving wide margins for notes, Excel allowed for continually adding columns on the same sheet.

The process required repeat playing of short audio segments of about 10 seconds at a time to enhance accuracy of transcription. Reading and re-reading interview transcripts while listening to the audio recordings helps with accuracy and familiarity with the data (Rossman & Rallis, 2012). Although transcribing in this manner was a tedious exercise, the benefit was that the process allowed the researcher to be immersed in the data. Some participants were very deliberate in speaking as if they had in mind the task of transcribing that lay ahead. They had clear diction and at a speed that made transcription fairly smooth. Some participants took a more conversational stance, with changes of thought in mid-sentences. Such participants were pleasant to listen to and got the researcher really engaged. However, transcribing such interviews was more challenging—requiring much shorter segments at a time and repeated more times. Resulting sentences had less structure than would have been the case, say, with written responses. To preserve authenticity of the transcripts, mannerisms were preserved. Mannerisms included expressions such as ‘um’, ‘so’, ‘you know’. The em dash, —, was used to indicated sudden change of line of thought in a sentence. The researcher found it beneficial to personally transcribe because aspects such as sudden changes of thought in a sentence might be construed as erroneous transcription if done by a third party but the researcher was able to visualize the interview context. A sample interview transcript is in Appendix F. Preserving mannerisms posed a dilemma of how the participants would react to their narratives, seen in print. To enhance integrity of the data, the transcripts were sent back to each participant for verification and addition of any further thoughts that could have occurred after the interview. Some participants did not get back to the researcher, some said they would get back later but did not do so. Feedback received includes the following:

- "The transcript looks good.  I need to be more mindful of my thoughts.  I jumped around in a few places.  Good luck on your study and your vision for CTE back home";
- "I did not see any glaring errors. If I can be of further help please let me know";
- "You are very welcome. Hope I could be of some assistance. Always glad to support the great work at Virginia Tech";
- "Looks good.  However, I was only an Assistant Principal here for one year.  It was nice to meet you and good luck to you!"
- "Thank you for the opportunity to be a part of your research study and for our discussion. I thoroughly enjoyed the experience. I will try to review the transcript as soon as I can. However, we have Open House/Orientation tomorrow and our System-wide Opening/Professional Development Day on Friday. So, Monday may be the earliest response I can get to you. Thank you for your friendly demeanor and for all of your kind words in your email. It was, indeed, a pleasure!"

**Codes**

Following after transcription of the interviews was a process of content analysis. According to Patton (2002), the first part of content analysis is to scrutinize the data and label appropriate units of meaning (Patton, 2002), i.e. assign codes. Sources for labels could be participants, field notes, and literature (Constas, 1992). A code is "most often a word or short phrase that symbolically assigns a summative, salient, essence capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2009, p. 3).

When the researcher decided to use Excel as a data organization tool, and that interview transcripts would be imported from *Word* into Excel as a tab-delineated files, an analytical decision on the 'codable unit' needed to be made. A *codable unit* is a piece of data segment that gets assigned a code. In Word, a tab-delineation would normally come at the end of a speaker's turn. This would go into Excel as a single row (which could be wrapped several times within the row), and constitute a codable unit. This would be practically convenient but would lead to loss of large amounts of meaningful units that could deserve a code each. Tab-delineation could come at the end of each sentence, which would be more work in preparing the transcript but also more refined codable units, and therefore, more codes (Meyer, & Avery, 2009). In this study, the researcher had each line as the codable unit. This size of codable units implies a large number of codes, including repetitions and occasionally, the lack of 'action' to adopt as a code. The researcher used gerunds for coding so as to be able to "detect processes and stick to the data" (Charmaz, 2006, p. 49). As far as possible, gerunds arose from participants' actual verbs, to preserve authenticity and to avoid premature data interpretation.

Regarding general guidelines, the researcher followed counsel from Saldaña (2009): (a) be organized, (b) exercise perseverance, (c) be able to deal with ambiguity, (d) exercise flexibility, (e) be creative, (f) be rigorously ethical, and (g) you need extensive vocabulary. “Quantitative research’s precision rests with numeric accuracy. In qualitative research, our precision rests with our word choices” (Saldaña, 2009, p. 29/30).

A *line* is quite short as a codable unit and codes remain hanging without much meaning. The researcher created a column for ‘issue’ in order to give context to the code, i.e. the first stages of data analysis involved assigning codes to the interviews transcripts on a line by line basis. After each code, an issue was assigned according to the matter the participant was addressing at that part of the transcript. A transcript with codes and issues is in Appendix G. According to Seidman (2013), the researcher knows when enough participants have been interviewed when there is data saturation, i.e. the coding process is not generating new codes. This process was used to analyze the data in this study. Data saturation was achieved with 13 interviews.

**Categories**

Having assigned codes and issues on a line-by-line basis in the interview transcripts (still as Excel files), the researcher sorted each participant’s data by *issue*. All codes on the same issue for all the participants were gathered into a single table for ease of comparing the codes. For example, all codes from all participants where the issue was *duties of a school division CTE director* were collected and made into a single table (see Appendix H. Note that in Excel, text did not have to wrap in a line). The researcher examined the codes to look for regularities, taking into account the purpose of the study and the research questions. Hatch (2002) gave the following hints for searching for uniting threads in the codes:

> Similarity (things happen the same way), difference (they happen in predictably different ways), frequency (they happen often or seldom), sequence (they happen in a common causation (one appears to cause the other) (p. 155).

**Themes**

To identify emerging themes, the researcher used processes of content analysis and constant comparative analysis. The constant comparative method of data analysis involves comparing one segment of data (codes in this study) with another to determine similarities and differences (Creswell, 2013; Merriam, 2009). Thus, codes were grouped together based on similar criteria into categories and then categories were further grouped as themes emerge. "Data analysis … involves moving back and forth between concrete bits of data and abstract concepts, between inductive and deductive reasoning, between description and interpretation" (Merriam, 2009, p. 176). The themes formed become the core of the findings for each research question (Seidman, 2013). Saldaña (2009) calls this form of analysis a 'cyclical' process; i.e. a repetitive process of comparing data to data, data to code, code to code, code to theme, theme to theme, theme back to data. The dual processes of content analysis and constant comparative analysis are inductive processes. Merriam (2009) stated that once the tentative themes had been formed, these would then be 'checked out' with subsequent interviews, which is a deductive process. In some cases, this process led to going back to revise codes in earlier transcripts. Additionally, the researcher paid attention to Merriam's (2009) criteria for generating themes, namely:

- Be responsive to the purpose of the study, i.e. answer the research questions;
- Be sensitizing to the data – it should signal an indication of what the theme is about;
- Be exhaustive – enough themes to encompass all relevant data;
- Mutually exclusive – a relevant unit of data can be placed in only one category; and

- Be conceptually congruent – same level of abstraction (number and quality of codes feeding into the theme. (p. 185-186)

Once again, the advantage of using Excel to organize the transcripts was the ability to keep adding columns to the same table and sort columns according to the needs of the task at hand. This allowed for comparison of codes on each issue and to generate categories. Categories were compared to generate themes. At each stage, coding, categorizing, and determining themes, there was need to keep going to the data to gain clarification on the context in which the participant made a statement. It was because of differences in circumstances in which similar statements could have been made that led to same codes being linked to different categories.

**Community of Practice**

The processes of study design, and of data analysis were both subject to scrutiny by a 'community of practice'. A *community of practice* is a group of, often peers but in general, people you share ideas with on a sustained basis (Rossman & Rallis, 2012). The community of practice critiques each other's work thereby helping the researcher refine the process of analysis, communication of ideas, and adherence to the purpose of the study (Creswell, 2013). For this study, the researcher's community of practice was a three-member School of Education Dissertation Writing Group and Faculty Advisors. In addition to comments on numerous aspects of the drafts, some specific examples of aspects of the study that changed in response to counsel in the community of practice are definitions—towards those that suited the purpose of this study more, and more care in citing internet sources since some links that had been given were not publicly accessible.

## Organizing Matrices

Matrices were used to bring order, structure, and interpretation to raw data. Anfara, Brown, and Mangione (2002) stated that qualitative researchers needed to provide their readers with detailed explanations of how research questions, data sources, development of categories and themes all related to each other; i.e. matrices enhance accountability. In Chapter 4, Results, directions to the matrices will be given wherever the matrices occur.

## Memo Writing

The data analysis process also involved observing the researcher's own processes through 'memo-writing'. *Memo-writing* involves researchers constructing informal analytic notes for purposes of capturing one's own thoughts with regards to comparisons and connections being made across the data, between data and codes, codes and categories, and categories and themes, and refining ideas and insights (Charmaz, 2006). In having the data analysis process go concurrently with the data collection process, the researcher was mindful of Patton's (2002) counsel that being overly concerned with analysis while field work was still going on because naturalistic inquiry requires open mindedness. Memo writing was used in the study. Samples of memos are in Appendix I.

# Pilot Study

A pilot study was conducted to test the interview process (Creswell, 2013; Kim, 2010; Seidman, 2013). The study involved two participants. According to Moore, Lapan and Quartaroli (2012), types of pilot studies include sharing the instrument with colleagues to ensure that questions are worded appropriately and are understood and interpreted as intended, or field testing a research study's instrument on participants. The two participants were selected based on convenience (Creswell, 2013), first with respect to geographic proximity to the researcher.

Second, with respect to how soon they had agreed to be interviewed. In addition, the two participants in the pilot study were former CTE directors who were working in different positions at post secondary institutions at the time of the study. Pilot studies enable the researcher have a feel of the practical aspects of establishing access, making contact, conducting the interview, transcribing, and analyzing the data; while making adjustments where needed for the main study. For example, the process of coding "demands meticulous attention to language and deep reflection on on the emergent patterns and meanings of human experience" (Saldaña, 2009, p.10).

The pilot study allowed the researcher to experience most phases of the study, from making contacts with participants through conducting the interviews, transcribing the interviews, and data analysis. Regarding making contact, the first of the two participants adjusted the letter of request for participation. The most significant change she made was addition of the following paragraph:

> I appreciate your time commitments, and would therefore like to schedule this within the next thirty days at a time and place most convenient for you. I will contact you by phone within the next week to confirm your willingness and availability, and to schedule a time for the interview. If it is more convenient for you, please do not hesitate to respond to this e-mail with a meeting time and venue that best fits your schedule. (Pilot study participant 1, later in this report to have the pseudonym Robin)

The addition above was significant in the following respects: (1) acknowledgement of the time commitment of the potential participants, (2) a time frame within which a response was expected and the follow up action by the researcher, (3) request for a suggested date for the interview. The initial phrasing of the request implied consent to participate then discussion of scheduling thereafter.

With respect to the process of making contact, the initial plan was to communicate by email only. It needed a telephone call for one of the two to secure commitment and scheduling an appointment. For the main study, most of the commiting and scheduling of the interviews was made by phone. Additionally, intital commucation was indicating duration of the interviews to be about an hour. The pilot interviews lasted about 30 minutes each. This duration was reflected in subsequent communication to prospective participants. This was an important alteration because most of the hesitations to participate were based on the time constraint.

Regarding coding, the researcher used gerunds but arising from verbs which were not necessarily those used by participants. To move to focus coding to be able to group codes into categories, the researcher needed to know the contect in which the intial code arose. Without the participants' actual wordrs, the process required going back to the data. This showed the researcher that he was making pre-mature interpretations of the data, and therefore, recoded the transcripts adhering as closely to participants words as possible.

Qualitative data collection is, by design, often progressive whereby a second or subsequent interview in a series can shift the thrust of probing as a result of insights gained from previous interviews (Lincoln & Guba, 1985; van Teijlingen and Hundley (2001). This means that "contamination is less of a concern in qualitative research" (van Teijlingen & Hundley, 2001, p. 3). Therefore, data can be carried forward to the main study, unless the pilot process leads to the redesign of the study procedures, the demographic survey, or the interview protocol. The pilot study did not lead to any changes in either the purpose of the study, or the research questions, or the methods of data collection. Therefore, the data from the pilot study was carried forward to the main study, i.e. the 13 participants in this study include the two from the pilot study.

## Quality and Rigor

A fundamental principle guiding qualitative research is the value for multiple realities constructed by different individuals in their varied circumstances (Erlandson, Harris, Skipper, & Allen, 1993). This premise implies that in addition to methodological soundness (trustworthiness) which all research is judged by, quality and rigor of qualitative research should be judged by respect for multiple realities (authenticity), and respect for the individuals whose experiences are being studied (ethics) (Erlandson, Harris, Skipper, & Allen (1993).

### Trustworthiness

Erlandson et al. (1993) posit that for intellectual inquiry to impact human knowledge, it must "guarantee some measure of credibility about what it has inquired, must communicate in a manner that will enable application by its intended audience, and must enable audience to check on its findings and the inquiry process by which the findings were obtained" (p. 28). These criteria for quality and rigor in qualitative research (demonstrating truth value relative to the participants and context; providing bases for applying results); and allowing for external judgments to be made about the consistency of research procedures, and the neutrality of its findings or decisions; have been termed credibility, transferability, dependability, and confirmability respectively, and collectively constitute *trustworthiness* of qualitative inquiry (Anfara, Brown, & Mangione, 2002; Creswell, 2013; Erlandson et al., 1993; Mertens, 2012; Patton, 2002).

**Credibility.** Patton (2002) stated that judging quality and rigor in qualitative inquiry varied depending upon the research approach, philosophical underpinnings, and purposes of the study. The theoretical framework guiding this study is the social constructionist view on knowledge and learning. Under this theoretical framework, there is no single objective reality. Of interest is the compatibility of the constructed realities with respect to the participants and their contexts (Erlandson et al., 1993). Thus *credibility* is about the degree of confidence in this compatibility. Strategies for attaining credibility include pilot study (Erlandson et al., 1993; Kim, 2010; Moore, Lapan & Quartaroli, 2012; Seidman, 2006); and prolonged engagement in the field, use of peer debriefing, triangulation; member checks, and time sampling (Anfara, Brown, & Mangione, 2002; Creswell, 2013; Erlandson et al., 1993; Mertens, 2012; Patton, 2002). In this study, the researcher used pilot study, triangulation, and community of practice.

***Triangulation*.** Triangulation is usually with reference to multiple sources of data collection. But as was the case in Anfara et al. (2002), triangulation need not be across different modes of data collection—it could be participants. Additionally, "triangulation puts the researcher in a frame of mind to regard his or her own material critically, to test it, to identify its weakness, to identify where to test further by doing something different" (Anfara et al. 2002, p. 33). For this study, triangulation was made as follows: (1) Matrices provide evidence of sources of findings; (2) Demographic and background data were collected using questionnaires; (3) The CTE Directors had approximate numbers of CTE teachers in their school districts, but for numbers of non-CTE teachers, the researcher used data from a website; and (4) Where an issue was not clear from the interviews, such as the dissatisfaction with the way the Virginia Department of Education was dealing with teacher endorsement for teachers of engineering courses, clarification was obtained by email communication.

**Transferability.** Transferability in qualitative research is a quality about the extent to which people in other contexts from the one studied can relate to the research results (Anfara, Brown, & Mangione, 2002; Creswell, 2013; Erlandson et al., 1993; Mertens, 2012; Patton, 2002). This requires the researcher to "describe in great detail the interrelationships and intricacies of the context being studied" (Erlandson et al., 1993, p. 32) because the onus to determine transferability is with those who want to apply the results. Transferability is attained by purposive sampling, and providing 'thick description' (Anfara, Brown, & Mangione, 2002; Creswell, 2013; Erlandson et al., 1993; Mertens, 2012; Patton, 2002).

***Thick description.*** Thick description is about providing all the details readers might need to understand the research results (Erlandson et al., 1993; Mertens, 2012; Merriam, 2009). Erlandson et al., (1993) suggested that while the field, the researcher should "stop to look, listen, smell, and feel the surroundings and interaction" (p. 146) so that when reading the description, one should be able to get a feel for what it is like to actually be in the context. In this study, data analysis has included narratives about each director. The narratives include demographic information and short, multiple quotes (Merriam, 2009). Description of context includes a synopsis of each district with respect to locale, and numbers of CTE and non CTE teachers. Presentation of results has been given in a way that makes linkages among data, codes, categories and themes. Discussion of results will provide interface between demographic information and the emerging themes.

Wolcott (1994) counsels that there is no such thing as "immaculate description" (p. 15). The benchmarks for in descriptive adequacy are purposiveness, and sufficiency; and that a researcher would do well to use critical readers to determine this (Wolcott, 1994). For this study, the community of practice will be the critical readers.

**Dependability.** Dependability is about consistency of the inquiry. This consistency is not in the sense of yielding the same results at different times in different contexts because, in any case, ‘reality’ is not fixed. Consistency is in the sense of ability to track the changes of the processes, decisions, and results (Erlandson et al., 1993). Dependability is attained through an audit trail, triangulation, and peer debriefing (Anfara, Brown, & Mangione, 2002; Creswell, 2013; Erlandson et al., 1993; Mertens, 2012; Patton, 2002).

***Audit trail.*** Audit trail is about giving a detailed account of the methods, procedures, and decision points in carrying out the study (Merriam, 2009). “The key to an audit trail is reporting ‘no’ fact without noting its source and making no assertions without supporting data” (Erlandson et al., 1993, p. 150). For this study, the researcher has provided in the following in the appendices: participant recruitment materials, interview protocol, demographic questionnaire, sample transcript, data analysis matrices, and samples of memos.

**Confirmability.** According to Erlandson et al. (1993), confirmability of qualitative research is scrutinized in terms of the “degree to which its findings are the product of the focus of its inquiry and not the biases of the researcher” (p. 34). Confirmability is also attained through an audit trail, but also through reflexivity (Erlandson et al., 1993).

***Reflexivity.*** A characteristic of qualitative research “is an exquisite sensitivity to personal biography” (Rossman & Rallis, 2012, p.10). “The researcher makes meaning of (interprets) what he learns as he goes along. Data are filtered through the researcher’s unique ways of seeing the world, his lens or world view” (p. 34). The researcher for this study believes that there is great potential for enhancing the learning achievement of all students through integration of CTE and STEM Education practices. An integrative approach to CTE and STEM education is supported by the constructivist view of knowledge and learning that students are not passive recipients of knowledge but active meaning makers. There are opportunities for nurturing a system-wide sustained culture of integrative approach between CTE and STEM education because of support from strategic stakeholders especially mostly federal and state governments, corporate entities, and professional organizations (Coppola, & Malyn-Smith, 2006). There already exist multiple linkages between CTE and STEM education (Stone, 2011b). There are challenges too, such as CTE fatigue as demonstrated by dwindling funding to CTE when overall funding to education has gone up. Changes to within-state Perkins funding formula is affecting teacher education programs in universities (Manley & Price, 2011) when, in fact, teacher education is essential to system-wide sustainable change in educational practice. Integrative teaching can be intimidating because it takes the educator outside the comfort of one's discipline. When the new territory is STEM education, the prospect might appear daunting. Such a position could influence what one sees, reads, hears, and feels in the research process. Conversely, the research experience could alter the researcher's position.

The researcher brought to the data his sense of what was important and worth coding (Seidman, 2013; Wolcott, 1994). Evaluation of what was taken as important depended on the researchers' lived experiences such as the classes taken at Virginia take and before, from reflections on the interviews and on the transcripts, from literature, and field notes. Memo-writing allowed for monitoring of self-perceptions, insights, and reasons for methodological decisions. The memos document and reflect on the data analysis process.

**Authenticity**

According to Erlandson et al. (1993), trustworthiness criteria relate to methodological adequacy of a study, and from the naturalistic paradigm in which multiple realities are constructed by different individuals, judging quality needs to go beyond methodological considerations and pay attention to the experiences of those individuals and their contexts. Authenticity is the researcher's awarding of status to the uniqueness of experiences participants bring to the inquiry process (Anfara, Brown, & Mangione, 2002; Creswell, 2013; Erlandson et al., 1993; Mertens, 2012). Patton (2002) stated that authenticity is about being "reflexive consciousness about one's own perspective, appreciation for the perspectives of others, and fairness in depicting constructions in the values that undergird them" (p. 546). In transcribing the interviews, the researcher documented the mannerisms as well as sudden changes in thought while participants responded to questions. The effect was that the transcripts were not necessarily pretty to read, but were authentic reflections of what transpired. The researcher has provided descriptions that include 'voices' of participants facilitate judging the authenticity of the study.

**Ethics**

Qualitative researchers are interested in constructions of meaning by participants and, therefore, participants must be "honored and protected from negative effects of the research" (Erlandson et al., 1993, p. 132). Thus the researcher should carry out the study in as ethical a manner as possible (Erlandson et al., 1993; Merriam, 2009; Patton, 2002; Rossman & Rallis, 2012). Ethical considerations include participant's understanding of the purpose of the study, voluntary participation, the right to privacy, provision for withdrawing from the study or declining to answer some questions, understanding rights and responsibilities, and protection from harm arising from the study (Merriam, 2009; Rossman & Rallis, 2012). These considerations were taken care of using the informed consent form, and by obtaining approval of Virginia Tech's Institutional Review Board for Research Involving Human Subjects (IRB). The IRB is guided by the ethical principles described in the 'Belmont Report' and in applicable federal regulations (Virginia Polytechnic Institute and State University, 2010). Additionally, the researcher had completed human subjects protection training.

As a practical measure to ensure participants views were documented correctly, interview transcripts were sent back to participants to verify accuracy. Some participants responded, some did not.

## Summary

In this chapter details of the methods used to achieve the purpose of the study have been given. The researcher used a qualitative study design to achieve the research purpose. A combination of extreme deviant sampling and convenience sampling was used to choose participants for the study. Data were mostly collected using face-to-face semi-structured interviews, and analyzed using constant comparative analysis and content analysis. The number of participants in the study was 13. Data were analyzed simultaneously with data collection.. Transcripts were coded and recoded and comparisons made across the transcripts. Coding used gerunds that adhered as closely as possible to the actual verbs used by the participants. Throughout the process, there were comparisons among interview transcripts and codes which led to categories and themes. Themes were the basis of the answers to the research questions. Measures to ensure quality and rigor of the study included triangulation of data sources, member checks, thick description of processes and results, and adhering to research ethics.

# CHAPTER 4 RESULTS

Chapter 4 provides a presentation of the research findings beginning with the purpose of the study, research questions, and a description of participants. The chapter includes a presentation of results for each research question, including the preliminary question to the participants on activities of their offices in a typical week. The chapter ends with a chapter summary.

The purpose of this study was to analyze the experiences of school district directors of Career and Technical Education (CTE) to better understand the linkages between CTE and Science, Technology, Engineering, and Mathematics (STEM) education. The main question the researcher was seeking to answer was as follows: What have been the experiences of local directors of CTE with linkages between CTE programs and STEM education implementation? The study was guided by the following sub questions:

1. How do CTE directors define STEM education?
2. What do directors consider to be the contributions of CTE programs to STEM education implementation?
3. What do directors describe as specific examples of CTE initiatives that have contributed to advancing STEM education at the school/district level?
4. How can the contributions of CTE in the advancement of STEM education be made more visible to and accepted both by CTE and STEM educators?
5. What are school division CTE directors recommendations concerning successful policy/curricula/pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education?

A qualitative study design was used to answer the research questions. Semi-structured interviews were the primary method of data collection. The researcher interviewed 13 participants all from the state of Virginia. Participant information was collected using a "hard copy" questionnaire. The purpose of collecting demographic information was to provide context to the narratives of the participants' experiences with CTE and STEM education

## Demographic Profile of Participants

The researcher obtained information on the following attributes of the participants: gender; age (in terms of the following age ranges, in years: less than 30, 30 to 49, 50 to 54, and 55 or more); race; highest degree attained; number of years of K-12 teaching experience (in terms of the following ranges: less than 4, 4 to 9, 10 to 14, 15 of more); number of years as director of CTE, using the same year-ranges as K-12 teaching experience; school district locale using the classification system of the National Center for Education Statistics which has four major locale categories—city, suburban, town, and rural (Provasnik, 2007); and 'home' curriculum area (defined as the curriculum area in which each participant had the most experience teaching).

The demographic information gathered is presented in three parts as follows: (1) Table 4.1, showing the demographic characteristics of the participants; (2) Synopsis; and (3) Description of the participants.

### Synopsis

Five of the participants were female and eight were male. Twelve of the participants were white and one was African American. The majority of them were in the youngest range of 30 to 49 years. Four were in the age range 50 to 54, and three were in the age range 55 or more years.

Table 4.1

*Demographic Profile of Participants*

| Serial No. | Pseudonym | Gender | Age (Years) | Race | Highest Degree | Experience K-12 (Years) | Years in Post | School District Locale | 'Home' Curriculum Area |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Allison | F | 50 to 54 | White | Master's | 10 to 14 | 4 to 9 | City | Health & Medical Sciences |
| 2 | Andrew | M | 50 to 54 | White | Master's | | Less than 4 | Suburban | Marketing |
| 3 | Bryant | M | 50 to 54 | White | Master's | 4 to 9 | 4 to 9 | Suburban | Technology Education |
| 4 | Cyrus | M | 39 to 49 | White | Education Specialist | 4 to 9 | 4 to 9 | City | Health & PE |
| 5 | Darell | M | 30 to 49 | White | Master's | 4 to 9 | Less than 4 | Rural | Construction |
| 6 | Gregory | M | 30 to 49 | White | Master's | 10 to 14 | Less than 4 | Town | Guidance & Business |
| 7 | Isobel | F | 55 or more | White | Master's | 15 or more | Less than 4 | Rural | English |
| 8 | Lauretta | F | 30 to 49 | White | Master's | 10 to 14 | Less than 4 | Suburban | Business |
| 9 | Layla | F | 50 to 54 | White | Master's | 15 or more | 10 to 14 | Suburban | Marketing |
| 10 | Robin | F | 55 or more | White | Doctorate | 15 or more | 4 to 9 | Suburban | FCS & Business Studies |
| 11 | Russell | M | 30 to 49 | White | Education Specialist | 15 or more | Less than 4 | Town | Government |
| 12 | Stephen | M | 55 or more | White | Master's | 15 or more | 4 to 9 | Town | Electrical Trades |
| 13 | Trevor | M | 30 to 49 | African American | Master's | 10 to 14 | Less than 4 | Rural | Geography |

*Note:* All names in the table are pseudonyms, listed alphabetically. 'Home curriculum area' was defined as a curriculum area in which one's teaching predominantly was.

All directors had attained at least a master’s degree, with two having an education specialist degree, and one having a doctorate degree. The amount of K-12 teaching experience ranges from 4 to 9 years for three of the directors to 15 years or more for five of them. Another five have K-12 teaching experience of 10 to 14 years. With respect to experience as school district directors of CTE, most of them (seven) had been in post for less than four years. Five had been in post for durations of 10 to 14 years, while one had 15 or more years. As for *home* curriculum area (defined as a curriculum area in which one’s teaching predominantly was), nine were from traditional CTE curriculum areas while four were non-CTE. In terms of school district locale descriptors, there was nearly an even spread of participation from each locale type. There were three participants from each of city, town, and rural school districts. Four participants were from suburban districts.

**Description of Participants**

The following is a brief description of each participant. In keeping with the confidentiality commitment to the participants, all the names used are pseudonyms, and they are presented alphabetically.

**Allison.** She was in the 50 to 54 year age bracket. Her K-12 teaching experience was in the range of 10 to 14 years. Her experience as Director of CTE was in the 4 to 9 year bracket, and in a city school district. She holds a master’s degree. Her home curriculum area is health/medical sciences. Her school district has two regular high schools and one CTE school, with a school district faculty of 32 CTE, and 185 non CTE teachers. Allison doubles as Principal of a technical education center, and as school district CTE Director. She takes particular pride in the fact that when industry certification started in her school district in 2007, only 39 certifications were earned by students. In 2013, the number had gone up to 696—a 781% percent growth in certifications.

**Andrew.** He was in the age range of 50 and 54 years. He has a master's degree, and his home curriculum area is marketing. He had been in the present post as Director of the Office of Professional Life Skills (OPOLS) for less than four years. Andrew's school district is suburban and huge in the sense that it has more than 20 high schools. The district has a CTE Coordinator who reports directly to Andrew, the Director OPOLS. Andrew is immediate past CTE Coordinator for the district, a position Lauretta, also a participant in this study, now holds. The researcher interviewed Andrew and Lauretta together.

**Bryant.** He was aged between 50 and 54 years. He had K-12 teaching experience in the range of 4 to 9 years, and has been CTE director in a suburban school district less than four years. He holds a master's degree. His home curriculum area is technology education. The district has three regular high schools and one career academy. Altogether, the district has 50 high school CTE teachers and 290 non CTE teachers. His job title is Director of Career, Technical and Adult Education. He also has ten years of experience working in the woodworking industry prior to coming into teaching.

**Cyrus.** He was aged between 39 and 49 years. He had experience in the range of 4 to 9 years each as a K-12 teacher and as school district Director of CTE. He holds an education specialist degree. His home curriculum areas are health and physical education. The locale classification of his school district is city, with two regular high schools and one CTE school. The three high schools together have 32 CTE teachers and 185 non CTE teachers. His job title is Director of Secondary Instruction, and one of his responsibilities is to direct CTE programs in the district. He did not consider himself to have had much background in CTE until he became director of secondary instruction.

**Darell.** Darell was in the age bracket of 30 to 49 years. He had K-12 level teaching experience in the range of four to nine years and has been director of CTE for a period of less than four years. He holds a master's degree. His home curriculum area is trade and industrial education, specializing in construction. His school district is rural, with one high school. The high school has 29 CTE teachers and 70 non CTE teachers. His job title is Director of CTE. He has been in the military, and has also worked as an electrician. Highlights of his teaching experiences include constructing houses for sale with proceeds going to scholarships for students.

**Gregory.** He was in the age bracket 30 to 49 years. He had K-12 level teaching experience in the range of 10 to 14 years and has been Coordinator of CTE for a period of less than four years. He holds a master's degree and his home curriculum areas are guidance and business. His school district locale is town. The district has three regular high schools and one CTE school with totals of 35 CTE teachers, and 90 non CTE teachers. Gregory doubles as Principal of a Technology Center, and as Coordinator of CTE for the district.

**Isobel.** She was in the age bracket 55 or more years. She had more than 15 years of teaching at the K-12 level. She is in a rural school district with one high school. The school has 20 CTE teachers and 43 non CTE teachers. Her job title is Director of Middle and Secondary Education, and by virtue of that position, she is also responsible for CTE in the district. She has been responsible for CTE for a period less than one year. She holds a master's degree, and her home curriculum area is English. In spite of her non-CTE background and being responsible for CTE programs for less than a year, her knowledge of CTE was extensive.

**Lauretta.** She was in the 30 to 49 year age bracket. Her K-12 teaching experience was in the range of 10 to 14 years. Her experience as Director of CTE is less than four years. She holds a master's degree, and her home curriculum area is business. Her school district is suburban and has 21 regular high schools, three combined schools (7-12), one Governor's Academy, two special schools, and three alternative schools. These schools together have 460 CTE teachers and 2,763 non CTE teachers. Her job title is Coordinator of CTE. She reports directly to Director, OPOLS (Andrew in this study).

**Layla.** She was in the 50 to 54 year age bracket, with 15 or more years of K-12 teaching. Her experience as school district Director of CTE is in the 10 to 14 year bracket. She holds a master's degree and her home curriculum area is marketing. Her school district is suburban. Relative to other districts in Virginia, her district is huge—having 13 regular high schools, one CTE school, one career academy, and one alternative school. Altogether, the district has 238 CTE teachers and 678 non CTE teachers. Her job title is Director of Career and Technical & Adult Education. She is the first generation to graduate from college on both sides of her family. She worked in retail before getting into teaching. She said she was a "worker-bee", and her enthusiasm during the interview bore testimony to that.

**Robin.** She was in the age bracket 55 or more years. She had more than 15 years of teaching at the K-12 level and has been Director of CTE for a period in the range of four to nine years. She holds a doctorate degree. Her home curriculum areas are family and consumer science and business education. Her school district has a locale classification of suburban. The district has five regular secondary schools, and one CTE school. Additionally, the district has 26 CTE teachers and 207 non CTE teachers. Her job title is Coordinator of CTE. Of special significance, she was also Vice President of the Virginia Association of Career and Technical Education Administrators (VACTEA).

**Russell.** She was in the age bracket 30 to 49 years. He had K-12 level teaching experience in the range of 15 years or more and has been Director of CTE for a period of less than four years. He holds an education specialist degree and his home curriculum area is government. His school district is located in a *town*. The district has one high school with 30 CTE teachers and 130 non-CTE teachers. Russell also doubles as a high school campus building administrator and as Supervisor of CTE for the school district. He comes from a "blue-collar" family setting, and he is the first person in his family to graduate from high school.

**Stephen.** He was in the age bracket 55 years or more. He holds a master's degree and his home curriculum area is trade and industrial education, specializing in electrical trades. He had more than 15 years of K-12 teaching experience and falls in the range of 4 to 9 years as CTE Director in a *town* school district. The district has four high schools with totals of 50 CTE teachers, and 300 non CTE teachers. His job title is Supervisor of CTE. He taught agriculture based on his horticulture degree, and taught electrical trades based on an electrician's certificate.

**Trevor.** He is African American in the age bracket 30 to 49 years. He had K-12 level teaching experience in the range of 10 to 14 years and has been Director of CTE for a period of less than four years. He holds a master's degree and his home curriculum area is geography. His school district is rural, with one general high school and one CTE school. Together, the two schools have 14 CTE teachers and 32 non CTE teachers. His job title is Director of Operations and CTE.

The overall impression the researcher got in meeting and talking to each of the participants was that they were a vibrant group of people passionate about their jobs. Without the demographic information obtained from both the interviews and the questionnaires, it would have hardly been possible to distinguish new directors from seasoned directors, and those with CTE home curriculum areas from non-CTE.

**Duties of a School Director of CTE**

As part of the process of understanding experiences Directors of CTE have had with connections between CTE programs and STEM education, the researcher asked participants to describe the duties they performed in a typical week. Examination of the responses showed that the directors have a wide array of duties. As Robin put it, “as-Director of CTE program, I am responsible for all of the CTE areas … which makes the responsibilities very varied in a week (Line numbers of the interview transcript [Ln#] 7-8)”. Expressing similar views, Layla said “on any given day, if there is a situation during school time where something is going on with students or there is an emergency, I am directly involved and all my attention gets re-routed from whatever it was I was going to be doing” (Ln# 22-25). Darell summed up the duties of a Director of CTE as being multifaceted and multi-disciplined. Summary responses of each participant with respect to the duties they performed as directors of CTE in a typical week are displayed in a matrix located in Appendix J.

The responses showed that the overarching duty of local CTE directors was that of overseeing all aspects of CTE programs in their district. A scrutiny of responses revealed further that the duties could be classified in seven broad categories, namely: (1) administration, (2) curriculum and instruction, (3) data and reporting, (4) finances, (5) purchasing, (6) professional development, and (7) outreach. There are some major overlaps across these categories. For example, most of the purchasing and the professional development were linked to the improvement of curriculum and instruction. The reason for categorizing overlapping duties separately was the frequency and emphasis with which these duties arose in participants' responses.

**Administration**

Among the duties associated with administration were attending meetings (Andrew, & Layla), providing schools with discipline support (Allison), hiring staff (Darell, & Stephen), liaising with school administrators (Lauretta, Layla, & Robin), liaising with the Virginia Department of Education (Isobel, & Lauretta), and attending to situations as the moment dictated (Cyrus, & Robin). Robin's summary captures the multiplicity of the nature of her duties when saying:

- Between the teachers, the vendors, the high school, and middle school administrators that need to talk to me about different situations that come or school guidance—I also have to be receptive to parents that call in and sometimes students that call in, as well, our general CTE Advisory Board. So my week from day to day I cannot tell you what I will be doing because it is directed by whatever fire occurs on that particular day (Robin, Ln# 14-19).

With specific reference to the numerous meeting she attended, Layla stated that "I am involved in not only the department of instruction meetings—director meetings, I have a hand in principal meetings as well and the leadership of those principals and their staff. So there's lots of opportunities for meetings at this level" (Ln# 13-16). Meetings were not described as a favorite part of the participants' jobs. To hear positive comments about meetings was unique.

**Curriculum and Instruction**

Duties relative to curriculum and instruction included initiating programs (Gregory), attending to teachers' needs (Darell, Gregory, & Robin), facilitating conduct of approved testing, licensure and credentialing (Allison, Bryant, Russell, & Trevor), insuring that the curriculum meets state standards (Bryant, Isobel, Russell, & Stephen); insuring that resources and materials in the classroom are adequate to teach the curriculum (Bryant, Cyrus, Robin, Russell, & Trevor), mentoring teachers (Gregory, & Russell), providing instruction support to teachers (Allison, Bryant, Layla, Trevor, & Stephen), and managing implementation of STEM education (Lauretta). The following statement shows typical curriculum and instruction related duties of a local CTE director:

- We oversee the curriculum in each of the career and technical education programs. That also includes making sure that we have equipment and the equipment is running for all of our programs. Making sure that there are books, making sure there is staff development, we are complying with what has to be done in Virginia. We need to make sure that our competencies are being taken care of (Bryant, Ln# 7-12).

The aspect of making sure competencies are being taken care of is of interest because it underscores the need for teachers to go beyond having a curriculum, teaching resources, and teacher-knowledge to converting these ‘teaching ingredients' into student learning.

**Data and Reporting**

Data and reporting related duties included gathering, maintaining, and reporting data (Russell); preparing state and federal reports (Bryant, Darell, Gregory, & Russell); and reading reports (Russell).

- We deal with state reports. We have several reports during the year. So pretty much weekly, we are working—compiling some data to make sure that we are getting reports ready (Russell, Ln# 23-25).
- I have reports to read (Bryant, Ln# 18).

- A lot of record keeping. A lot of reports for Virginia Department of Ed., and that is extensive. We are constantly looking at the reports that we have to file—with what's called the master record collection which looks at the numbers of teachers, their endorsements, numbers of classes and students and then which of those are in the CTE program and making sure that those match (Isobel, Ln# 9-13).

The sample of responses above represent a wide range of report related activities including data collection, report preparation, and an aspect easily underplayed, reading incoming reports. Additionally, CTE directors are responsible for interpreting all of the information provided on various reports and compiling into a master collection record.

**Finances**

Responses concerning financial duties included developing budgets (Isobel, Lauretta, & Stephen), managing Perkins federal grants (Cyrus, & Gregory), managing local funds (Cyrus, Gregory, & Layla), and ensuring accountable use of funds (Isobel, & Layla). Cyrus gave an extensive response concerning funds. He said:

- I would say my influence in terms of CTE is to provide the resources necessary for our CTE staff, and primarily I oversee the Perkins grant, which provides funding to our CTE programs and our state equipment grant and then any local funding that we provide for CTE. So, the majority of my time, in terms of CTE, is spent just managing that grant, purchasing necessary equipment. If teachers have requests above and beyond what the Perkins grant or the state equipment grant will pay for, then I go to the school board and request local funds to provide funding for those projects (Cyrus, Ln# 6-12).

**Purchasing**

Purchasing related duties included purchasing, planning, and executing purchases (Stephen); dealing with vendors (Robin); making purchasing decisions (Darell); and purchasing necessary equipment (Bryant, Cyrus, Layla, Robin, & Russell). Some specific statements regarding purchasing are as follows:

- [Having the success of students in mind,]give teachers the facilities, the resources, the things that they need to make those students succeed (Darell, Ln# 17-18).
- I am always having to make sure that the resources and the materials in the classroom are adequate to teach the curriculum that we have (Robin, Ln# 13-14).
- If teachers have requests above and beyond what the Perkins grant or the state equipment grant will to pay for, then I go to the school board and request local funds to provide funding for those projects (Cyrus, Ln# 9-16).
- We are making sure that we have equipment and the equipment is running for all of our programs (Bryant, Ln# 9).
- We are getting all the equipment repaired, so that when the teachers come back in the Fall, we'll have everything tip-top because there is heavy use when you are in our middle and high school programs—all of that done in advance so that is teachers have what they need in hand (Layla, Ln# 49-54).
- I spend a lot of time with budgeting, with planning for those purchases. and executing those things (Stephen, Ln# 8-10).
- Teaching on today's state of the art, cutting edge technology—what is really being used in industry. There's no bargain. There's no lesser version because you don't want to teach

your kids on something that they're not going to see anymore because industry doesn't have it (Andrew, Ln# 287-290).

- So, in a typical week, we'd be … looking at possibly new technologies that are coming down in each of the different areas to make sure we are up to date (Bryant, Ln# 13-17).

It is evident from the comments made by participants, that purchasing is not just some routine task. It is multi-faceted, and includes knowing the needs, budgeting, planning, sourcing the funds, negotiating with vendors, follow-ups that the equipment is working, and keeping an eye on trends in industry with the view to keeping current.

**Professional Development**

Professional development related duties included the following: planning and executing professional development and training (Stephen); providing professional development support (Darell); providing training opportunities for teachers at the local, regional, and state levels (Bryant, Cyrus, Russell); providing information on conferences (Cyrus); and making sure teachers are aware of professional development activities (Isobel).

Some of the salient aspects of professional development the researcher identified were the following:

- The onus to improve on practice lies with the teacher: It is my duty to provide training opportunities to teachers, information on conferences, and local, regional, state professional development opportunities (Cyrus, Ln# 16-18).
- Professional development was a regular feature in a district: "So, in a typical week we may be running a staff development …" (Bryant, Ln# 14).
- Professional development, if interpreted to mean taking measures to become a more effective teacher, can take many forms: "I spend time with hiring new teachers and

*mentoring* new teachers (Stephen, Ln# 11); Making sure that I am in the classroom, they [teachers] are engaging students in the activities. With the CTE world, we don't want to walk into a classroom too often and see kids sitting in seats learning out of a book (Russell, Ln# 38-43).

The excerpt of the interview that follows captures well the essence of professional development:

*Researcher*: If it was all within your control, where would you place your priorities [considering the numerous duties stated earlier], your energies in a week?

*Lauretta*: If it was within my control? I think activities that directly impact student learning and student achievement. And by achievement I don't necessarily mean, you know, 'A's or 'B's in class, but the student learning environment. Making sure that we are able to provide the professional development to teachers so that they can do the turn-around training and make a difference in what students are learning in the classroom (Lauretta, Ln# 29-33).

Two things stand out from Laurretta's statement above. Professional development is only as useful as it translates into quality of student learning. This statement was in response to what the priority for her office was, and it was professional development.

**Outreach**

Duties related to outreach included the following: being involved within the community (Allison; Layla; & Stephen), marketing CTE programs and activities (Layla; Russell; & Trevor), promoting school/business/education partnerships (Isobel; Layla; Stephen), looking after CTE in other programs (Allison), and serving on committees (Allison; & Robin). Outreach is discussed further under the measures needed to make the contributions of CTE programs to STEM education implementation visible.

It is evident that school district CTE directors have a large diversity of responsibilities. However, in the diversity, the researcher found the constant theme of linking activities to the teacher and students. The importance of supporting the work of teachers was emphasized in a variety of ways.

## Definition of STEM Education

Participants were asked to provide their definitions of STEM education. Codes were assigned in each transcript on a line-by-line basis. Where the participant was addressing the issue of definition, the corresponding code was assigned ‘definition’ as the issue. All codes with the issue *definition* were compiled into a single table. A comparison of the codes allowed the researcher to form categories, which in turn formed a basis for identifying themes. This process required constantly going back to the data to understand the context in which a participant made a statement. The following four themes were identified as related to the definition of STEM education: (1) application, (2) integration, (3) problem solving, and (4) technology/engineering content and processes. A comprehensive table showing participants, codes, categories and themes relating to the definition of STEM education is in Appendix K. Each of the four themes served as a basis for four different definitions.

Examination of the responses led the researcher to determine the existence of some overlaps among the definitions. For example, application and problem solving are related processes. Furthermore, a participant’s response could be identified with more than one category. Such situations arose mostly from participants elaborating on their responses. In addition, parts of the definitions provided by the participants related to existing definitions found in the literature. The four definitions are given next, followed by the basis for their construction as related to each theme.

Definition 1: STEM education is the teaching of science, technology, engineering, and mathematics (STEM) and *applying* concepts to work contexts.

Definition 2: STEM education is *integrated* teaching of the STEM disciplines.

Definition 3: STEM education is the use of interdisciplinary/integrative concepts of the STEM disciplines to *problem solving.*

Definition 4: STEM education is using the application of *technology/engineering-based content and processes* to teach science and mathematics.

**Definition 1: Teaching of STEM Disciplines and Applying to Work Context**

The first definition resulting from the data analysis was that STEM education is the teaching of science, technology, engineering, and mathematics (STEM) and applying concepts to work contexts. The theme which gave rise to this definition was *application*. Categories relating to the theme and ultimately the definition included: (1) application work context, (2) applying STEM disciplines, and (3) learning in context. Table 4.2 provides the codes and categories related to the first theme and definition.

Examples of participant comments related to this theme and the first definition are as follows:

- STEM education includes more than just what you might consider your typical STEM programs … you can include business, you can include automotive, you can include welding (Darell, Ln# 34-36).

Table 4.2

*Application Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Using STEM disciplines in career fields<br>Learning how to do wiring<br>Becoming part of every occupation<br>Using math, science and engineering<br>Looking to do<br>Being one and the same [CTE and STEM education]<br>Wiring a circuit | Application to work context | Application |
| Applying to individual programs<br>Developing a STEM program | Applying STEM disciplines | |
| Showing STEM connections in all CTE<br>Involving CTE<br>Needing 100% [for correct wiring]<br>Infusing into the program | Learning in context | |

*Note:* The full meaning of some codes is better appreciated in the context of the data.

- STEM education basically is any program that has science, technology, engineering or mathematics infused into it. You can have a business program, and it's going to be STEM if it emphasizes engineering, math, or technology in it (Trevor, Ln# 26-30).
- All those different STEM areas are covered in each of our content areas in different ways where the students actually have hands-on experience using those concepts that they might learn in a math class and applying it into one of our programs" (Robin, Ln# 27-29).
- I would say STEM education would be any education that deals with expanding students' understanding and knowledge of the use of science, technology, engineering, and mathematics in the career fields. So, I would say STEM education can be anything from

advanced science courses at a high school, to engineering and technology courses at a high school, (and) advanced mathematics courses" (Cyrus, Ln#.30-34).

- You can't learn engineering but not math, because when you go to wire that circuit, that circuit is not going to work. So, unlike in English class where we are happy if someone gets 80 per cent of the material and can pass a test with 80 per cent, you can't pass 80 per cent on wiring a circuit. You've got to be a 100 per cent because it's not going to work" (Russell, Ln# 65-69).

The responses relating to the first theme and definition focused on applying science, technology, and mathematics theories and concepts to authentic work contexts. Participants believed that by applying these concepts to authentic contexts would assist students in understanding them at higher levels of cognitive and affective learning. They also stated that there is a direct link between STEM education and CTE because CTE program curricula relates to specific career-related areas and incorporates a wide variety of hands-on student engaged methodology.

**Definition 2: Integrated Teaching of STEM Disciplines**

The second definition resulting from the data analysis was that STEM education is integrated teaching of the STEM disciplines. The theme giving rise to this definition was *integration*. There was one category relating to this theme, that being 'integrating disciplines'. Table 4.3 provides the codes and category related to the second theme and definition. As seen in this table some of the codes used 'integration' in the code statement, while others described the integration process without using 'integration'.

Table 4.3

*Integration Theme: Codes and Categories*

| Code | Category | Theme |
|---|---|---|
| Doing STEM in every curriculum | Integrating disciplines | Integration |
| Integrating STEM | | |
| Being able to connect entities | | |
| Having it as integrated STEM education | | |
| Intermingling of subjects | | |
| Seeing it as an integration of STEM disciplines | | |
| Being bigger than people think | | |
| Having no silos | | |
| Involving STEM disciplines | | |
| Building integrations | | |
| Infusing with STEM | | |
| Integrating STEM into any curriculum | | |
| Triggering students | | |
| Being an integral part of it | | |
| Expanding students' understanding | | |

Examples of participant comments related to this theme and the second definition are as follows:

- We know we have some really neat programs going in science, or in math, or in engineering, or in technology in our different (CTE) programs. What we don't have is a formalized integration of those programs (Andrew, Ln# 42-45).
- We really want to break down the silos of science and mathematics or CTE, and we have *really* done a lot with cross collaboration (Layla, Ln# 128-129).
- I like to have it as integrated STEM education. I take STEM education as science, technology, engineering and math. And I don't see those as individual letters. I see those

as working all together for a common practice, and for our students to have an understanding that science isn't just science education. There is a connection to math, there is a connection to technology and there is a connection to engineering with that. … That's kind of how I see it. I see it more as an interdisciplinary program of these (Bryant, Ln# 28-36).

- STEM education was bigger than its constituent disciplines cited. For example, health sciences is an integral part of STEM education  (Gregory, Ln# 11).
- STEM education is integrating those areas of science, technology, engineering, and mathematics into virtually any curriculum (Allison, Ln# 25-26).

A uniting feature of the responses relating to definition two was that STEM education goes beyond disciplinary silos towards curriculum integration. This integration can and should take place in every curriculum in the school, not just those that have a connection to engineering. It is a mechanism that connects entities or in other words 'intermingles subjects'. This integration will help to expand students' understanding of the STEM disciplines, as well.

**Definition 3: Using Interdisciplinary/Integrated Concepts of STEM to Problem Solving**

The third definition resulting from the data was that STEM education is the application of interdisciplinary concepts of the STEM disciplines to problem solving. The theme which gave rise to this definition was *problem solving*. There were two categories relating to the theme and ultimately the definition. The two categories were: (1) applying to problem solving, and (2) integrating disciplines. Table 4.4 provides the codes and categories related to the third theme and definition.

Table 4.4

*Problem Solving Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Integrating STEM in a project-based curriculum<br>Integrating program areas<br>Doing STEM in every curriculum<br>Weaving STEM together | Integrating disciplines | Problem Solving |
| Pulling together STEM to solve a problem<br>Ensuring students solve real life problems<br>Living-learning process<br>Integrating STEM in a project-based [problem solving] curriculum<br>Working together for common practice [problem solving] | Applying to problem solving | |

Note: Words inserted in brackets indicate the reference of the statement in relation to the context of participants' statements earlier and/or later in the interview.

Examples of participant comments related to this theme and the third definition are as follows:

- STEM education is integrating those areas of science, technology, engineering, and mathematics into virtually any curriculum. ... You don't realize how much science, technology, engineering, and math are involved in auto technology, in building trades, in culinary arts, as well as in our pre-engineering programs (Allison, Ln# 25-29).
- STEM education is advanced math, advanced science, engineering, technology; and ultimately STEM would be a way to kind of weave those together to help students understand how they work together to provide career opportunities for students in those fields (Ln# 37-39).

- The integration of science, technology, engineering, the arts, and mathematics. We like to consider it STEAM … and making sure that students have the ability to solve real world problems across curricula areas, and not in silos (Ln# 37-40).
- I see STEM as encompassing an issue or a problem and then pulling together these other areas of science and technology and engineering and math to solve the problem (Isobel, Ln#38-42).

Responses relating to Definition 3 all have a focus, not only on integration across the STEM disciplines, but also application to problem solving. Participants felt that problem solving was a skill that every person needs to be successful in life. Because STEM disciplines rely heavily on the scientific approach for investigating phenomena and solving problems, STEM education is in a unique position to focus on this approach to real life personal and work-related problems.

**Definition 4: Applying Technology/Engineering-based Content and Processes**

The fourth definition that emerged from the data analysis was that STEM education is using the application of *technology/engineering-based content and processes* to teach science and mathematics. The theme which gave rise to this definition was *technology/engineering-based content and processes*. The only category relating to the theme and ultimately the definition 'using technology/engineering to teach science and math'. Table 4.5 provides the codes and the category for the fourth theme and definition.

Table 4.5

*Technological/Engineering-based Content and Processes Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Understanding connections to M,T,&E<br>Incorporating [technology and engineering] to learn sciences [to learn science and math]<br>Emphasizing engineering<br>[Technology and engineering] being the linchpin between science and math<br>Integrating between academic and technical areas [in engineering] | Using technology/engineering to teach science and math | Technology/engineering-based content and processes |

Note: Words inserted in brackets indicate the reference of the statement in relation to the context of participants' statements earlier and/or later in the interview.

Examples of participant comments related to this theme and the fourth definition are as follows:

- I think that sometimes when we look at pure academics, we don't include the technology and engineering to that. I really see technology and engineering bringing them [science and math] all together. And I think that's why we [CTE] are part of it [teaching science and math] (Bryant, Ln# 56-61).
- I believe that the most critical part of defining STEM is defining it as a true integration between academic and technical skill sets, and I think that the whole intent of STEM education, in my mind, is to facilitate and build those integrations that allow students to learn the theoretical science and math skills in a technical settings (Stephen, Ln# 192-200).
- I know some states are working at STEM curriculums. They are really focusing on math and science... We don't need to take our curriculums and put it into their curriculums. We

need to blend the curriculums [to teach science and math concepts] (Andrew, Ln# 170-175).

The category and the theme leading to Definition 4 incorporate integration and application as have the other three definitions. However, the researcher deemed this to be a stand-alone definition because a close examination of the codes shows a specific focus on the use of technology and engineering content and processes. That is, while the other three definitions are about gaining knowledge from integration, problem solving, or application; this definition goes a step further to place technology/engineering content and processes at the center of STEM education integrative efforts in science and mathematics.

## Contributions of CTE to STEM Education Implementation

The second research question was related to CTE Directors' perceptions on contributions made by CTE to assist in STEM education implementation. The same process used to analyze responses to question one were used with the responses to the second question; that being, coding each response according to issues, sorting the codes into categories based on similarity of meaning or having a common referent, and comparing categories to determine themes. For question two, this process yielded four themes. With this particular question, each theme ended up representing a contribution made by CTE to assist in STEM education implementation. The four themes/contributions are: (1) context for learning, (2) multiple pathways; (3) platform for program delivery, and (4) administrative leadership and framework. A comprehensive table showing codes, categories and themes relating to CTE's contributions to STEM education implementation is presented in Appendix L. A detailed description of the findings regarding each of the themes/contributions and the basis for their construction is provided next.

**Provides Context for Learning**

A commonality of participants' responses relating to contributions of CTE to STEM implementation was the provision of a *context for learning* STEM disciplines. Categories relating to this theme/contribution included: (1) motivation to learn, (2) pedagogy, (3) program development, (4) program management, and (5) program organization. Table 4.6 presents the codes and categories for the theme/contribution of *context for learning*.

Table 4.6

*Context for Learning Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Having higher enrolments<br>Seeing where to use STEM<br>Having interest in<br>Being interested | Motivation for learning | Context for Learning |
| Bringing project-based learning<br>Manipulating things<br>Collaborating between theory and practice<br>Having hands-on experience<br>Concentrating more on some skills<br>Getting your hands dirty | Pedagogy | |
| Piloting sustainable technology<br>Having benefits for STEM education<br>Being the heart of STEM<br>Taking computer and digital animation class | Program development | |
| Calling it the center for STEM education<br>Leading effort has been CTE<br>Looking at programming | Program management | |

Examples of participant comments related to this theme/contribution are as follows:

- The integration of a lot of ‘manipulatives’ and ‘relevancing’ into methods of teaching has helped students gain a broader understanding of things. Too many times we hear ‘when am I ever going to use this math'? And, in STEM you can start seeing that and seeing when it can be used (Bryant, Ln# 84-86).
- Using CTE classes where we apply and say, ‘this is why you need to learn math, this why you need to learn science material. … We get to show them why. Some of the core classes don’t get to show them why. We get to show them why all the time (Andrew Ln# 159-163).
- Living—learning process. It’s not something that you say, ‘we are going to address the math part today, we going to address the engineering part of electricity today’. It’s all incorporated in every lesson (Russell, Ln# 70-73).
- They are applying all that knowledge. And, I think that’s what makes CTE a catalyst for STEM because we are the application. Now what’s happening is they’re going science and they are going to math and say you guys gotta apply your subjects. You’ve got to get these kids to show them why, how they’re really use [the knowledge] in the world. We’ve been doing that for years (Andrew, Ln# 376-380).
- I think that integration of those skill sets into a technical subject area in which a kid is interested is the true strength of a good STEM program (Stephen, Ln# 198-200).

When examining the responses, it was determined that CTE administrators believed CTE provided opportunities for learning how STEM education theories and concepts are used in the real world. CTE provides a 'context' for learning science, technology, and mathematics. It also provides hands-on experiences for students through project-based learning. It can demonstrate collaboration between theory and practice. In addition, CTE provides an avenue for science and mathematics teachers to work with teachers of applied disciplines.  It provides a means for motivating students to learn science and math.

**Provides Multiple Pathways**

A second commonality of participant responses relating to contributions of CTE to STEM education implementation was the provision of *multiple pathways*. Supporting this theme were two categories, occupational and/or career diversity, and opening opportunities. Table 4.7 presents the codes and categories for the theme of *multiple pathways*.

Table 4.7

*Multiple Pathways Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Having many more skills<br>Seeing STEM identified in some business areas<br>Giving kids multiple pathways<br>Having multiple program offerings<br>Being a master brick layer<br>Having 21st century skills<br>Making students marketable<br>Teaching math for advanced manufacturing jobs<br>Applying to career path | Occupational and/or career diversity | Multiple pathways |
| Being about marketing to kids<br>Talking with students and parents [about opportunities<br>Having best opportunities for life<br>Making 25 dollars an hour<br>Thinking about opportunities | Opening opportunities | |

Examples of participant responses related to this theme/contribution are as follows:

- When we go to our technology education association meetings, there are still people that say I want to do my wood shop, and I'm not going to do anything else. But really, that's not opening students' eyes and really giving them an opportunity to really go as far as they can. I think that's where we need to be looking—how can we give a student an opportunity to really grow and go further than we did? And, if we don't change the way we do things, if we just change a name, we don't change the way we're doing things, we are still limiting our students (Bryant, Ln# 245-252).
- I think about again, what we are giving kids that can take them into multiple pathways because life happens. Like in many of our situations, everyone has a story, and I'm always thinking about how we are going to arm and equip our students to have the best possible opportunities and experiences for life (Layla, Ln# 404-407).
- Although we are in rural America here, a lot of these kids here want to take the high tech classes. They want to take the graphic design, gaming and stuff like that, but we just don't have the resources. … So we are doing the best to accommodate them [of the pathways that are available within the classes we do have] (Trevor, Ln# 125-133).
- Our biggest push is to kind of blend agriculture out of CTE with the mathematics and the science and the technology and the engineering within that field [to show different pathways they can follow] (Isobel, Ln# 105-107).

In Virginia, CTE programs are in a unique position to show students how gaining knowledge and skills associated with the STEM disciplines can be used throughout the nationally-accepted 16 career pathways. Not only can it give a 'context for learning', but also provide a 'diverse context' of how these disciplines are used in a wide variety of occupational areas within the 16 pathways. CTE and STEM education, together, can help students become aware of the many opportunities that are available for them. Furthermore, this collaboration can be used for devising a common and unique approach for reaching out to students and parents.

**Platform for Program Delivery**

The third theme coming from the data regarding the contributions of CTE to STEM education implementation was that CTE providing a platform for delivery of STEM education. In essence, however, responses to this theme revealed evidence of reciprocal contributions. Two categories emerged that are associated with *platform for program delivery.* These categories included: (1) boosting image, and (2) program management. Table 4.8 presents the codes and categories for the theme of *platform for program delivery*.

Table 4.8

*Platform for Delivery Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Making CTE valuable to schools<br>Bolstering programs<br>Beginning to change<br>Being [CTE] different now<br>Bringing STEM to where it should be<br>Improving STEM through CTE | Boosting image | Platform for delivery |
| Running through CTE<br>Being under the umbrella of CTE<br>Having two health sciences academies<br>Having two STEM academies<br>Opening health sciences academies<br>Opening STEM academy | Program management | |

Examples of participants' comments are follows:

- I believe CTE is STEM and I think that the difficulty has been making the public aware and the Boards aware that everything we teach in the CTE areas and the STEM area, and when people are concerned about offering more STEM, what we really need to be talking about is the integration of the CTE programs, the math and science programs, and that becomes stronger STEM programs or CTE programs—I think the terms are largely interchangeable, and I don't think a lot of people understand that or possibly agree with that (Stephen, Ln# 51-57).
- We know that STEM stands for science, technology, engineering, and mathematics. The exciting thing about CTE is that all of those areas have been part of our program forever—long before STEM became the popular educational phrase of the day (Robin, Ln# 24-26).
- We are very, very conscious and very excited about what we can do to improve STEM through CTE through applying for, implementation, and management of the academies [Virginia Governor's STEM academies] through CTE administrative structures (Robin, Ln# 62-63).
- CTE programs are the synthesis for STEM education, and my academic colleagues recognize that. They recognize that without a CTE program, we don't have the core of any STEM program. So they [CTE programs] have served as the core of STEM efforts in this county (Stephen, Ln# 60-63).
- This distinction of being a Governor's STEM academy, and we are going to run it through the CTE programs in your counties. To me that is significant (Andrew Ln# 215-217).

The participants believed that the emergence of STEM education has been instrumental in bolstering CTE programs and making it more valuable to schools. STEM education has contributed to improving the image of CTE.  CTE is being viewed differently now because of its association with STEM education. On the other hand, the participants felt that CTE has had a major impact on improving STEM education and an awareness from both educators and the general public concerning the concept of STEM education. When perusing the literature one can see a misunderstanding of this concept. CTE has been able to bridge the gap for many people concerning how STEM education can be implemented in schools. It gives concrete examples of how STEM is an integrative process. The participants also stated that CTE gives STEM a 'platform' from which to develop and implement programs. An example of this platform is the emergence of Governor's  STEM academies. In Virginia, these academies are designed to expand options for the general student population to acquire STEM literacy and other skills necessary for high-demand, high-wage, and high-skill careers (Virginia Department of Education, 2012). Among the participants in this study (Bryant, Darell, Isobel, Lauretta - 2 in her district, Layla, Robin, and Stephen), there are eight Governor's STEM academies that are housed in the administrative units of CTE. They are implemented and administered by the participants of the study and there are direct linkages between  CTE and STEM education. :

**Administrative Leadership and Framework**

The fourth theme with respect to CTE and STEM education linkages was *administrative leadership and framework.* Three categories emerged to support this theme. They were (1) administrative guidance; (2) departmental/classroom/program organization, development, structure, and management; and (3) funding mechanism. Table 4.9 presents the codes and categories for the theme of *administrative leadership and framework.*

Table 4.9

*Administrative Leadership and Framework Theme: Codes and Categories*

| Code | Category | Theme |
|---|---|---|
| Looking top CTE<br>Being about careful stewardship<br>Falling under CTE<br>Involving government agencies<br>Leading the effort | Administrative guidance | Administrative leadership and framework |
| Putting them in a STEM department<br>Being a CTE teacher [if you are a STEM teacher]<br>Going for final approval<br>Being a STEM teacher<br>Having industry experts<br>Having local advisory committees<br>Having industry standards<br>Being students who complete a sequential elective<br>Being receptive to partnership | Departmental/classroom/program organization, structure, and management | |
| Doing the grants<br>Funding [from the state]<br>Stating how STEM benefits from CTE's funding<br>Tying [about 40%] to STEM education<br>Having grant dollars | Funding mechanism | |

The follow are examples of participant comments related to the theme:

- One of the things that we have been working on in our division is professional development for teachers. And, the core areas are looking to CTE on how to do a lot of the real world application piece of it because that's what we have always done. We are starting to become leaders in that area because we're the experts and I think that's something that’s now beginning to change people’s perception of what we are doing in our classes (Lauretta, Ln# 92-99).

- They [teachers] need to be prodded [to integrate STEM]. However, when we look at the entire curriculum, our CTE teachers are much more likely to look at integration than our traditional core [teachers] … They tend to be very departmentalized” (Isobel, Ln# 116-118) They tend to be very departmentalized (Isobel, Ln# 116-118).
- Teachers need to be led in that direction [integrative teaching]. Some programs and/or with some teachers it’s a natural integration. I mean, it’s intuitive, it’s accepted that STEM is a large part of what their program is about (Stephen, Ln# 91-93).
- We have been the driving force behind developing and doing all the program writing to [receive Perkins money] apply [for academies] (Layla, Ln# 113-114).
- This distinction of being a Governor’s STEM academy, and we going to run it through the CTE programs in your counties. To me that is significant (Andrew Ln# 215-217).
- Success with obtaining funds was based on careful stewardship of managing those public funds to do the greater good and to move our programs and to keep industry-current (Layla, Ln# 235-237).
- I think one of the exciting connections we have is that we can make our programs 'dual enrollment' with the local community college (Robin, Ln# 70-71).
- CTE directors are also the ones who lead the way to overcome in-school hurdles in order to foster integrative efforts required for STEM education. The hurdles include scheduling and siloing of program areas. The school needs to take responsibility for breaking those barriers down and the division needs to take responsibility for assisting with the integration of curricula (Stephen, Ln# 203-206).

- So I think we’re trying to run this gauntlet—that is STEM (Allison, Ln# 56) and ...that’s really the beauty of my job, it’s because there are lots of different opportunities to stretch my skill-sets (Layla, Ln# 64-65).

Upon analyzing the data, it was determined the participants believe that CTE could provide STEM education much needed administrative leadership and structure. They stated that the concept of STEM education was nebulous (which is also found in the literature) and needed guidance in developing an administrative framework and to administer its implementation. They described that placing STEM education administratively with CTE could greatly assist in STEM departmental, program, and classroom organization. This organization could serve as a mechanism for structure and management. It could serve as a catalyst for developing departmental, program, and classroom partnerships.

In addition, the participants stated that CTE partnerships with industry experts already exist through the use of consultants and advisory committees and could be used to advance efforts and ideas for STEM education. These partnerships could also provide opportunities for private funding sources. CTE administrators are also in charge of administering resources from the Perkins Act (a federal funding source), which has provisions for supporting STEM-related programs and activities. Furthermore, one of their duties is to write grants for funding and their expertise would be a valuable asset for advancing STEM education, since there are a variety of funding sources for STEM. Finally, because of CTE's support from the community, it could be of great assistance for outreach efforts.

**Specific Examples of CTE Initiatives Contributing to Advancing STEM Education**

Research question number three related to identifying specific examples of CTE initiatives that have contributed to advancing STEM education at the school/district levels. Due to the nature of this question, the data was analyzed differently than data collected to answer the other research questions. It was not necessary to utilize codes and categories to identify themes. They were determined by grouping similar examples together. Specific examples of CTE initiatives that have contributed to advancing STEM education, by theme, are in Table 4.10.

Examples of participant responses related to CTE initiatives are as follows:

- That [First Lego League] has been excellent. The kids have enjoyed the robotics, they have competed, they have done a number of activities (Robin, Ln# 89-91).
- We have brought in math and career and technical teachers to work together to come up with integrated subjects—integrated activities [by participating in the Math-in-CTE model]. And I think that really has helped get more people involved and to have that understanding of STEM. (Bryant, Ln# 95-98).
- I think it’s [involvement in Project Lead the Way] a very obvious STEM effort (Stephen, Ln# 109-112).
- We are very, very conscious and very excited about what we can do to improve STEM through CTE through applying for, implementation, and management of the academies [Virginia Governor's STEM academies] through CTE administrative structures (Robin, Ln# 62-63).
- The teacher in that program [Building Construction] talks a lot to kids about geometry, about math, about science, about the science piece of the universal design, and the sustainable technologies as well as the math piece of all the cutting and the measuring that they do within the house. The last house sold for 815,000 dollars (Lauretta, Ln# 133-137).

Table 4.10

*Specific Examples of CTE Initiatives That Have Contributed to Advanced STEM Education by Themes*

| **Specific Program/ Initiative Examples** | **Descriptions** | **Theme** |
|---|---|---|
| First Lego League | A robotics program for 9 to 14 year olds being used to introduce engineering in the middle school. | Special Programs |
| Math-in-CTE-based programs | A researched-based Math-in-CTE curriculum integration professional development model. The model is designed to utilize new pedagogy involving collaborative teaching between math and CTE teachers to enhance math instruction in different occupational contexts to influence student learning of math concepts performance on standardized tests of mathematics. (National Center for Research in Career and Technical Education, 2013) | |
| Project Lead the Way | Project Lead The Way (PLTW) is the nation's leading provider of STEM programs. PLTW's world-class, activity-, project-, and problem-based curriculum and high-quality teacher professional development model, combined with an engaged network of educators and corporate partners, helps students develop the skills needed to succeed in our global economy. (Project Lead the Way, 2013) | |
| Virginia Governor's STEM Academy | Governor's STEM Academies are programs designed to expand options for the general student population to acquire STEM (Science, Technology, Engineering and Mathematics) literacy and other critical skills, knowledge and credentials that will prepare them for high-demand, high-wage, and high-skill careers in Virginia. Each academy is a partnership among school divisions, postsecondary, institutions and business and industry. (Virginia Department of Education, 2012) | Institutions |

| Specific Program/ Initiative Examples | Descriptions | Theme |
|---|---|---|
| Construction Program | A Trade and Industrial program that builds real houses for sale to the local community | Programs |
| Pre-engineering Program | A Technology Education program that includes a three-year sequence of courses comprising of engineering exploration, engineering application, and engineering analysis | |
| School-Higher Education Partnership (Middle School Agriculture and Technology | A program that involves partnerships between local school districts and higher education institutions for the purpose of preparing students to understand STEM areas | Partnerships |
| Partnerships (School-Higher Education-Business/Industry) | A project that involves partnerships with a community colleges and local school districts for the purpose of incorporating STEM into high schools | |
| Industrial Math | A course that teaches calculus and trigonometry needed to go into these advanced manufacturing jobs | Courses |
| Sustainable and Renewable Technologies | A course that enables students to address issues affecting the health of the environment and explore solutions. | |

- Students [the pre-engineering program] graduate with up to 36 credit hours from high school. They can have 36 credit hours at the college level. I think that benefited the most in terms of STEM (Allison, Ln# 76-78).
- We have done some projects [through the School-Higher Education partnership (Middle School Agriculture and Technology Education programs)] primarily with Virginia Tech, to improve STEM education at middle schools and that has been centered around middle school agriculture and technology education teachers. So, those teachers have largely taken the lead of STEM education at the middle school level (Stephen, Ln# 66-69).
- Very project based [the Partnerships (School-Higher Education-Business/Industry)], critical thinking, learner centered, and there is some professional development that's taking place with that (Allison, Ln# 49-52).
- It's [Industrial Math course] really going to teach these kids the calculus and trig that they need to go into these advanced manufacturing jobs, and that's where I think STEM is really (Russell, Ln# 75-77).
- [The Sustainable and Renewable Technologies] is geared towards the new STEM (Russell, Ln# 84).

The findings of the study revealed a number of specific examples of CTE initiatives that have contributed to advancing STEM education. Examples of special programs included the Math-in-CTE-based program, sponsored by the National Center for Research in Career and Technical Education (NCRCTE). Program requirements involve utilizing new pedagogy for collaborative teaching between math and CTE teachers to enhance math instruction in different occupational contexts (NCRCTE, 2013). Another special program included Project Lead the Way, sponsored by national organization entitled Project Lead the Way. This project involves utilizing world-class, activity-, project-, and problem-based curriculum and a high-quality teacher professional development model, combined with an engaged network of educators and corporate partners, to help students develop the integrative STEM-related skills (Project Lead the Way, 2013).

The flagship initiative regarding examples of how CTE has contributed to Advancing STEM Education is the administration and implementation of Virginia Governor's STEM Academies. These academies are designed to expand options for the general student population to acquire STEM literacy and other critical skills, knowledge and credentials that are needed for high-demand and high-wage, and high-skilled careers (VDOE, 2012).

CTE programs such as a Building Construction program have integrated STEM perhaps at the highest level by having students actually build houses that are sold for occupancy in the local community of the school. The last house sold for $800,000.00 dollars. Of course this program has a multitude of industry partners to make the program successful. Another partnership that has been instrumental in advance STEM education is the School-Higher Education Partnership.  This program involves partnerships between local school districts and higher education institutions for the purpose of  preparing students to understand STEM areas. In particular, one of the school systems represented in the study has been partnering with an academic program at Virginia Tech targeted to middle school Agricultural and Technology Educations students. Finally, new CTE courses highly involved in integrating STEM education are being provided in local systems. Two examples of these courses are Industrial Math and Sustainable and Renewable Technologies.

## Visibility of CTE's Contributions to STEM Education Implementation

In reference to research question four, participants were asked how the contributions of CTE in the advancement of STEM education could be made more visible to and accepted both by CTE and STEM educators. Examination of their responses revealed four themes regarding this visibility The four themes were: (1) Marketing CTE, (2) Valueing of CTE, (3) Enhancing curriculum and instruction, and (4) Rebranding CTE. As with other research questions there were major overlaps in the themes and their contributory codes. For example, a strategy for demonstrating the value of CTE can easily be interpreted to also be a marketing strategy, or a strategy for rebranding CTE. The categories were emphasized differently by participants to warrant separate categorization.  A comprehensive table showing codes, categories and themes relating to CTE's contributions to STEM education implementation is presented in Appendix M. A detailed description of the findings regarding each of the themes and the basis for their construction is provided next.

### Marketing CTE

The predominant theme that emerged from the data analysis with respect to recognition of the contributions of CTE programs to advancing the goals of STEM education was *marketing*. Four categories emerged to support this theme. They were: (1) creating awareness, (2) lobbying, (3) promotion, (4) stakeholder involvement. Table 4.11 presents the codes and categories for the theme *marketing CTE*.

Examples of participant responses related to this theme are as follows:

- We just need to do a better job of promoting the STEM work that is going on within all the different CTE areas (Cyrus, Ln# 97-98).

Table 4.11

*Marketing CTE Theme: Codes and Categories*

| Code | Category | Theme |
|---|---|---|
| Advertising [what we are doing]<br>Having them spread the word<br>Getting right information to parents<br>Doing public relations<br>Flooding the market with information | Creating awareness | Marketing CTE |
| Making policy makers aware<br>Lobbying organizations<br>Doing public relations<br>Making aware of efforts | Lobbying | |
| Getting people to see<br>Promoting some of the things we do<br>Promoting CTE activities<br>Promoting the STEM work that is going on<br>Hosting career fairs<br>Giving [newsletter] to all schools<br>Publicizing what students are doing<br>Talking at schools, to parents<br>Talking about partnership<br>Highlighting what's going on in classrooms<br>Increasing visibility<br>Inviting teachers into classrooms<br>Talking about what we are doing | Promotion | |
| Getting more parents involved<br>Involving them in what you are doing<br>Getting representation | Stakeholder involvement | |

- I think you need to promote. You know, getting the word out. Getting it out to different venues to be able to highlight it—getting more parents involved and having them spread the word that way. So, I really do think that promotion and getting people to see what we're doing and the connections that we're doing [CTE programs contributing to STEM education implementation] is the best advertising and the best way to promote and to spread STEM (Bryant, Ln# 128-139).
- I think we need to promote those activities more so that people out there will start to see all CTE areas as kind of promoting STEM education as opposed to just those that lend themselves more neatly to promoting STEM (Cyrus, Ln# 102-104).
- It's a constant thing to reach parents, to reach these counselors. … It's about constant marketing. It's about constant outreach. It's an ongoing publicity campaign for CTE (Layla, Ln# 264-272).
- I also have a career and technical education foundation made up of business leaders, employers from all around the area that represent all of my programs and I found success marketing my program through this group (Allison, Ln# 88-94).

Many participants expressed the view that the role of CTE programs, in general education and STEM education implementation in particular, was not being sufficiently recognized. They pointed out the need for stakeholders to gain knowledge of the 'neat' things happening in programs, multiple pathways available to students, and post-school achievements of students. They felt that making CTE's contribution to STEM education implementation more visible required a major effort to increase the awareness of these contributions. This could be done by planning and implementing a comprehensive promotional campaign. All stakeholders should be targeted in this campaign. The campaign should have a comprehensive plan for flooding the market with information about CTE's contributions. Various promotional strategies should be used to get the information out. Examples of these strategies could include, but not be limited to, continually advertise all STEM education-related  initiatives by using as many types of promotional media as possible, inviting stakeholders into the classroom, inviting stakeholders to special STEM education-related projects or programs, involving stakeholders in providing STEM education-related activities with teachers, and seeking ideas for STEM education-related activities from stakeholders. The participants also felt that a special effort needed to be made to promote to local policy makers. Their comprehensive knowledge of CTE's contributions are vital to gaining support and approval for any type of CTE STEM-related initiative.

**Valuing of CTE**

A second theme that emerged from the data analysis regarding contributions of CTE in the advancement of STEM education was *valuing of CTE*. Three categories emerged to support this theme. They were: (1) achievements, (2) credentials, and (3) evaluating CTE. Table 4.11 presents the codes and categories for the theme *valuing of CTE*.

Examples of participant responses related to this theme are as follows:

- There was a perception that the CTE courses were a dumping ground, and we have worked hard in the school division to show that CTE is no dumping ground—that it is very rigorous, it is very academic, and we have a high percentage of students doing dual enrolment where they take courses—and we have a lot of our courses in CTE set up as dual credit, where they can get high school credit and college credit. We have industry certification in CTE and so that’s something we follow very closely with our students (Isobel, Ln# 207-214).

Table 4.12

*Valuing of CTE Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Seeing how successful they are<br>Doing better than those with bachelors' degrees<br>Gaining sustainable employment<br>Going on to do great things<br>Making our high school shine<br>Making me proud<br>Getting better paying jobs<br>Seeing results of their students [jobs and education] | Achievements | Valuing of CTE |
| Acknowledging industry certification<br>Being a higher requirement than SOL<br>Giving credibility from outside<br>Passing [industry standard exams]<br>Following closely industry certification | Credentials | |
| Adding industry certifications<br>Looking at what business and industry needs<br>Tracking some of the students<br>Assuming being effective<br>Being difficult to prove efficacy | Evaluating CTE | |

- You can see [in the Program of Studies handbook for the district] the extent of the course offerings that we do provide to the students. It is a very strong program, and when I talk to the high school, it is the CTE program that makes our high school shine. And so now we have to work with our other programs to help them develop too (Isobel, Ln# 220-223).

- He is the longest serving Superintendent in the Commonwealth of Virginia. So he gets out a lot, and often in principals meetings, he is talking about what we are doing in career and technical ed. That makes me very proud and I think that the community gets it. I hear from school board members and when I see the open houses we have, and I look at the enrolments—we have over 28,000 students this year enrolled in career and technical education out of 70,000 kids. That's *significant*. That's on the website if you look under CTE. But I think that's meaningful data to put out there because that's a significant part of our population. So, yes I'm thankful now. Is there always room to get out there and tell the story? Yes! Cos often what we hear of is, you know, certain programs, 'it's the best kept secret'. We don't want it to be a secret (Layla, Ln# 181-192).
- I think when you [see the value of CTE programs when you] start looking at some of the certifications that students are getting as they are going through—and we are preparing them for those, as they are getting some of the industry certifications that typically people do once they've been in industry (Byrant, Ln# 153-155).
- People say it's just about fixing cars. Well, cars today are so much more sophisticated with computerized systems and everything else. You don't just hear noise, turn a wrench, and fix something. It takes a lot more to get certified in car repair, cosmetology, all of them (Andrew, Ln# 156-159).
- [Because of the leverage industrial certifications offer CTE students for employment] ... we'll start moving CTE out of the red-headed step-child position more into the equal peer [with academic subjects]" (Robin, Ln# 150-151).
- The other thing that we need to do a little bit more is really track some of our students, in a good way, not track them in classes but see where they go and where they are two, four,

six years after high school and seeing how successful they are. Because I don't think we promote that as well either. We need more data like that to hold up and say hey, our students are well prepared for a career, for post-secondary education—whichever they want to go, wherever their career takes them (Bryant, Ln# 156-164).

- Support for CTE waxes and wanes. The fact that he [Secretary of Education, Arne Duncan] is saying we haven't proved that we are effective—there's probably some truth in that because we live in a world where it is very difficult to prove efficacy. We're dealing high school students who are required to take classes and are required to choose certain electives and go through a number of CTE electives, and are searching for their path post high school, and my personal experience in 36 years, is we graduate a large number of students who haven't chosen their final pathway, and that's a very difficult thing for a high school student to do for whatever reason. So the efficacy of CTE programs may never be fully proven. A lot of what we do, we have to do with the assumption that we are being effective (Stephen, Ln# 128-143).

The participants stated that in order to make CTE's contributions to STEM education implementation more visible, STEM education stakeholders needed to value CTE. To establish value in CTE, the participants expressed the need to make STEM education stakeholders aware of the achievements of students taking CTE. These achievements include, but are not limited to, gaining sustainable employment with better paying jobs, in some cases 'doing better than those with bachelor's degrees', furthering their education,  and providing a foundation for students to continue their education after high school graduation. Making the stakeholders aware of the impact industry credentialing has on CTE programs and students. This impact includes, but not limited to, developing curriculum based on industry credentials, giving credibility to CTE, adhering to a higher requirement than state SOLs, and students passing industrial credentialing exams. In addition, participants believed that conducting evaluations of CTE programs and disclosing the results of the evaluations would also increase value in their programs. This evaluation could include, but not be limited to, requiring industry credentialing and using student success rate in passing credentialing exams as part of the evaluation, evaluating the degree to which CTE programs base their curriculum on business and industry needs, and conducting follow-up surveys of CTE completers and examining the new data set on school-career transitions that track some students two, four, or six years after high school graduation to determine the impact CTE has had on their lives.

Finally, the participants believed that valuing CTE will result in establishing trust in them to be able to make significant contributions to STEM education implementation. Without this trust, a great deal of CTE's potential to assist in this implementation will be discarded.

**Enhancing Curriculum and Instruction**

The third theme with regards to making the contributions of CTE in the advancement of STEM education more visible to and accepted both by CTE and STEM educators was *curriculum and instruction*. Four categories emerged to support this theme. They were: (1) curriculum, (2) individual needs, (3) pedagogy, and (4) teacher capacity. Table 4.13 presents the codes and categories for the theme *enhancing curriculum and instruction.*

Examples of participant responses related to this theme are as follows:

- I think all of our programs link with STEM in a variety of different ways and in areas that you wouldn’t necessarily think they would. Our construction program, our trade and industrial program do a really good job of using the math and the science and pointing that out to students (Lauretta, Ln# 130-133).

Table 4.13

*Enhancing Curriculum and Instruction Theme: Codes and Categories*

| **Code** | **Category** | **Theme** |
|---|---|---|
| Stepping up the curriculum<br>Making it [STEM course] a requirement<br>Spreading STEM<br>Spreading technology education<br>Being rigorous<br>Going through a number of CTE electives<br>Getting involved as early as elementary<br>Setting up programs early | Curriculum | Curriculum and instruction |
| Finding the niche<br>Figuring their GPA<br>Bringing kids along<br>Doing our best to accommodate<br>Getting all kids exposed<br>Having programs that interest kids | Individual needs | |
| Emphasizing STEM concepts<br>Incorporating different strategies<br>Letting teachers [explore]<br>Realizing that they are doing STEM | Pedagogy | |
| Stepping up teacher training<br>Continuing education and PD<br>Having more staff development, resources & funding | Teacher capacity | |

- In our county, I think we've changed [our curricula] with the times. I think if you looked at our courses—no matter what course in CTE you look at, it is not the same as it was five years, and certainly not ten years ago (Lauretta, Ln# 228-230).

- I think they need a push—continue to push CTE programs to stay with times, to teach high level curriculums. Going back to some of those places that haven't stepped as much. I think to continue to put the pressure on them to step up. You've got to serve your community, no question—but at the same time you've to help these kids get something for the future. But a lot of it will come through that they need to make sure that we are current—cutting edge technology… A good example is in our dental program. Now they are going to whole digital X-rays. So that will help CTE and STEM if we are teaching literally the latest state-of-art equipment, programs, software, and so on (Andrew, Ln# 277-295).
- I know that in Maryland, one of the things that they have done is that they have made it a requirement that students take a technology education component ... as part of the STEM. But then people started connecting technology and, like music or technology and this is kind of watering down really what the purpose of the law was. So, you know, I really do think though that promotion and getting people to see what we're doing and the connections that we're doing is the best advertising and the best way to promote and to spread STEM (Bryant, Ln# 131-139).
- We had a student—he was a struggling reader. He did not do work. People had him pretty well pegged as he just didn't care. And we worked with him and we loved him but we could not turn him on to anything. I saw him again when he was one of the leaders in one of the CTE programs, and he did a presentation, and he spoke brilliantly. He had invented some things that created a new line of business for his family, and it was because of the CTE program. *It was the CTE program where he found his niche in education* (Isobel, Ln# 256-262).

- I think that we need to let the teachers get in there and explore and realize some of the things that they are doing—how they connect that with STEM. And some of the things they may be doing may be related to STEM but they can just put a little bit more effort—go out and do a little bit more research or incorporate some different strategies, and to really emphasize the STEM concept in their class (Russell, Ln# 135-143).
- Making sure that they [teachers] are engaging students in the activities. With the CTE world, we don't want to walk into a classroom too often and see kids sitting in seats learning out of a book. My teachers are told that they use textbook as supplements, not as a teaching source—something they can use as a reference (Russell, Ln# 38-42).
- I think we have stepped up our teacher training and knowledge levels and everything else and now they realize that's the standard [students' industrial certification] they are being held to—SOLs for core. This is kind of our SOL and to be honest, I think it's a much higher level of requirement than an SOL (Andrew, Ln# 263-267).
- We have to start with teachers cos you need good qualified teachers in order to have instruction for students. You need to partner again with the Virginia community college system, the university system. We need to improve instruction overall for all students, but in STEM you need to make instruction too very learner centered and project based, and I think CTE lends itself to that. But we need more professional development in those particular areas to make STEM work (Allison, Ln# 110-116).
- Give teachers professional development to perhaps gain an endorsement or certification in STEM to go along with their teaching certificate (Allison, Ln# 120-121).
- So any new initiatives that could train the teachers better, as that's a huge return on investment… Always invest dollars in teacher training professional development so that

you get a high return on your investment. Good high quality, high standard professional development training. It can even be done on the local school division level, or it can be done state-wide. It can be done effectively either way (Darell, Ln# 176-184).

Participants indicated that enhancing CTE curriculum and instruction would increase the value of CTE and thereby, improve the visibility of its contributions to STEM education implementation. They felt that curriculum and instruction could be enhanced by emphasizing (integrating) STEM concepts in the curriculum. They also felt that incorporating different strategies for this integration would assist with the enhancement. Allowing teachers to explore linkages between STEM education and their curriculum would help them to realize that they are already integrating STEM concepts and would help them to increase and improve the rigor of this integration. They felt that 'stepping up the curriculum' with STEM concepts would enhance the chance for schools to require students to take CTE courses with intentional STEM-related integrated curriculum. Furthermore, enhancing curriculum and instruction could be accomplished by addressing student's individual needs. Addressing these needs would require programs to provide courses that are of particular interest to students. It would assist students in finding their niche (in STEM education) and it would assist in 'bringing them along' with the STEM education movement. Finally, the participants felt that in order for all of the enhancement initiatives to occur, 'stepping up the teacher' with continuing education and professional development would be required. This professional development would place teachers in a position that would allow them to accomplish all that is needed to enhance their curriculum and instruction.

**Rebranding CTE**

The fourth theme with regards to making the contributions of CTE in the advancement of STEM education more visible to and accepted both by CTE and STEM educators was *rebranding CTE*. As with a previous theme, participants felt this theme also had reciprocal implications. Three categories emerged to support this theme. They were: (1) lingering image, (2) new image, and (3) strategy for change. Table 4.14 presents the codes and categories for the theme *rebranding CTE.*

Examples of participant responses related to this theme are as follows:

- We are starting to call it college *and* career readiness, but we still have that college *or*. I always try to say, it's career *and* college because if you're not going to college for a certain career path, you're just going to flounder and you're not going to have a focus on getting all the way through. But I do still think there is that stigma. However, I think people are starting to see that it's more of a benefit. But it's still—there is still a lot of work to done (Bryant, Ln# 143-148).
- When our district got some CTE classes 'weighted'[worth a percentage more in points compared to regular courses], enrollment in some our engineering classes recorded large increases in enrolment. That's *huge*. But I do think that CTE, in all our areas not just STEM, is the application of the core, and I think that makes us very valuable to schools (Andrew, Ln# 104-106).
- It's public relations. I mean, we have to brand CTE …if we really wanted to make a sustainable change quickly, we would have to flood the market (Lauretta, Ln# 179-187).

Table 4.14

*Rebranding CTE Theme: Codes and Categories*

| Code | Category | Theme |
|---|---|---|
| Being a mindset<br>Dumping ground<br>Dispelling old vocational education<br>Thinking it's for kids not going to college<br>Fighting historical image<br>Fighting image of chocolate chip cookies<br>Taking back seat to core subjects | Lingering image | Rebranding CTE |
| Changing their image<br>Preparing for career<br>Being rigorous<br>Moving CTE into an equal peer | New image | |
| Starting to call it college and career readiness<br>Getting the distinction of Governor's academy<br>Connecting [STEM] to technology education<br>Getting industry certification<br>Seeing all CTE as promoting STEM<br>Doing dual enrolment<br>Having to be NATEF certified (accredited)<br>Connecting with STEM | Strategy for change | |

- The CTE program that we offer through our school district has more dual enrolment courses than any of our core areas. So the linkage to college is there. The players that know CTE, appreciate CTE, and that includes the parents, because they are seeing the results of their students'—of their children getting jobs right out of school or getting better paying jobs from the skills that they learn (Robin, Ln# 113-117).

- The whole work force right now—if you look at what industry is demanding … if just read the local newspaper and look at all the job openings, there are going to be in the CTE related area… They're looking for those CTE related skills. So eventually the pendulum is going to have to shift because of the economic needs. When there is an economic need for something, policy makers start paying attention and policies start to change (Robin, Ln# 151-157).

Salient points from the data analysis are that rebranding must involve improved rigor of courses, obtaining the distinction of Governor's academies, being associated with industry certification, offering dual enrolled courses, being accredited by national industry foundations or boards such as the National Automotive Technicians Education Foundation NATEF, and having all CTE programs intentionally integrate STEM education-related curriculum and activities. It was perceived that the rebranding of CTE would have reciprocal implications for CTE and STEM education. Of course, the rebranding would be a major achievement for and improvement of CTE. Participants stated that being a part of the STEM education movement would assist in this rebranding. On the other hand, if the rebranding is accomplished, it could have a major impact on how CTE could foster the advancement of STEM education.

## Participants' Recommendations for Policy, Curriculum, and Pedagogy

Research question five of the study requested participant recommendations concerning successful policy, curriculum, and pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education. As with question three, due to the nature of the fifth question, it was not necessary to utilize codes and categories to identify themes. The data were organized by the three categories imbedded in the question, that being: policy, curriculum, and pedagogic strategy. Table 4.15 presents the recommendations made.

Table 4.15

*Recommendations for Mutually Enhance Goals of CTE and STEM Education*

| **Recommendation** | **Category** |
|---|---|
| Mandate integrative STEM education<br>Strengthen cross-institutional integration<br>Create a STEM education advisory council<br>Create a position of state STEM education coordinator<br>Increase funding<br>Provide high quality teacher training and professional development<br>Virginia Department of Education to re-examine licensure and endorsement requirements for teachers | Policy |
| Strengthen industry validation<br>Introducing STEM competencies<br>Provide for a common period for cross-curricula planning<br>Re-focus curriculum beyond local workforce needs | Curriculum |
| Strengthen project-based learning<br>Emphasize hands-on learning with real world applications<br>Strengthen intentional integrative teaching | Pedagogic Strategy |

Examples of participant responses related to mutually enhancing goals of CTE and STEM education are as follows:

- If you are really going to increase STEM education, it has to be a mandate from the state because everything else is mandated (Lauretta, Ln# 304-306).
- In order for it to happen it would almost have to be some either policy or procedure or some sort of mandate every so often a teacher has do this and document it or else …most likely it won't happen (Cyrus, Ln# 152-154).

- Public schools will tend to respond more to the state directive, but we find greater benefit when it's coming from higher education and incorporating us as partners (Isobel, Ln# 156-157).
- If you really want to push STEM, you need someone in charge of STEM education for the entire state of Virginia. That can help aid schools, can work with schools, can put advisory councils together, that can develop core competencies that are associated with STEM—much like what they did with workplace readiness skills (Allison, Ln# 61-65).
- CTE can be a huge catalyst in this [STEM education implementation], but it still needs to be a concerted effort at the state level first (Andrew, Ln# 408-409).
- If we had a STEM coordinator, they could ask us to think broader that it would be pulling in people from the sciences and mathematics, and not just CTE, engineering, and technology. So, I would like the broader picture (Isobel, Ln# 89-92).
- They could increase the funding that's there because these programs are expensive to operate and we can't always rely on business and industry to give you donations. So, better financial support would be good (Darell, Ln# 166-172).
- Localities have a hard time managing CTE projects in Virginia… But, you know, kind of a little bit more support for not only the programming but all the things that go with the programming (Layla, Ln# 311-321).
- Our proposed new advanced technology academy would bring over our academy of science program, and we would literally call that the center for STEM education—and you would think that it would be sexy enough for the school board to get (Layla, Ln# 316-321).
- I think always, teacher training is of paramount importance (Darell, Ln# 176-177).

- Good high quality, high standard professional development training (Darell, Ln# 183).

When analyzing the data and reflecting on the tone of the interviews when asking for recommendations that would mutually enhance goals of CTE and STEM education, participants were adamant about need for structure and guidance from the Virginia Department of Education (VDOE) and other key stakeholders by way of institution of higher learning, advisory committees, as well as industry consultants. They stated that mandating integrative STEM education would provide directives from the VDOE, to which most school systems adhere. Establishing a state coordinator for STEM education would provide a person who could be work entirely on STEM education initiative and give direction and assistance to local school systems. This person could serve a champion for STEM education and provide advocacy for STEM education initiatives. There are also needs for policies supporting teacher training and professional development, and for efforts to source more funding. For example, Layla wished there was a ‘state building’ fund for large projects such as STEM academies.

With regard to recommendations related to curriculum, the participants suggestions included introduction of STEM competencies and to strengthen industry validation, school systems providing common planning periods for cross-curricula planning, and for a re-focus on curriculum beyond local workforce needs. In regards to integrative STEM education implementation, a major effort needs to be made to strengthen the use of project-based learning and emphasize hands-on learning with real world applications. There also needs to be efforts to strengthen intentional integrative teaching.

## Chapter Summary

Chapter 4 is a presentation of the findings of the study. It emerged that the duties of a local CTE director relate to a multiplicity of responsibilities. These duties and responsibilities revolve around: (1) administration, (2) curriculum and instruction, (3) data and reporting, (4) finances, (5) purchasing, (6) professional development, and (7) outreach.

Four definitions of STEM education emerged among the participants. Each related to one of the following for themes: (1) application, (2) integration, (3) problem solving, and (4) technology/engineering content and processes. The diverse nature of the emergence of four definitions reflect the national trend regarding STEM education meaning different things to different people.

The data revealed a number of contributions made by CTE to assist in STEM education implementation. They include: (1) context for learning, (2) multiple pathways; (3) platform for program delivery, and (4) administrative leadership and framework.

A variety examples of CTE initiatives that have contributed to advancing STEM education were also identified. Theses specific examples revolved around four themes, including: (1) specials programs, (2) institutions, (3) programs, (4) partnerships, and (5) courses. Examples of these initiatives include, but are not limited to, the First Lego League, Virginia Governor's STEM Academies being housed in CTE units in local schools systems, pre-engineering programs, school-higher education partnerships, and a sustainable and renewable technologies course.

Four themes emerged from the data concerning how the contributions of CTE in the advancement of STEM education could be made more visible to and accepted both by CTE and STEM educators. They include: (1) Marketing CTE, (2) Value of CTE, (3) Enhancing curriculum and instruction, and (4) Rebranding CTE.

With regard to recommendations concerning successful policy, curriculum, and pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education, examples included: (1) mandating integrative STEM education, (2) create a position of state STEM education coordinator, (3) introduce STEM competencies, (4) strengthen industry validation, and (5) strengthen intentional integrative thinking.

Chapter 5 provides a summary of the study, conclusions, discussion of the results, and recommendations for practice relating to linkages between CTE and STEM education as well as recommendations for further research.

# CHAPTER 5 DISCUSSION OF RESULTS AND CONCLUSIONS

Chapter 5 provides a summary of the study, conclusions arising from the researcher's interpretation of the results, and recommendations for practice and for further research.

## Summary of the Study

The summary of the study is presented in a brief description of the statement of the problem, purpose of the study, research questions, methodology used, and highlights of the findings.

### Statement of the Problem

In spite of the large overlap in the goals of CTE and STEM education, there is little evidence of the role(s) CTE delivery systems, programs, curricula, or pedagogical strategies can play in advancing STEM education. As Meeder and Suddreth (2012) observed, the goal of ensuring that all students graduated from high school ready for college, careers and life had taken hold in every state across the U.S. and "yet all too often, the focus on 'college readiness' and 'career readiness' remains in two distinct silos" (p. 4). This is in spite of reform efforts to integrate academics and, at that time, vocational education going as far back to John Dewey early 20$^{th}$ century, who advocated for contextualize learning in America's high schools (Castellano, Stringfield, & Stone, 2003). Because of their responsibilities especially for organizational and instructional leadership, school district authorities, and of special interest to this researcher, local directors of CTE (Usdan, McCloud, Podmostko, & Cuban, 2001), could illuminate our understanding of linkages between CTE and STEM education. The problem is that we do not know enough about the experiences of local directors of CTE.

**Purpose of the Study**

The purpose of the study is to analyze the experiences of school district directors of CTE with the contributions CTE programs have made to STEM education reform.

**Research Questions**

The main question to be answered was as follows: What contributions have CTE programs made to the STEM education reform, as perceived by the CTE directors? The study was guided by the following sub questions:

1. How do CTE directors define STEM education?
2. What do directors consider to be the contributions of CTE programs to STEM education implementation?
3. What do directors describe as specific examples of CTE initiatives that have contributed to advancing STEM education at the school/district level?
4. How can the contributions of CTE in the advancement of STEM education be made more visible to and accepted both by CTE and STEM educators?
5. What are school division CTE directors recommendations concerning successful policy/curricula/pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education?

**Methodology**

To conduct the study the researcher utilized a qualitative research design. Face-to-face interviews were conducted with 13 local school district CTE directors. A semi-structured interview protocol was used to conduct the study. Each interview was audio recorded and field notes were taken as well. Participant demographic information was collected using a "hard copy" questionnaire for the purpose of gaining context that influenced participants' answers. To analyze the data, the researcher utilized constant comparative analysis to begin compiling the data to identify emerging themes. Categories were identified from a process of comparing codes. Finally, themes were determined by examining the categories.

**Highlights of the Findings**

Highlights of the findings include the following:

- Four definitions of STEM education emerged among the participants. Each related to one of the following for themes:  (1) application, (2) integration, (3) problem solving, and (4) technology/engineering content and processes. The diverse nature of the emergence of four definitions reflect the national trend regarding STEM education meaning different things to different people.
- Contributions made by CTE to assist in STEM education implementation include: (1) context for learning, (2) multiple pathways; (3) platform for program delivery, and (4) administrative leadership and framework.
- A variety examples of CTE initiatives that have contributed to advancing STEM education were also identified. Theses specific examples revolved around four themes, including: (1) specials programs, (2) institutions, (3) programs, (4) partnerships, and (5) courses. Examples of these initiatives include, but are not limited to, the First Lego League, Virginia Governor's STEM Academies being housed in CTE units in local schools systems, pre-engineering programs, school-higher education partnerships, and a sustainable and renewable technologies course.
- Four themes emerged from the data concerning how the contributions of CTE in the advancement of STEM education could be made more visible to and accepted both by

CTE and STEM educators. They include: (1) Marketing CTE, (2) Value of CTE, (3) Enhancing curriculum and instruction, and (4) Rebranding CTE.

- With regard to recommendations concerning successful policy, curriculum, and pedagogic strategies for mutual enhancement of the goals of CTE and of STEM education, examples included: (1) mandating integrative STEM education, (2) create a position of state STEM education coordinator, (3) introduce STEM competencies, (4) strengthen industry validation, and (5) strengthen intentional integrative thinking.

## Discussion of Results

### Definition of STEM Education

As presented in Chapter 4, the findings of the study resulted in a variety of definitions of STEM education. The definitions were as follows: (1) STEM education is the teaching of science, technology, engineering, and mathematics (STEM) and *applying* concepts to work contexts; (2) STEM education is *integrated* teaching of the STEM; (3) STEM education is the use of interdisciplinary/integrative concepts of the STEM disciplines to *problem solving*. and (4). STEM education is using the application of *technology/engineering-based content and processes* to teach science and mathematics.

The definitions above focused on either an integrated approach to teaching STEM disciplines, or real world applications, or both integration and real world applications. The lack of a unique definition of STEM education is not much of a surprise. The difficulty in defining STEM education is widely acknowledged. For example, writing a commentary in the National Science Teachers Association's *NSTA Reports*, Gerlach (2012) made the rather pessimistic conclusion that "it is truly impossible to define STEM because it means so much for so many different groups of people" (p. 3). As discovered in this study, examples of STEM education were found in health and medical sciences programs, technology education programs, pre-engineering programs, and welding and machine operations programs. In fact, one participant indicated that all of what we teach in CTE is partly based on STEM education. CTE curriculum has typically integrated core academic standards and in the 1990's there was a major effort to have teachers intentionally plan this integration in their curriculum and to make it as visible as possible (Castellano, Stringfield, & Stone, 2003). Today, there are many states that have created "crosswalks" to match specific competencies taught in CTE to academic standards (Castellano, Harrison, & Scheider, 2008). However, the visibility of this work still remains a problem. Integrating academic standards into CTE curriculum is quite similar to the goals of the STEM education movement. The lack of visibility of CTE's contributions to fostering STEM education could be seen from two perspectives. One perspective is that the lack of visibility arises from the lack of consensual definition of STEM education, and the other perspective could be that the lack of visibility contributes to the problem of not being able to come up with a clear definition of STEM education. Either way, as Stephen, in this study observed "it makes it difficult to communicate with the general public and our boards when there is not a clearly understandable delineation of STEM" (Ln# 34-36).

According to Herschbach (2011), part of the explanation for the national frenzy over STEM programming is money. "Grants from the National Science Foundation in addition to other organizations are funding program experimentation. Scores are jumping onto the money cart to get their share" (Herschbach, 2011, p. 97). The lack of a clear definition of STEM education is partly due to so many disciplines/groups trying gain access to these resources. Some people and organizations are even attempting to revise the acronym. For example, there has been an effort to change STEM to STEAM (Science, Technology, Engineering, Arts, and

Mathematics). This initiative is headed by the Rhode Island School of Design (RISD, 2013). Leaders of the RISD 'STEM to STEAM' initiative stated that America was turning to innovation as the way to ensure a prosperous future, and that this innovation was tightly coupled with STEM subjects when, in fact, "Art + Design are poised to transform our economy in the 21st century just as science and technology did in the last century. We need to add Art + Design to the equation — to transform STEM into STEAM" (RISD, 2013, n.p.).

A factor to consider in the difficulties to define STEM education is in the motivation for the STEM education movement. Drivers of STEM education reform include "the shock effect of the Soviet's successful launch of Sputnik in 1957 [which] jarred the United States into taking appropriate actions to win the space race" (National Science Board, 2007, p. 6). In the 1980s, a major impetus for reforms came from the report, *A Nation at Risk*. This report alerted the nation to the fact that America's pre-eminence in science and technological innovation was being overtaken by competitors because "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (National Commission on Excellence in Education, 1983, n.p.). Williams (2010) identified the non-educational motivation for STEM education reform as a possible cause of the difficulty to spell out clearly what STEM education is. Williams, in the article STEM Education: Proceed with Caution stated as follows:

> The STEM movement has developed from a non-educational rationale. Although some think it may enliven the delivery of maths and science in classrooms, the social and economic rationales are those that have initiated this movement. …. The problem for educators here is that the consequent absence of a sound educational rationale for this combination of subjects inhibits its development. (Williams, 2010, p. 31)

Even though there were variations in the definitions from participants, nonetheless, they all had core elements of the definition that were quite similar to Basham, Israel, and Maynard (2010) that STEM education was:

> … an interdisciplinary approach that integrates knowledge from diverse academic disciplines into authentic problem-/project-based learning experiences as related to instruction in STEM content areas. Each of these is embedded with the scientific method and engineering design processes, as well as 21st century skills. (p. 11)

Given the natural connections between CTE and STEM education, and considering further the centrality of workplace readiness skills in CTE courses in Virginia, it is evident that CTE programs could play a major role in the technological/engineering design processes and the scientific inquiry method, mathematical problem solving abilities, and in nurturing 21st century skills in students. Therefore, even if the CTE/STEM education community was to agree to disagree on the definition of STEM education, it is imperative to agree on fundamentals. STEM education should be seen as an effort towards transforming the traditional teacher-centered classroom towards encouraging a curriculum that is driven by problem-solving, discovery, exploratory learning, and require students to actively engage a situation in order to find its solution. Ultimately, the purpose is to improve student learning of content, process and problem solving abilities.

To achieve the above ideals, both CTE and STEM education require educators to be active and continuing learners. This could be facilitated by defining a signature pedagogy that is applied to teacher training and continuing into extensive and sustained professional development. As suggested much earlier, the signature pedagogy linking CTE and STEM education could be built on the principles of *Integrative* STEM education, as defined by Wells and Ernst (2012), in which the application of content, context, and pedagogical approaches of CTE are used to *intentionally* teach content and processes of STEM education. According to Huber and Hutchings (2005), integrative learning leads to personal liberation and social empowerment—ideals Dewey strived to bring to the center of educational theory and practice in the early 1900s.

According to Bybee (2010), STEM has its origins in the National Science Foundation, when in the 1990s, the acronym was a generic label to mean any event, policy, or practice involving at least one of the STEM disciplines; and that to many within the education community, STEM education was essentially mathematics and science. The definitions arising in this study show that local directors have all moved on from the initial perceptions of STEM education. The definitions given all suggest an integrated approach to the teaching and/or application of STEM disciplines to real world applications.

**Contributions of CTE to STEM Education Implementation**

Regarding what directors considered to be the contributions of CTE programs to STEM education implementation, the researcher identified the following themes of contributions: context for learning, multiple pathways, platform for program delivery, and administrative leadership and framework.

CTE curriculum has always included the application of academic standards. It was not until the 1990's, however, that a major thrust was introduced to make this integration more rigorous and much more visible (Castellano, Stringfield, & Stone, 2003). This movement within CTE has led to a great improvement of the curricula in the various programs within CTE. In addition, one can now find a 'crosswalk' between the academic standards of learning and job tasks/competencies that are taught in CTE courses. Castellano, Harrison, & Schneider, 2008; Often, 2011). Although there have been great strides within CTE to promote the increased rigor in the integration of academics standards into the CTE curriculum, there is still a lack of knowledge about this improvement among many individuals in the education community and in the general public (U.S. Department of Education, 2013).

High-tech and high-paying jobs are in the STEM career cluster. Taking maximum benefit of the opportunities in the STEM career cluster might require more than just high achievement in the STEM disciplines. It needs being college and career ready, i.e. having core academic skills, employability skills, and technical skills (ACTE, 2011). CTE is designed to accomplish college and career readiness through three 'corner stones'. These corner-stones are: (1) Classroom instruction, which is the essential component for students to master academic and technical competencies, attitudes, and work ethics; (2) Student organizations, which is an avenue for experiences that reinforce classroom learning and prepare students for individual responsibility, teamwork, and leadership; and (3) Employment experience where students have opportunities to apply and refine knowledge, skills and attitudes through supervised work experience directly related to career goals. (Virginia Department of Education, 2009)

While CTE is a major platform for STEM education implementation, it can also be said that CTE is a beneficiary of 'hosting' STEM education through a syndrome of 'boost your image, be seen with me'. A major goal of reform within CTE was to re-image CTE to get rid of the stigma of being for less able students, or as Robbin put it, "moving CTE out of the red-headed step-child position and more into being an equal peer" (Ln# 150). The close linkage to STEM education is a major contributor to CTE's rebranding efforts because of STEM's positive international image. For example, *Race to the Top Fund*, a competitive grant program aimed to encouraging and rewarding states that are creating the conditions for education innovation and reform; and achieving significant improvement in student outcomes has, as a "competitive preference priority: emphasis on Science, Technology, Engineering, and Mathematics" (U.S. Department of Education, 2009, p. 4). STEM education elevating CTE is exemplified in this study by the widely held sense of accomplishment in having Governor's STEM academies. A potential participant declined to participate in this study suggesting instead that "you may have already reached out to the CTE directors in X and Y counties, but if not, they are both on board with Governor STEM academies and a better resource to answer these type of questions [in the interview protocol]" (Prospective participant, personal communication July 17, 2013).

In Virginia, the approval process for each Governor's STEM Academy includes evidence of collaborative efforts among local school divisions, business and industry, community, and higher education partners. Additionally, goals of the Academy should meet the following criteria:

1. Incorporate rigorous academic content with career and technical instruction;
2. Have an emphasis on the [specified] STEM career pathway;
3. Develop individualized high school plans to ensure course selections that are aligned with students' transition and career goals after high school;
4. Ensure that graduates complete a college and career readiness curriculum for a particular career pathway; and
5. Incorporate Virginia's *Workplace Readiness Skills for the Commonwealth*. (Virginia Department of Education, & State Council of Higher Education for Virginia, 2013, p. 10)

In a nationwide survey of the state of science and mathematics education in state-supported residential academies, Pfeiffer, Marguerite-Overstreet, and Park (2010) found that students in Governor's STEM academies were exposed to a challenging curriculum that reflected science education reforms that emphasized research and inquiry-based learning. Regarding career development, a study in the state of Georgia found one of the advantages of STEM academies was that each academy's career cluster was based on a survey of the needs of local business and industry (Lakes, & Burns, 2012). Thus, the perception of the local CTE directors in this on the glowing success of Governor's academies is validated by experiences elsewhere.

**Examples of Effective CTE Initiatives in Advancing Goals of STEM Education**

As indicated in chapter 4, specific examples of CTE initiatives in advancing goals of STEM education included initiatives at three different levels, the school/district level, programmatic level, and pedagogical level.

At the school/district level, most participants presented Governor's STEM Academies as a very distinct flag-ship CTE initiative in leveraging STEM education. Based on Virginia Department of Education (VDOE) requirements, these academies house programs designed to expand options for students to acquire STEM literacy and other credentials that will prepare them for high-demand, high-wage, and high-skill careers (VDOE, 2012). All of the programs at each of these academies identified by participants were highly immersed in CTE and STEM related curriculum. Each of the academies were distinguished as having a partnership among their school divisions, postsecondary institutions, and business and industry; all of which had input to specific technical curricula and integrated STEM curricula. Based on the foregoing, Governor's STEM academies were designed not only to embrace core principles of CTE, but to actually succeed in providing students with an education that truly made them career and college ready. It is clear that these academies are one of several initiatives leading the way and serving as a champion for the advancement of STEM education in Virginia.

At the programmatic level, nearly all of the programs cited in this study as being the most successful in leveraging STEM education were those directly related to technology and/or engineering (e.g. pre-engineering, robotics, First Lego League, and Project Lead the Way). This does not mean, however, that technology/engineering programs are the only CTE programs that can have an impact on enhancing STEM education. In a landmark National Research Center for CTE (NRC for CTE) study entitled "Math-in-CTE," it was found that a new pedagogy combined with professional development designed to enhance mathematics instruction in *different occupational contexts* did, indeed, improve the performance of students on standardized measures of mathematical achievement (Stone, Alfeld, Pearson, Lewis, & Jensen, 2006). The significance of the Math-in-CTE study illustrates that STEM related areas can be enhanced in more CTE programs/courses than just technology and engineering.

**Visibility of CTE in Advancing Goals of STEM Education**

As to how the contributions of CTE in the advancement of STEM education could be made more visible to and accepted by stakeholders, the researcher grouped participants' suggestions into four categories as follows: marketing CTE, value of CTE, enhancing curriculum and instruction, and rebranding CTE.

The need for sustained marketing efforts was premised on a belief that the role of CTE programs in enhancing learning in general, and STEM education in particular, were not sufficiently appreciated by stakeholders. The marketing efforts were to show the value of CTE's contributions in a variety of ways such as, demonstrating achievements of students during and after high school, attainment of industry credentials, and how it is through CTE that some students have found a niche in STEM education. Additionally, the participants wanted it known that CTE was not a dumping ground for academically weak students, but that CTE had rigorous curricula that were relevant to learners, and used pedagogy that took into account individual students' needs. Holzer, Linn, and Monthey (2013) provided characteristics of such CTE programs. Holzer et al. (2013) stated that high quality CTE programs were open to all students, challenged students with rigorous academic and technical work, provided opportunities for students of all demographic backgrounds, and allowed a mix of both general and career-specific skill development.

Participants were cognizant of the lingering historical stereo type of CTE being for less academically gifted students. This mindset has lingered even though it has been recently reported that 70% of students taking CTE courses do, indeed, continue their education after high school graduation in two-and four-year colleges and universities (National Association of State Directors of Career and Technical Education, 2013). This misguided image is still causing, again to some degree, CTE to take a back seat in schools to core subjects, despite the fact that CTE courses do teach selected SOLs in their curriculum. Participants stated that dispelling the old vocational image will take a rebranding of CTE. This rebranding must transition the image of CTE being only for career bound students upon graduation to a program that embodies preparation for college and career readiness. CTE now has a two-pronged mission to enable students be college ready and career ready (ACTE, 2009; U.S. Congress, 2006). The views expressed by participants show that CTE Directors are actively working towards accomplishing this mission. According to Brizard (2013), some states, including Virginia, are already implementing "the new Common Core State Standards … and other rigorous college-ready standards" (p. 5). Additionally, providing avenues for exploring STEM career pathways is a natural linkage between CTE and STEM.

Of specific concern regarding perceptions of the role of CTE in relation to goals of STEM education is that the misconceptions can be at the highest levels of policy with implications for funding decisions. For example, Perkins IV mandates for the National Assessment of Career and Technical Education (NACTE) to evaluate implementation of the law, in addition to the implementation of the law, to also analyze the impact CTE has on academic achievement and employment outcomes. Authors of the *NACTE Interim Report*, U.S. Department of Education [USDOE], 2013), reported that:

> Gains in basic and intermediate mathematics skills and concepts are unrelated to occupational credits earned in the last two years of high school. However, taking relatively more occupational courses and fewer academic courses during the last two years of high school *limits the acquisition of advanced mathematical skills and concepts*. (p. 54/55)

Additionally, "in general, STEM courses in the CTE curriculum *neither enhance nor compromise* overall math achievement… Attendance at a full-time CTE school or a school located in a rural area is *not* related to mathematics gains" (UDSOE, 2013, p. 55). It if further stated in this report that it was traditional mathematics that improved learning. The researcher noted that the chapter in the NACTE 2013 Interim Report on the impact CTE on academic achievements was based on a commissioned study by Bozick and Dalton (2013). Bozick and Dalton reported as follows:

> Using a nationally representative sample of high school students, we examine the relationship between CTE coursework and mathematics achievement in high school. Accounting for observed and unobserved characteristics of students, we find that CTE courses *neither limit overall gains in mathematics learning nor the acquisition of basic*

> *and intermediate mathematics skills*. Additionally, engineering and technology courses, a subset of CTE courses that incorporate quantitative reasoning, logic, and problem solving, are unrelated with math achievement. (p. 123)

In its fiscal year (FY) 2011, Congress drastically reduced funding to CTE and Secretary of Education Arne Duncan warned of the need for state educators to make a compelling, data-driven case to justify increased federal investment (Richards, Klein, Pfeiffer, & Schoelkopf, 2013). “The lack of accurate, reliable data that can be used to quantify the return on federal investment in CTE has raised concerns about the reauthorization of the legislation [Perkins IV]” (Richards et al., 2013, p. 1). Another way of saying this is that the impact of CTE programs was being doubted. Bryant made this point when he said “I think that we’re always seeming to have to prove ourselves” (Ln# 152). The researcher has no evidence of any linkage between federal budget decisions of FY 201 and the studies by either VDOE (2013) or Bozick and Dalton apart from the coincidence of the rationale for the cut to federal appropriating to CTE in a year when the overall education budget went up. An implication of NACTE 2013 Interim Report for local CTE Directors is that their marketing efforts might need lobbying and advocacy at the highest levels of policy decisions in the country.

Bozick and Benjamin (2013) described two ways in which CTE/academic integration was done. One was ‘integrated course schedule’ in which students took a of mix academic of and occupational courses. The second was ‘integrated course content’ in which the teaching of CTE courses incorporated academic skills and applications and vice versa. With respect to the two types of integration, the research findings were that:

> With respect to an integrated course schedule, we find that learning gains in math are not compromised when occupational courses are taken *at the expense of academic courses*.

> The development of advanced skills such as solving multistep word problems is slightly impeded when occupational courses comprise a larger share of students' course schedules. (p. 13)

Reference to occupational courses being taken "at the expense of academic courses" provides evidence of the lingering stigma of vocational education had. It is significant that such stigma is prevalent among researchers operating at high levels of the education system, and in the field of education for that matter. However, the researcher noted that the principal researcher in the Bozick and Dalton study was neither from the CTE curriculum area, nor a STEM discipline, nor education. He was a sociologist while the second researcher was only described as a research education analyst. The aspect of the finding about solving multistep word problems being impeded when occupational coursed comprised a larger load for students implies CTE is harmful to problem solving ability. This is a finding that contradicts the vast body of research and theory about curriculum integration, authentic learning, project-based learning, and constructivism.

Finally on the issues arising from the two reports NACTE 2013, and Bozick and Benjamin (2013), the challenge of reconciling different results from different studies about the benefits of CTE to academic subjects was acknowledged (USD OE, 2013). Both studies drew heavily on the Education Longitudinal Study of 2002 conducted by the National Center for Educational Statistics (NCES). This researcher was troubled by the fact that quantitative studies of this nature, rigorous as they were with a politically powerful captive audience, could have had high levels of statistical significance but unable to capture high levels of 'significance' of the energy and passion exhibited by participants in this study concerning the achievements they see on a regular basis in their district, nor the Isobel's students whom, because of their special learning needs had been written off academically, and yet went on to blossom in CTE/STEM education projects.

### Policy and Curriculum Recommendations to Advance CTE and STEM

Policy recommendations to be discussed in this section include mandating integrative STEM education, creating a state level STEM education coordinator, and pedagogical focus.

**Mandating integrative STEM education.** Mandating integrative STEM education has its pros and cons. Some people feel that if not mandated, there would never be a state-wide effort to fully implement the concept behind the mandate. Others feel that when mandating something, some teachers never really understand the rationale for the mandate and do not know how it should be implemented.

Tennyson and Nguyen (2001) conducted a study to examine the relationship between existing state mandates for personal finance education and student knowledge of personal finance. At the time, twenty states were found to articulate some form of educational policy in the specific area of personal finance. The policies included setting guidelines for educational standards that should be met or defining essential skills that should be imparted to students. The researchers found that mandates that required the teaching of a specific course did exhibit a significant and positive association with test scores, even though when averaged over all forms of mandates, no association between mandates and student test scores was found. Therefore, there could be a point in having a mandate even though the benefits might not be overwhelming.

**State level STEM education coordination.** A recommendation for creating a state level STEM education coordinator was made because STEM education is such a large educational agenda and there was need to implement it on a more systematic basis. A major piece of evidence for the urgent need of state level coordination was the lack of clarity on what STEM education should be—leaving districts to interpret as they deemed appropriate. According to Bybee (2010), clarifying STEM education and establishing the fundamental purpose of school programs was the prerequisite to advancing STEM education. As stated by Basham, Israel, and Maynard (2010) operationalizing STEM for all requires: (a) financial and personnel commitment to resources; (b) changes in school culture toward increased expectations for STEM education for *all*; and (c) professional development and support within schools. These factors, coupled with the need for guidelines on at least the fundamentals of STEM education implementation, necessitates state level coordination mechanisms. Without these mechanisms, the impact of STEM education will never be realized.

Curriculum policy recommendations centered on state-level guidance concerning what STEM education should be. With respect to curriculum integration in general, a common concern related to work load teachers already have. There would be little time for them to adequately plan integrative approaches for teaching STEM curricula. In making a comprehensive case for integrated curriculum given the concerns for accountability and mandates, Drake and Burns (2004) posited that "the generic process to design integrated curriculum maximizes coherence by beginning with both vertical and horizontal review of the curriculum. This review identifies overlaps or common learning as natural areas for integration" (p. 20). Again, teachers have very little time to complete such a review. Curriculum integration models provided by the state would increase the likelihood of the integration actually occurring. Many states have state-supported CTE curriculum development centers. Virginia's VERSO is a prime example and is highly regarded by CTE teachers across the state. Integrated STEM education curriculum models developed by them would be well received by Virginia CTE teachers.  Career and Technical

Student Organization (CTSO) sponsored competitive events that include integrated STEM curriculum is another source for assisting teachers with this integration.

**Pedagogical focus**. Recommendations relating to pedagogy centered around three issues: (1) the need to teach higher order thinking skills in students, (2) use of hands-on methods of teaching, and (3) intentional, rather than incidental integrative teaching. Additionally, these pedagogical ideals were best realized through project-based learning. According to Bell (2010), Project-Based Learning (PBL) is a student-driven, teacher-facilitated approach to learning in which learners pursue knowledge by asking questions that have provoked their natural curiosity. Additionally, the PBL approach "focuses on the central concepts and principles of a discipline, involves students in problem-solving investigations and other meaningful tasks, allows students to work autonomously to construct their own learning" (Berns & Erickson, 2001). However, a study to document experiences of how campus leaders implemented PBL with which they had not been familiar with, Vega and Brown (2013) struggled to implement project based learning authentically while at the same time having to meet curriculum and assessment requirements of the school district, and as a result, "although most of the teachers and administrators indicated that PBL has had overall positive effect on their campus, they also indicated not all teachers and students have openly accepted PBL" (Vega, & Brown, 2013, p. 26). And yet, one of the fundamental premises to successfully provide STEM education is the utilization of project-based instruction (Bell, 2010; Berns & Erickson, 2001; Snyder & Snyder, 2008; Wurdinger, Haar, Hugg & Bezon, 2007). Students need hands-on activities where they can apply STEM related curricula to the real world. CTE is in the forefront with this methodology of teaching. CTE teachers have used this type of instruction from the very beginning of its history. It is a fundamental fiber of the CTE culture and is the pinnacle of CTE instruction (Elliot, & Deimler, 2007). With this experience, CTE teachers can provide a multitude of contributions to the advancement of STEM education. First and foremost, coupled with the fact that CTE curriculum is driven by industry needs and the project-based instruction being the primary methodology used in the field, integrating STEM education into the CTE curriculum is a natural fit. In addition, CTE teachers can provide professional development for teachers of other fields with regard to using project- based instruction. And finally, CTE teachers can be a source of support for other teachers when they run into any problems using this method of instruction.

## Conclusions

Based on the data presented in chapter 4 of this study, it can be concluded that:

1. If there remains a proliferation of definitions of STEM education, all of them should have at least two threads of commonality, using an integrated approach and using real world applications when teaching STEM-related concepts.
2. CTE can provide contexts for learning STEM education concepts, avenues of multiple pathways for learning STEM concepts as related to a wide variety of careers, a platform for program delivery, and administrative leadership and framework.
3. There are endless creative ways for teaching, both CTE and STEM education, given there are strong, mutual, and intended linkages between the two programs.
4. Aligning STEM education and CTE administratively into STEM Governor's academies has many benefits and can enhance both programs.
5. There are tremendous reciprocal benefits that CTE and STEM education can provide for one another with a strong, mutual, and intended linkage of the two.
6. The creation of a STEM education advisory board at both the local and state levels will serve to enhance STEM education.

7. Establishing a state-level STEM education coordinator position, would result in providing much needed leadership, having someone serve as a champion for advancing STEM education initiatives, and providing much needed guidance to local school systems.
8. The provision of high quality professional development  for all teachers and administrators involved in STEM-related activities is an absolute prerequisite for advancing STEM education to its optimal potential.
9. Integrating STEM education intentionally into various curricula school-wide is an absolute prerequisite for advancing STEM education to its optimal potential.
10. The fundamental pedagogical strategies for implementing integrated STEM education instruction is the utilization of project-based, hands-on-learning with real world applications.

## Recommendations

**For practice:**

1. In view of the perceptions that STEM education means many things to many people, it is recommended that two common threads of fundamental principles be an intricate part of all definitions, those being the use of an integrated approach and the use of real world applications when teaching STEM-related concepts.
2. In view of the perceptions that STEM education is a nebulous concept, and that each district is in order to define STEM education for their purpose, it is recommended that a state-level position be establish for the purpose of providing administrative leadership , the championing of STEM education initiatives, and guidance for organization and implementation of STEM education at state and local levels .
3. In view of the perceptions that CTE and STEM education have natural linkages and that reciprocal benefits can be experienced by both programs with these linkages, it is recommend

that continued intentional and mutual collaborative initiatives be implemented and supported at the highest level.

4. In view of the perceptions that Virginia Governor's Academies, which align STEM education with CTE, have already experienced tremendous success, it is recommended that this linkage rapidly continue throughout the Commonwealth of Virginia.
5. In view of the perceptions that professional development is crucial for advancing integrated STEM education to its optimal potential, it is recommended that resources be provided to support this development on a continual basis as long as STEM education is a priority at the local, state, and national levels.
6. In view of the perceptions that collaboration among teachers is essential for the success of STEM education implementation, it is recommended that planning periods for teachers involved in STEM education-related initiatives, be intentionally scheduled during common times for the purpose of cross-curricula planning.

**For further research:**

1. In view of the perceptions that there are natural linkages between STEM education and CTE and many reciprocal benefits each can provide for one another, it is recommended that a study be conducted to evaluate the natural linkages, the success of collaborative initiatives, the reciprocal benefits each receive from one another, and the impact all this has on student learning.
2. In view of the perceptions that Virginia Governor's Academies, which align STEM education with CTE, have experienced great success, it is recommended that a study be conducted to evaluate the academies in terms of, but not limited to, organizational and administrative structures; teacher performance in terms of intentional integration of subject matter, as well

as, collaboration with other teachers; administrator performance; general community perceptions of the academies and business and industry perceptions of the academies.

3. In view of the perceptions that Virginia Governor's Academies, which align STEM education with CTE, have experienced great success, it is recommended that a longitudinal study be conducted on the impact these academies are having on student morale, growth, learning, and future endeavors.
4. In view of the perceptions that various partnerships for the purpose of enhancing STEM education implementation have been successful, it is recommended that a study be conducted that measures the effectiveness.
5. In view of the perceptions that collaboration among teachers to implement STEM education is a key element for  the success of this implementation, it is recommended a study be conducted to determine the effectiveness of these partnerships.

## Final Thoughts

The researcher’s delight in interviewing each of the 13 participants face-to-face was more than for the shear opportunity to gather information on their experiences with regards to CTE’s contributions to STEM education implementation. But the delight came equally as much from seeing and feeling their belief and passion for their jobs and the potential they saw in CTE programs contributing to advancing the goals of STEM education. The general impression the researcher got in meeting and talking to each of the participants was that of a vibrant group of people passionate about their jobs. Some participants offered time for interviews clearly in between pressing commitments but they believed that in sharing information, they were opening a window into their programs. As one of them said, “we don’t want our programs to be ‘the best kept secret’, and you never know, someone might pay attention to your report."

## References


American Association for the Advancement of Science (AAAS). (1989). *Science for all Americans.* Washington, DC: Author.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy, Project 2061.* Washington, DC: Author.

Anfara, V., Brown, K., & Mangione, T. (2002). Qualitative analysis on stage: Making the research process more public. *Educational Researcher*, *31*(7), 28-38.

Association for Career and Technical Education (ACTE). (2009). *CTE's role in science, technology, engineering and math.* 1-8. Retrieved from http://www.acteonline.org/uploadedFiles/Publications_and_Online_Media/files/STEM_Issue_Brief.pdf

Association for Career and Technical Education. (2011). ACTE Issues Briefing. Handout at the 2011 National Policy Seminar, Alexandria, VA: Author.

Association for Career and Technical Education. (2011). *What is "career ready"?* Alexandria, VA: Author. Retrieved from https://www.acteonline.org/uploadedFiles/Publications_and_Online_Media/files/Career_Readiness_Paper.pdf

Association for Career and Technical Education. (2012). *What is career and technical education?* Retrieved from https://www.acteonline.org/cte_info.aspx

Association for Career and Technical Education, National Association of State Directors of Career Technical Education Consortium, & Partnership for 21st Century Skills. (2010). *Up the challenge: The role of career and technical education and 21st century skills in* *college and career readiness*. Retrieved from http://www.p21.org/storage/documents/CTE_Oct2010.pdf

Balka, D. (Summer, 2011). Standards of mathematical practice and STEM. Math-Science Connector Newsletter. Stillwater, OK: School Science and Mathematics Association.

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond, & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3-32). San Fransisco, CA: Jossey-Bass.

Basham, J. D., Israel, M., & Maynard, K. (2010). An ecological model of STEM education: Operationalizing STEM for all. *Journal of Special Education Technology*, *25*(3), 9-19.

Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through universal design for learning. *Teaching Exceptional Children, 45*(4), 8-15.

Beatty, A. (2011). *Successful STEM education: A workshop summary.* Washington, DC: National Academies Press.

Beltram, P. (2010). Total CTE program model: Makes CTE the answer. *Techniques: Connecting Education & Careers, 85*(5), 10-11.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83*, 39–43. doi: 10.1080/00098650903505415

Berns, R.G. & Erickson, P.M. (2001). Contextual teaching and learning: Preparing students for the new economy. *The Highlight Zone, 5*. Retrieved from http://www.cord.org/uploadedfiles/NCCTE_Highlight05-ContextualTeachingLearning.pdf

Bozick, R., & Dalton, B. (2013). Balancing career and technical education with academic coursework: The consequences for mathematics achievement in high school. *Educational Evaluation and Policy Analysis, 35*(2), 123-138. doi: 10.3102/0162373712453870

Bransford, J., Darling-Hammond, L., & LePage, P., (2005). Introduction. In L. Darling-Hammond, & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 1-39). San Fransisco, CA: Jossey-Bass.

Brizard, J. C. (September, 2013). Toward a common model of career and technical education. *Special Supplement to Kappan*, 1-7.

Bryan, L. A. (2003). Nestedness of beliefs: Examining a prospective elementary teacher's belief system about science teaching and learning. *Journal of Research in Science Teaching, 40*(9), 835-868.

Bybee, R. W. (2010). Advancing STEM education. *Technology and Engineering Teacher, 70*(1), 30-35.

Castellano, M., Harrison, L. & Schneider, S. (2008). State secondary career and technical education standards: Creating a framework from a patchwork of policies. *Career and Technical Education Research, 33*(1), 25-44.

Castellano, M., Stringfield, S., & Stone, J. R. S. (2003). Secondary career and technical education and comprehensive school reform: Implications for research and practice. *Review of Educational Research, 73*(2), 231-272.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Los Angeles, CA: Sage.

Clark, R. W., Farmer, E. I., & Welch, S. M. (2010). An examination of leadership issues facing Pennsylvania career and technical administrators. *Career and Technical Education Research, 35*(1), 47-62.

Cockcroft, W. H. (1982). *Mathematics counts*. London: Her Majesty's Stationary Office.

Constas, M. A. (1992). Qualitative analysis as a public event: The documentation of category development procedures. *American Educational Research Journal, 29*(2), 253-266.

Coppola, R. K., & Malyn-Smith, J. (Eds). (2006). *Preparing for the perfect storm – A report on the forum "Taking Action Together: Developing a national action plan to address the "T&E" of STEM*. Retrieved from http://www.edtechpolicy.org/Cyberwatch/GuidanceCounselor/2007/PresenterFiles/PTC-NAE_LowRes2.pdf

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Los Angeles, CA: Sage.

Darling-Hammond, L., & Hammerness, K. (2005). The design of teacher education program. In L. Darling-Hammond, & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 390-441). San Fransisco, CA: Jossey-Bass.

Darling-Hammond, L., Pacheco, A., Michelli, N., LePage, P., & Hammerness, K. (2005). Implementing curriculum renewal in teacher education: Managing organizational and policy change. In L. Darling-Hammond, & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 443-479). San Fransisco, CA: Jossey-Bass.

Datnow, A. (2005). The sustainability of comprehensive school reform models in changing district and state contexts. *Educational Administration Quarterly, 41*(1), 121-153.

DeLuca, W. V. (1991). Implementing technology education problem-solving activities. *Journal of Technology Education*, *2*(2). Retrieved from http://oaj.unsri.ac.id/files/scholar/jte-v2n2.pdf#page=5

Dewey, J. (1917). *Democracy and education*. New York, NY: Macmillan.

Dewey, J. (1977). Education vs. trade-training. *Curriculum Inquiry, 7*(1), 33-39.

Dewey, J. (1977). On industrial education. *Curriculum Inquiry, 7*(1), 53-60.

Doolittle, P. E., & Camp, W. G. (2009). Constructivism: Career and technical education perspective. *Journal of Vocational and Technical Education, 16*(1). Retrieved from http://www.eric.ed.gov/PDFS/EJ598590.pdf

Drake, S. M., & Burns, R. C. (2004). *Meeting standards through integrated curriculum*. Alexandria, VA: Association for Supervision and Curriculum Development.

Eladrel Technologies, LLC. (2011). Public schools k12. Retrieved from http://publicschoolsk12.com/all-schools/va/

Elliot, J., & Deimler, B. (2007). The premier educational delivery system. *Techniques: Connecting Education & Careers, 82*(1), 44-46.

Elmore, R. F. (1996). Getting to scale with good educational practice. *Harvard Educational Review, 66*(1), 1-27.

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. D. (1993). *Doing naturalistic inquiry: A guide to methods*. Newbury Park, CA: Sage.

Gerlach, J. (April, 2012). STEM: defying a simple definition. *NSTA Reports*, 3

Ginsburg, A., Cooke, G., Leinwand, S., Noell, J., & Pollock, E. (2005). *Reassessing U.S. international mathematics performance: New findings from the 2003 TIMSS and PISA*. Washington, DC: American Institutes for Research.

Gray, K. (2004). Is high school career and technical education obsolete? *Phi Delta Kappan, 86*(2), 128-134.

Government Accountability Office. (2009). *Career and technical education: States have broad flexibility in implementing Perkins IV - Report to congressional requesters*. Washington, DC: Author.

Hansen, D. T. (2008). Values and purposes in teacher education. In M. Cochran-Smith, S. Feiman-Nemser, & D. J. McIntyre, *Handbook of research on teacher education: Enduring questions in changing contexts* (pp.10-26). New York, NY: Routledge

Hatch, J. A. (2002). *Doing qualitative research in educational settings*. Albany, NY: State University of New York.

Herschh, D. R. (2011). The STEM initiative: Constraints and challenges. *Journal of STEM Teacher Education, 48*(1), 96-122.

Holzer, H.J., Linn, D., & Monthey, W. (2013). *The promise if high-quality career and technical education: Improving outcomes for students, firms, and the economy*. Washington, DC: College Board.

Horowitz, F. D., Darling-Hammond, L., & Bransford, J. (2005). Educating teachers for developmentally appropriate practice. In L. Darling-Hammond, & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 88-125). San Fransisco, CA: Jossey-Bass.

Huber, M. T., & Hutchings, P. (2005). *Integrative learning: Mapping the terrain*. Washington, DC: Association of American Colleges and Universities/Carnegie Foundation.

Hyslop-Margison, E. J., & Sears, A. M. (2006). *Neo-liberalism, globalization and human capital learning: Reclaiming education for democratic citizenship*. Dordrecht, Netherlands: Springer.

Jamerson, B. F. (2011). *Constitution of Virginia*. Richmond: Commonwealth of Virginia. Retrieved from http://constitution.legis.virginia.gov/ConstOfVa.pdf

Johnson, A. B., Charner, I., & White, R. (2003). *Curriculum integration in context: An exploration of how structures and circumstances affect design and implementation.* Minneapolis, MN: National Research Center for Career and Technical Education, University of Minnesota. Retrieved from http://www.pacareerstandards.com/documents/RA-6_Curriculum_Integration.pdf

Kim, Y. (2010). The pilot study in qualitative inquiry: Identifying issues and learning lessons for culturally competent research. *Qualitative Social Work*, *10*(2), 190-206. doi: 10.1177/1473325010362001

Kister, J. (2001). *State leadership for career and technical education*. Washington, DC: The National Associate of State Directors of Career Technical Education Consortium.

Knotts, G., Henderson, L., Davidson, R. A., & Swain, J. D. (2009). The search for authentic practice across the disciplinary divide. *College Teaching, 57*(4), 188-196.

Lakes, R. D., & Burns, J. Z. (2012). Strategic global advantage: The career academy/technical college state initiative. *Community College Journal of Research and Practice, 36*(6), 422-435. doi: 10.1080/10668920902917492.

Lapan, S. D., Quartaroli, M. T., & Riemer, F. J. (2012). Introduction to qualitative research. In S. D. Lapan, M. T. Quartaroli, & F. J. Riemer (Eds.), *Qualitative research: An introduction to methods and design* (pp. 3-18). San Fransisco, CA: Jossey-Bass.

Lederman, L. (September, 1998). ARISE: American Renaissance in Science Education. Fermilab-TM-2051. Batavia, IL: Fermi National Accelerator Lab.

Leithwood, K., Louis, K. S., Anderson, S., & Wahlstrom, K. (2004). *How leadership influences student learning*. New York, NY: Wallace Foundation.

Lewis, M. V., & Pearson, D. (2007). *Sustaining the impact: A follow-up of the teachers who participated in the math-in-CTE study*. St. Paul, MI: National Research Center for Career and Technical Education. Retrieved from http://136.165.122.102/UserFiles/File/pubs/Sustaining_the_Impact.pdf

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Lund, L. & Wild, C. (1993). *Ten years after 'A Nation at Risk'*. New York, NY: The Conference Board

Manley, R. A. (2011). The decentralization of Perkins: History, impact, and recommendations for future CTE legislation. *Journal of Career and Technical Education Research, 36*(2). 119-152. doi: 10.5328/cter36.2.119

Manley, R. A., & Price, W. T. (2011). The operational infrastructure of secondary-level CTE: Definition, validation, and application. *Journal of Career and Technical Education, 26*(1), 20-31.

Marshall, S. P. (2010). Re-imagining specialized STEM academies: Igniting and nurturing decidedly different minds, by design. *Roeper Review, 32*, 48–60. DOI: 10.1080/02783190903386884

McDiarmid, G. W., & Clevenger-Bright, M. (2008). Rethinking teacher capacity. In M. Cochran-Smith, S. Feiman-Nemser, D. J. McIntyre, & K. E. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts* (3rd ed.). (pp. 134-156). New York, NY: Routledge.

McLaughlin, M. W., & Talbert, J. (2003). *Reforming districts: How districts support school reform*. Seattle, WA: Center for the Study of Teaching and Policy.

McCormick, R. (2004). Issues of learning and knowledge in technology education. *International Journal of Technology and Design Education*, 14, 21-44.

Meeder, H., & Suddreth, T. (2012). *Common core state standards & career and technical education: Bridging the divide between college and career readiness*. Retrieved from http://www.achieve.org/files/CCSS-CTE-BridgingtheDivide.pdf

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Mertens, D. M. (2012). Ethics in qualitative research in education and the social sciences. In S. D. Lapan, M. T. Quartaroli, & F. J. Riemer (Eds.), *Qualitative research: An introduction to methods and design* (pp. 19-39). San Fransisco, CA: Jossey-Bass.

Meyer, D. Z., & Avery, L. M. (2009). Excel as a qualitative data analysis tool. *Field Methods, 21*(1), 91–112. doi: 10.1177/1525822X08323985.

Michigan Department of Education, Office of Career and Technical Education. (2011). *Administrative guide for career and technical education in Michigan.* Retrieved from http://www.michigan.gov/documents/mde/Administrative_Guide_for_CTE_369521_7.pdf

Moore, T. S., Lapan, S. D., & Quartaroli, M. T. (2012). Case study research. In S. D. Lapan, M. T. Quartaroli, & F. J. Riemer (Eds.), *Qualitative research: An introduction to methods and design* (pp. 243-270). San Francisco, CA: Jossey-Bass.

National Association of State Directors of Career Technical Education Consortium. (2011). Carl D. Perkins Career and Technical Education Act Fiscal Year 2012 Budget. Retrieved from https://www.acteonline.org/uploadedFiles/Assets_and_Documents/Global/files/Resources/Industry/Business_Industry_One-Pager.pdf

National Association of State Directors of Career and Technical Education. (2013). *Learning that works for America - CTE: CTE at-a-glance*. Silver Spring, MD. Retrieved from http://www.careertech.org/career-technical-education/

National Center for Education Statistics. (n.d.). *Census 1990 concepts & definitions*. Retrieved from http://nces.ed.gov/surveys/sdds/ref.asp#S

National Center for Research in Career and Technical Education. (2013). *Math-in-CTE: Overview*. National Center for Research in Career and Technical Education. Louisville, KY. Retrieved from http://www.nrccte.org/resources/curriculum-maps/architecture-and-construction

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Department of Education.

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering and mathematics*. Washington, DC: National Academy Press.

National Science Board. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system*. Arlington, VA: Author.

National Science Foundation. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system*. Arlington, VA: Author.

National Science and Technology Council Committee on STEM Education. (2011). *The federal science, technology, engineering, and mathematics: A Report from the federal inventory of STEM Education*. Washington, DC: Author.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317-328.

Often, E. (March, 2011). Crosswalks and quality: Linking math, language, and CTE standards. *Techniques*, 52-55.

Organization for Economic Co-operation and Development (OECD). (2011). *Building a high-quality teaching profession: Lessons from around the world*. Retrieved from http://www.oecd.org/education/preschoolandschool/programmeforinternationalstudentassessmentpisa/47506177.pdf

Palmer, P. J. (1998). *The courage to teach: Exploring the inner landscape of a teacher's life*. San Fransisco, CA: Jossey-Bass.

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Pearson, D., Sawyer, J., Park, T., Sanatamaria, L., van der Mandele, E., Keene, B., & Taylor, M. (2010). *Capitalizing on context: Curriculum integration in career and technical* *education*. Louisville, KY: National Research Center for Career and Technical Education, University of Louisville.

Pfeiffer, S. I., Marguerite-Overstreet, J., & Park, A. (2010). The state of science and mathematics education in state-supported residential academies: A nationwide survey. *Roeper Review, 32,* 25–31. doi: 10.1080/02783190903386579.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher, 24*(7), 5-12.

Pitt, J. (2011). Blurring the boundaries – STEM education and education for sustainable development. *Design and Technology Education: An International Journal, 14*(1), 37-48.

Project Lead the Way. (2013). *PLTW: Who we are.* Project Lead the Way. Indianapolis, IN. Retrieved from http://www.pltw.org/about-us/who-we-are

Provasnik, S. (2007). *Status of Education in Rural America*. Washington, DC: National Center for Education Statistics

Rhode Island School of Design. (2013). What is STEAM? Retrieved from http://stemtosteam.org/

Richards, A., Klein, S. G., Pfeiffer, J., & Schoelkopf, J. (2013). *State Perkins accountability congress: Final report*. Washington, DC: U.S. Department of Education, Office of Vocational and Adult Education.

Rorrer, A. K., Skrla, L., & Scheurich, J. J. (2008). Districts as institutional actors in educational reform. *Educational Administration Quarterly, 44*(3), 307-358.

Rossman, G. B., & Rallis, S. F. (2012). *Learning in the field: An introduction to qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.

Ryndak, D. L., Reardon, R., Benner, S. R., & Ward, T. (2007). Transitioning to and sustaining district-wide inclusive services: A 7-year study of a district's ongoing journey and its accompanying complexities. *Research & Practice for Persons with Severe Disabilities, 32*(4), 228-246.

Saldaña, J. (2009). *The coding manual for qualitative researchers*. Los Angeles, CA: Sage.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4), 20-26. Retrieved from http://esdstem.pbworks.com/f/TTT%2BSTEM%2BArticle_1.pdf

Sanders, M. G. (2012). Achieving Scale at the district level: A longitudinal multiple case study of a partnership reform. *Educational Administration Quarterly, 48*(1), 154 -186.

Seidman, I. E. (2013). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (4th ed.). New York, NY: Teachers College.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Shulman, L. S. (1993). Teaching as a community property: Putting an end to pedagogical solitude. *Change, 25*(6), 6-7. doi: 10.1080/00091383.1993.9938465

Shulman, L. S. (2005a). Signature pedagogies in the profession. *Daedalus, 134*(3), 52-59.

Shulman, L. S. (2005b). Pedagogies of uncertainty. *Liberal Education, 91*(2), 18-25.

Shulman, L. S., & Shulman, J. H. (2004). How and what teachers learn: A shifting perspective. *Journal of Curriculum Studies, 36*(2), 257-271. doi: 10.1080/0022027032000148298

Sindelar, P. T., Shearer, D. K., Yendol-Hoppey, D, & Liebert, T. W. (2006). The sustainability of inclusive school reform. *Exceptional Children, 72*, 317-331.

Smith, M. S., & O'Day, J. (1990): Systemic school reform. *Journal of Education Policy, 5*(5), 233-267.

Snyder, L. G., & Snyder, M. J. (2008). Teaching critical thinking and problem solving skills. *Delta Pi Epsilon, L*(2), 90-99.

STEM Education Caucus. (2011). *Innovation.* Retrieved from http://stemedcaucus2.org/

Stone, R. J., III. (February, 2009). A Perkins challenge: Assessing technical skills in CTE. *Techniques*, 21-23.

Stone, R. J., III. (2011a). *Delivering stem education through career and technical education schools and programs.* Retrieved from http://www7.nationalacademies.org/bose/STEM_Schools_Stone_Paper_May2011.pdf

Stone, R. J., III. (2011b). The Role of CTE in STEM education: An exploration of CTE delivery systems, curricula and pedagogy in advancing STEM education. Retrieved from http://www7.nationalacademies.org/bose/STEM_Schools_Stone_Presentation_May2011.pdf

Stone, J. R., III, Alfeld, C., Pearson, D., Lewis, M. V., & Jensen, S. (2006). *Building academic skills in context: Testing the value of enhanced math learning in CTE*. Columbus, OH: National Research Center for Career and Technical Education.

Symonds, W. C., Schwartz, R., & Ferguson, R. F. (2011). *Pathways to prosperity: Meeting the challenge of preparing young Americans for the 21st century*. Cambridge, MA: Pathways to Prosperity Project. Retrieved from http://www.gse.harvard.edu/news_events/features/2011/Pathways_to_Prosperity_Feb2011.pdf

Tennyson, S., & Nguyen, C. (2001). State curriculum mandates and student knowledge of personal finance. *Journal of Consumer Affairs, 35*(21), 241-262.

Threeton, M. D. (2007). The Carl D. Perkins Career and Technical Education (CTE) Act of 2006 and the roles and responsibilities of CTE teachers and faculty members. *Journal of Industrial Teacher Education, 44*(1), 66-82. Retrieved from http://www.eric.ed.gov/PDFS/EJ830476.pdf

Toulmin, C. N., & Groome, M. (2007). *Building a science, technology, engineering, and math agenda.* Washington, DC: National Governors Association.

Tsupros, N., Kohler, R., & Hallinen, J. (2008). *STEM education in Southwestern Pennsylvania: Report of a project to identify the missing components*. Pittsburgh, PA: Carnegie Mellon University

U.S. Congress. (2006). *Carl D. Perkins career and technical education Act of 2006*. Washington, DC: U.S. Government Printing Office.

U.S. Department of Education. (2004). *National assessment of vocational education: Final report to Congress*. Washington, DC: Author.

U.S. Department of Education. (2008). *A nation accountable: Twenty-five years after 'A Nation at Risk'.* Washington, DC: Author. Retrieved from http://www.ed.gov/rschstat/research/pubs/accountable/

U.S. Department of Education. (2009). Race to the Top Program: Executive Summary. Retrieved from http://www2.ed.gov/programs/racetothetop/executive-summary.pdf

U.S. Department of Education. (2010). *A blueprint for reform: The reauthorization of the elementary and secondary education Act*. Washington, DC: U.S. Department of Education.

U.S. Department of Education. (2013). *National assessment of career and technical education: Interim report*. Washington, DC:  Author.

U.S. Government Accountability Office. (2009). *Career and technical education: Report to congressional requesters*. Retrieved from http://www.gao.gov/assets/300/293150.pdf

Usdan, M., McCloud, B., Podmostko, M., & Cuban, L. (2001). *Leadership for student learning: Restructuring school district leadership*. Washington, DC: Institute for Educational Leadership.

van Teijlingen, E. R. & Hundley, V. (2001). The importance of pilot studies. *Social Re-search UPDATE*. Retrieved from http://eprints.bournemouth.ac.uk/10149/

Vega, A., & Brown, C. G. (2013). The implementation of project-based learning. *National Forum of Educational Administration and Supervision Journal*, *30*(2), 4-27.

Viadero, D. (2005). Scholars eye 'signature' method of teacher training. *Education Week*, *25*(7), 8-8.

Virginia Department of Education (2012). Governor's STEM academies. Retrieved from http://www.doe.virginia.gov/instruction/career_technical/gov_academies/index.shtml

Virginia Department of Education. (2012). Governor's STEM academies. Retrieved from http://www.doe.virginia.gov/instruction/career_technical/gov_academies/

Virginia Department of Education. (2013). CTE Administrators – March 22, 2013. Retrieved from http://www.doe.virginia.gov/instruction/career_technical/cte_resources/alpha_cte_admin_directory.pdf

Virginia Department of Education and the CTE Resource Center. (2009). Career and technical education cooperative education handbook. Richmond, VA: Author.

Virginia Department of Education, & State Council of Higher Education for Virginia. (2013). *Establishing a Governor's science, technology, engineering, and mathematics academy: Guidance document*. Richmond, VA: Virginia Department of Education, Office of Career and Technical Education Services.

Virginia Polytechnic Institute and State University. (2010). *Protection of human subjects in research*. Retrieved from http://www.irb.vt.edu/

Virginia Technical Education Administrators (VACTEA). (2013). Virginia technical education administrators. Retrieved from http://www.vactea.org/board10.html

Wells, J. G. (November, 2008). *STEM education: The potential of technology education*. Paper presented to the 95th Annual Mississippi Valley Technology Teacher Education Conference. St. Louis, MI.

Wells, J. G. (2010). Research on teaching and learning in science education: Potentials in technology education. In P. A. Reed, & J. E. LaPorte (Eds.), *Handbook of Research on Technology Education: 59th yearbook* (pp. 192-217). Reston, VA: Council of Technology Teacher Education.

Wells, J. G., & Ernst, J. V. (2012). *Integrative STEM education*. Retrieved from http://www.soe.vt.edu/istemed/

Wheelan, B. D., DeMary, J. L., & DuBois, G. (2005). Virginia plan for dual enrollment between Virginia public schools and community colleges. Retrieved from http://www.doe.virginia.gov/administrators/superintendents_memos/2005/inf073a.pdf

Williams, J. (2010). STEM education: Proceed with caution. *Design and Technology Education, 16*(1), 26-35.

Wirth, A. G. (1974). Philosophical issues in the vocational-liberal studies controversy (1900–1917): John Dewey vs. the social efficiency philosophers. *Studies in Philosophy and Education, 8*(3), 169-182.

Wolcott, H. F. (1994). *Transforming qualitative data: Description, analysis, and interpretation*. Thousand Oaks, CA: Sage.

Wonacott, M.E. (2001). Students with disabilities in career and technical education. *ERIC Digest*. 230.

Wormeli, R. (2005). Busting myths about differentiated instruction. *Principal Leadership, 5*(7), 28-33)

Wurdinger, S., Haar, J., Hugg, R., & Bezon, J. (2007). A qualitative study using project-based learning in a mainstream middle school. *Improving Schools, 10*(2), 150-161. doi: 10.1177/1365480207078048.

## Appendix A: Email Message to Regional CTE Coordinators

**Request for information on CTE/STEM education linkages**

Dear … (VA Region … CTE Coordinator)

I am a graduate student at Virginia Tech conducting a research project entitled "Career and Technical Education (CTE) Directors' Experiences with CTE's Contributions to Science, Technology, Engineering, and Math (STEM) Education Implementation". The research project is in partial fulfillment of my doctor of philosophy degree in CTE.

I am writing to seek your help with information on CTE programs in your region that are involved in integrating STEM initiatives in their programs.

Data will be collected from local directors of CTE using interviews and a brief demographic questionnaire. Please help me identify the directors I can invite to participate in the study.

Results of the study may provide insights for the formulation of CTE/STEM educational policy, and with the development of implementation guidelines, especially with respect to professional development. The research study has been approved by the Virginia Tech Institutional Review Board.

If you have any questions about this research or its conduct, you may contact the researcher, Bentry Nkhata (Tel. 540-449-1558; email: bentryn9@vt.edu); or Faculty Advisor, Dr. Bill Price (Tel. 540-231-7390; email: wprice@vt.edu).

I will be grateful if you will send me a list of directors (and their contact information) who could talk about integrating STEM content into CTE courses for.

Thank you in advance for giving my request attention.

Sincerely,

Bentry Nkhata

**Principal Researcher**

## Appendix B: Email Message to School District Directors

Dear …..

I am a graduate student at Virginia Tech conducting a research project entitled "Career and Technical Education (CTE) Directors' Experiences with CTE's Contributions to Science, Technology, Engineering, and Math (STEM) Education Implementation". The research project is in partial fulfillment of my doctor of philosophy degree in CTE.

I am writing to seek a personal interview with you to learn about your experiences with Career and Technical Education's (CTE) contributions to STEM education implementation. I believe your experience and expertise can illuminate my understanding of the research topic. The interview will be audio recorded and notes will be made to further insure the integrity of the research. I will also ask you to complete a brief questionnaire to allow me to collect demographic information about you and your school district.

Results of the study may provide insights for the formulation of CTE/STEM educational policy, and with the development of implementation guidelines, especially with respect to professional development. The research study has been approved by the Virginia Tech Institutional Review Board.

I appreciate your time commitments, and would therefore like to schedule this within the next thirty days at a time and place most convenient for you. I will contact you by phone within the next week to confirm your willingness and availability, and to schedule a time for the interview. If it is more convenient for you, please do not hesitate to respond to this e-mail with a meeting time and venue that best fits your schedule.

Questions will be on the following issues:

1. Your activities as a school division CTE director in a typical week.
2. What you consider to be STEM education.
3. Your experiences regarding linkages between CTE and STEM education.
4. Specific examples of CTE initiatives that you consider to have contributed to advancing STEM education at the school/district level.
5. Examples of CTE initiatives aimed to advance STEM education that did not achieve their intended results.
6. How the contributions of CTE in the advancement of STEM education could be made more visible and accepted to both CTE and STEM education personnel.
7. Your recommendations for policies that would mutually enhance of the goals of CTE and those of STEM education.

8. Your recommendations for curriculum that would mutually enhance of the goals of CTE and those of STEM education.

9. Your recommendations for pedagogic strategies that would mutually enhance of the goals of CTE and those of STEM education.

10. Any other information you might provide with regards to the contributions of CTE to STEM education reform.

11. About yourself (name; your education background, your work background).

If you have any questions about this research or its conduct, you may contact the researcher, Bentry Nkhata (Tel. 540-449-1558; email: bentryn9@vt.edu); or Faculty Advisor, Dr. Bill Price (Tel. 540-231-7390; email: wprice@vt.edu).

Thank you in advance for giving my request consideration.

Sincerely,

Bentry Nkhata

**Principal Researcher**

Appendix C: Interview Protocol

## Interview Protocol

The main question to be answered by this study is as follows: What have been the experiences of local directors of CTE with linkages between CTE programs and STEM education implementation? Below is a list of interview prompts that will be used to gather information necessary to answer the research questions. The interview will be of a semi-structured nature, so it is  anticipated that the participants will speak about many aspects of the topics without being prompted to do so.

The interview will be guided by the following questions:

1. Tell me your name and your job title. (Please call me Bentry. How do you prefer that I address you?)
2. What activities are typical for you as a school district CTE director? (Which ones take up most of your time and effort? If it was within your power, these would these still be the priority tasks, or something else?)
3. We are meeting today to discuss linkages between CTE and STEM education. Could you please describe your definition of STEM education? (Does it matter at all that STEM education might mean different things to different people?)
4. What have been your experiences regarding linkages between CTE and STEM education?
5. What contributions have CTE programs made to the STEM implementation? (Please describe examples of CTE initiatives that you consider to have contributed to advancing STEM education at the school/district level? Are there any common characteristics to the initiatives that have been successful?)

6. Do you have examples of CTE initiatives aimed to advance STEM education that never achieved their intended results? (What lessons can we learn from such efforts?)
7. How can the contributions of CTE in the advancement of STEM education be made more visible and accepted to both CTE and STEM education personnel? (Do you consider the desire for an integrative approach to the teaching of CTE and STEM education to be mutual?)
8. What policies would you recommend that would mutually enhance of the goals of CTE and those of STEM education?
9. What curriculum would you recommend that would mutually enhance of the goals of CTE and those of STEM education?
10. What pedagogic strategies would you recommend that would mutually enhance of the goals of CTE and those of STEM education?
11. Are there things about linkages between CTE and STEM education I haven't asked that you would like to share with me? (If an issue arises later for which I need further information or clarification from you, do you mind if I contacted you by phone or e-mail?)
12. Finally, tell me a little more aboput your educational and professional background.

At the conclusion of the interviews, each participant will be thanked for participating in the study. The interviews will be transcribed as soon as is possible after each is completed.

Appendix D: Demographics Questionnaire

**The Contribution of CTE to STEM Education Reform**

Thank you for participating in the research study, "Career and Technical Education (CTE) Directors' Experiences with CTE's Contributions to Science, Technology, Engineering, and Math (STEM) Education Implementation". To put the findings of the study in context, I would like to gather some personal information from you, as well as information on numbers of teachers in your school district.

**Personal Demographics**

1. What is your gender?

| | |
|---|---|
| Female | |
| Male | |

2. What is your age?

| | |
|---|---|
| Less than 30 years | |
| 30 to 49 years | |
| 50 to 54 years | |
| 55 years or more | |

3. What is your race?

| | |
|---|---|
| American Indian or Alaska Native | |
| Asian | |
| Black or African American | |
| Hispanic or Latino | |
| Native Hawaiian or other Pacific Islander | |
| White | |
| Other (specify) | |

4. What is your highest academic degree?

| | |
|---|---|
| Associate | |
| Bachelor's | |
| Master's | |
| Doctorate | |
| Other (please specify) | |

5. What was your college major?

6. How many years have taught at the K-12 level?

| | |
|---|---|
| Less than 4 years | |
| 4 to 9 years | |
| 10 to 14 years | |
| 15 years or more | |

7. What is your 'home' curriculum area (one in which most of your teaching was)?

8. What is your current job title?

9. Including this school year, how many years have you been in your current job?

| | In this school district | Prior to this district |
|---|---|---|
| Less than 4 years | | |
| 4 to 9 years | | |
| 10 to 14 years | | |
| 15 years or more | | |

10. What is the locale categorization of your school district?

| | |
|---|---|
| City | |
| Suburban | |
| Town | |
| Rural | |

11. Please provide the number of secondary (high) schools in your district and the numbers of teachers.

| **School type** | **No. of schools** | **No. of CTE teachers** | **No. of non CTE teachers** |
|---|---|---|---|
| Regular secondary school | | | |
| CTE school | | | |
| Career academy | | | |
| Special education school | | | |
| Alternative school | | | |
| Other type of school (please specify) | | | |
| **Total** | | | |

THE END

Appendix E: Informed Consent for Participants

# VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

## Informed Consent for Participants in Research Projects Involving Human Subjects

**Title of Study:** Career and Technical Education (CTE) Directors' Experiences with CTE's Contributions to Science, Technology, Engineering, and Math (STEM) Education Implementation

**Name of Primary Researcher:** Bentry Nkhata

### I. Purpose of the Study

The purpose of this study is to analyze the experiences of school district directors of CTE to better understand the linkages between CTE and STEM education.

### II. Procedures

You will be interviewed face-to-face for about an hour about your experiences with the contributions of CTE to STEM education reform. The interview will be audio recorded and notes will be made about the interview. The interview will take place at venue convenient to you.

Questions will be on the following issues:

1. Your activities as a school division CTE director in a typical week.
2. What you consider to be STEM education.
3. Your experiences regarding linkages between CTE and STEM education.
4. Specific examples of CTE initiatives that you consider to have contributed to advancing STEM education at the school/district level.
5. Examples of CTE initiatives aimed to advance STEM education that did not achieve their intended results.
6. How the contributions of CTE in the advancement of STEM education could be made more visible and accepted to both CTE and STEM education personnel.
7. Your recommendations for policies that would mutually enhance of the goals of CTE and those of STEM education.
8. Your recommendations for curriculum that would mutually enhance of the goals of CTE and those of STEM education.
9. Your recommendations for pedagogic strategies that would mutually enhance of the goals of CTE and those of STEM education.
10. About yourself (name; your education background, your work background).

11. Any other information you might provide with regards to the contributions of CTE to STEM education reform.

You will also be asked to complete a brief questionnaire for demographic information, and numbers of CTE and non CTE teachers in your district. The information will be used to provide context to the research results.

**III. Risks**

No more than minimal risk.

**IV. Benefits**

The results will of this study might, (a) inform policy formulation with regards to curriculum integration in general, but more specifically, an integrative approach to CTE and STEM education, and (b) inform the development of implementation guidelines for the mutual leveraging of CTE and STEM education.

**V. Extent of Anonymity and Confidentiality**

Every effort will be made to protect your identity in any written work resulting from this study. Where need arises to use a name, pseudonym will be used to identify you in any written materials. The researcher will make every effort to mask identifiers. For example, your school district will not be identified by name or other identifying characteristics.

The researcher is the only individual who will have access to the recordings of the interviews. Transcripts may be viewed only by the researcher and members of the dissertation committee.

It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

**VI. Compensation**

There will be no compensation given to you for participating in this study.

**VII. Freedom to Withdraw**

You are free stop participating in this study at any time. You may feel free to decline to answer any questions during the interview or in the questionnaire.

**VIII. Respondent's Responsibilities**

I voluntarily agree to participate in this study. I have the following responsibility:

- I agree to participate in a face-to-face audio-recorded interview and to answer questions honestly.

Initial ________ Date ________

**IX. Subject's Permission**

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_______________________________________________ Date__________

Subject signature

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

| | |
|---|---|
| Bentry Nkhata<br>Researcher | 540-449-1558/bentryn9@vt.edu<br>Telephone/e-mail |
| Dr. Bill Price<br>Faculty Co-Advisor | 540-231-7390/wprice@vt.edu<br>Telephone/e-mail |
| Dr. Penny Burge<br>Faculty Co-Advisor | 540-231-9730/burge@vt.edu<br>Telephone/e-mail |
| David M. Moore<br>Chair, Virginia Tech Institutional Review<br>Board for the Protection of Human Subjects<br>Office of Research Compliance | 540-231-4991/moored@vt.edu<br>Telephone/e-mail |

**[NOTE: Subjects will be given a complete copy (or duplicate original) of the signed Informed Consent.]**

Appendix F: Sample Interview Transcript

August 5, 2013, 2:00 pm.

Interview transcript with Participant P12, later given the pseudonym Isobel.

| P | Text |
|---|---|
| I | Ok. This is August 5. Good afternoon. May I say, again, how grateful I am for this opportunity. I know you have been exceedingly busy in preparation for the new school year. Just for the record purpose, let me have your name again and your job title. |
| P12 | Ok. My name is X. I'm with Y County Public Schools and my title is Director of Middle and Secondary Education. |
| I | Thank you. I'm here in connection with directors' experiences with linkages between CTE and STEM education. From the perspective of CTE director, what activities typically occupy your office? |
| P12 | Ok. A lot of record keeping. A lot of reports for Virginia Department of Ed, and that is extensive. We are constantly looking at the reports that we have to file—with what's called the master record collection which looks at the numbers of teachers, their endorsements, numbers of classes and students and then which of those in the CTE program and making sure that those match. The other thing we're trying to do, and this is very frustrating, to pretty much all the directors across the state—and that is changes that the department of education makes in the middle of the year. For instance, we will publish our program of studies booklet [reaches out to collect a copy of the booklet], and we publish this in the Spring for the next school year so that we have it for registration, and as soon as we take it to the publisher, then there are lists of changes that DOE makes and so, by the time we publish this, it's already out of date. So we are constantly—one of the duties that I do is—we are constantly looking at DOE's website and comparing that to our program of studies and trying to update our program studies with competencies as well as course name and numbers and letting teachers know that. So it's pulling information and disseminating information to the teachers, it's extensive record keeping and reporting, tracking budget, so tracking the funds and making sure the funds are spent appropriately, and making sure our teachers are aware of professional development activities. Those are some the major areas that I am involved in. |
| I | If it was within your power, where would you rather spend more time and effort on? |
| P12 | Of those things that I mentioned? |
| I | Yah, of the responsibilities of your office. I know some you have no choice, you've got to do them, like the reporting. But if it was within your control, where would you concentrate? |

P12 Within my control, because I love curriculum and instruction, I would be doing more direct supervision of the curriculum and instruction and working with the teachers to look at where we are with CTE in relationship to STEM and the connection from the CTE curriculum and STEM to the other areas of the curriculum.

I In my study—looking at connections between CTE and STEM education, CTE seems to be fairly clear what it is—not quite STEM education. So I would like to know what you would prefer STEM education to be considered to be.

P12 Ok. For me, STEM education is a true integration of the sciences, technology, engineering and mathematics in a project based curriculum. That's how I would define it. Whereas CTE is more defined by specific competencies and more discipline specific. I see STEM as encompassing an issue or a problem and then pulling together these other areas of science and technology and engineering and math to solve the problem.

I Ok. I know before we started recording the interview, you mentioned that you have not been in this office for long, but in the time you have here, what have been your experiences with the connections between CTE and STEM education?

P12 Ok. Again, I've been here less than a year—in this particular position. Prior to that time, I have been in the school division for 15 years—part of that as principal and then part of it Director of School Improvement. But in this last year, I see CTE very well fleshed out, very well spelled out, very well defined. I see STEM as being a little bit more nebulous. It's a little bit non defined, and where it comes to fruition is through grants and through special programs like our regional program that we have for STEM. Because we are a small school division, we do not have great success of obtaining grant funds because those grant funds look at numbers, and our numbers are small in our school division. We have approximately 4,000 students. But when you look at the number at the high school level for 9 through 12, we are talking approximately 12 hundred students, 1,200. So when we compete against Fairfax or Virginia Beach or Chesterfield—some of the larger areas, or if we even go into national competition, it's very difficult for us to compete for the funds. So we really depend on the colleges—Radford, Virginia Tech are the two most prevalent institutions of higher ed that look at funding, and we have to do it through partnership. I'm seeing more and more discussion about STEM, as we are trying to get our students in our gifted program at the elementary level involved in doing some experiences within STEM, also identifying our students who are the under-represented students to try to expand their opportunities and their awareness.

I Talking about difficulties in obtaining grants, let me jump to a question which I was going to come to later on about policy.

P12 Ok.

I Is there a way you would wish the grant application system could take into account difficulties that a division which doesn't have many students may face?

P12 Absolutely. I wish that the grants would be increased partnership, I wish that they would look at partnership between higher ed and a collection of counties. I wish they would look at the geographic location—that that would be given some priority. I wish they would look at under-representation—not in numbers, but as a pattern. Also looking at budgetary constraints. In our school division, we wear many hats, and so I wear several hats, and that's true of any small school division. So I wish they would take that into consideration. I would like to see more training for CTE directors in STEM education. That would also include other directors—director of elementary ed, directors of principals, you know, of expanding that—so it's not limited. It's not that STEM is coming out of CTE, STEM encompasses more than CTE. So I wish they would expand the training opportunities as part of the grant—if there would be some grants for training, for professional development.

I While we are still on this issue, an issue that has had mixed reaction from the directors I have talked to already—a few said that "we would be better off with a state level of STEM education so that that person would pull together the various views, the curriculum issues, and so forth". Others have been apprehensive about that, that it would be creating a new territory that is competing for the same funds. What would be your take on the idea of a state-level STEM coordinator.

P12 I would like to see the state level STEM coordinator because with it coming under CTE or part of CTE, it has a tendency sometimes to be lost because the CTE directors focus so much on CTE because of the legal requirements, that if we had a STEM coordinator, they could ask us to think broader that it would be pulling in people from the sciences and mathematics, and not just CTE, engineering, and technology. So, I would like the broader picture.

I Ok. Thanks. What programs—CTE programs in your county would you say have been particularly beneficial to supporting STEM education?

P12 Within the CTE program?

I Yes, within CTE.

P12 Definitely the technology area, definitely the business end of it, those that are in the nursing—those are the areas that tend to want to incorporate that. When we look at this brochure [drawing attention to the brochure of the Blue Ridge Crossroads Governor's Academy] these are the areas that—you will see [Engineering and Technology; Architecture and Construction; and Agriculture, Food, and Natural resources]—and you can keep this brochure. But you can see the courses and the areas that tend to come into this. Agriculture is a very big—a very important cluster in this area because this is a rural area. That's one area that is also one that would very easily to look at what are the newer inventions and the technology within that area. And so that probably would be our biggest push to kind of blend agriculture out of CTE with the mathematics and the science and the technology and the engineering within that field.

I On the other, are there programs in CTE which have potential for advancing STEM education but, in your opinion, they are not living up to expectation?

P12 I would say—I would like to see nursing expand into more STEM. That to me—that's an area that would be very easy to expand. They tend to have done the traditional nursing. Even though they want to keep up and are very linked to the current practices in the field, I'm not sure that the current practices in the field are where we want to go when you talk about STEM. So that's an area that I would like expanded into STEM.

I Generally, do teachers take to integration quite naturally or do they need a bit of prodding?

P12 They need to be prodded. They need to be prodded. However, when we look at the entire curriculum, our CTE teachers are much more likely to look at integration than our traditional core, like English or just traditional math and science and social studies. They tend to be very departmentalized. Our CTE program tends to look at more project based learning, more hands and more integrating and they are the ones who will take the first step to help and go integrate with the other traditional content areas.

I You talked of professional development, are there opportunities for joint professional development between CTE teachers and the academic teachers?

P12 Yes. In fact, this Friday, we are having our system-wide professional development day and that's where we bring all of our teachers in—K-12 and we look for generic strands. So, during the year our teachers in the CTE programs and within English and math and science will go to sessions that are particular to their area. But this opening day, we are looking at things that cross. So it may be looking at effective classroom strategies. It may be looking at understanding the English language learner, it may be looking at effective classroom management, it be looking at the flipped classroom. So, yes. They have opportunities for that.

I The one issue that comes up every now and then about successful integration, is a group of teachers working together as a community of practice and one reason why I was particularly keen to come here and—I haven't been to Floyd yet—where maybe you have one school, is that that may not be as easy as in a district where you have a number of schools for people to link up. Is that a particular challenge for a district that maybe just has one high school?

P12 It can be a challenge, and it's also a positive. It can be a challenge in that we may have one nursing teacher, and so she links up with community colleges, and she makes an effort to link up and network with other divisions. So, she has to make an effort. But the benefit is that we are broadening outside this division. On the other hand, being a comprehensive high school, it's a one-stop shop and our children are more likely to take a CTE course because it's housed in the high school than going to a career tech center. We have children who don't want to participate in the Governor's school because they leave the high school. So we also have an advantage of having everything here too.

I My next question is on policy. I know some issues on policy we have touched upon. But other policy recommendations that you would wish were in place in order to strengthen linkages between CTE and STEM education.

P12 Um [pause for thought]

I We dealt with funding issues …

P12 Right, right. I would like to see more of a directed—I don't know the right words to use here—but more of an intentional method of providing STEM education. The area that we are short in is engineering. Ok, that is a critical area. So I would like more intentional planning, support, marketing, and policy that drives STEM.

I What would you want the source of that support to be? The colleges, or the state?

P12 Public schools will tend to respond more to the state directive, but we find greater benefit when it's coming from higher ed and incorporating us as partners.

I Ok. How about curriculum—are there things you would wish to see in curriculum in way that there would be more mutual support between CTE and STEM—from the curriculum point of view?

P12 I would love to see more in the robotics field, both in STEM and in CTE. More of the aeronautics, and I know that the eastern part of the state where they have Langley Airforce base and others, they have a very strong aeronautics program. But I would like to see that added to the curriculum.

I Ok. How about classroom practice—what teachers do in class, is there something you would wish you could be seeing more in terms of CTE supporting STEM education, or vice versa.

P12 I would like to see more higher order thinking in both areas. I would like to see more higher order and more project based learning and more of real life application—those three thinks, that's what I would like to see.

I Is it something you are addressing in professional development?

P12 Yes, yes. We are. We are constantly bringing up the 21st century skills and all the different skill continuums that's involved in that. And that's with all of our teachers, not just CTE. But we are also constantly talking about higher order thinking skills and questioning of our teachers. Some of our CTE teachers tend to—they are very hands-on and the students are very responsive to the teachers. But some of our teachers may not have come through the training of educational specialist, and so they may not think in terms of asking questions at a higher level or think about guiding the thinking—that they are doing more of the concrete. I would like to see them get into more of the abstract. To think about solving problems that don't even exist now. We have to train our students how do you go about solving problems on things that don't exist so that they are ready when they are out there in the world. Entrepreneurship isn't now. Entrepreneurship is another thing that needs to be embedded with everything that we do.

I Focusing linkages on linkages between CTE and STEM education, what have been your joys, what have been you frustrations?

P12 The joys are seeing it work. Seeing the excitement on the part of the teachers as well the students. Of seeing the teachers in the math and the science become more a part of this. Frustrations are in licensure—the endorsements from the state department. When we were trying—there was a course we were trying to do, and it was going to be a STEM, and all at once, the state was telling us we had to have person endorsed in this area but, most of it was in the engineering area and it was like, there was a disconnect. So the licensure is a challenge.

I Anything else that you would wish to inform me about in connection with this subject that I may not have asked directly?

P12 I didn't know exactly how much that you wanted to know about what we were doing. This is something that we are very proud of, and this is something that we initiated in our school division … [bring attention to the brochure of the Blue Ridge Crossroads Governor's Academy for Technical Education]

I This is the Regional Governor's Academy for STEM?

P12 For STEM, right. And we are very pleased with that, and it was a way of, again, partnering because we couldn't do it by ourselves. So we had to reach out to other school divisions, and that's an important thing. The other things, I'm just going to [presenting a newsletter] …

I Yah, sure.

P12 This is a newsletter. It’s CAT Tales, it’s Career And Technical information that we try to give out to all of our schools so that everyone is aware of what we are doing and to try to involve more students in the CTE courses. They are very academic courses and years ago, long time ago, there was a perception that the CTE courses was a dumping ground, and we have worked hard in the school division to show that CTE is no dumping ground—that it is very rigorous, it is very academic, and we have a high percentage of students doing dual enrolment where they take courses—and we have a lot of our courses in CTE set up as dual credit, where they can get high school credit and college credit. We have industry certification in CTE and so that’s something we follow very closely with our students. And then I do have the two programs of study [presenting the interviewer with handbooks of Program of Studies for secondary education, and for middle schools] this is middle school, but this secondary education.

I Secondary, yah that’s the one I’m more interested in.

P12 And this shows you the courses that we offer, if you would like to have a copy of it.

I Yah, yah …

P12 …and you can see the extent of the course offerings that we do provide to the students. It is a very strong program, and when I talk to the high school, it is the CTE program that makes our high school shine. And so now we have to work with our other programs to help them develop too.

I Within CTE, which is your flagship program?

P12 Aaaah, oh my goodness [pause for thought]!

I You are proud of all of them.

P12 Oh yes, I am. I would have a hard time picking out one that would be a flagship because I really am proud of all of them. I really am, because I have been to the different little graduation services—and they not separate graduation, they are like pinning services and certification services and seeing what it does for kids. Everything from Agro science to JROTC, which is an extension of that program, and everything in between. So, I’m proud of all them.

I Finally, may I have a little more about your background, some of which you shared off the record, but now on the record …

P12 …on the record, ok [laughter]

I …and your work background to come to where you are now.

P12 Ok, and you have to cut me off because I love education and I have a passion for teaching and learning, and I tend to go on and on and on. So you just cut me out, just do this [hand sign for time-out] …

I [laughter]

P12 … for sign of time. I have been in education over 30 years. I started in North Carolina teaching English in an inner city classroom. I saw the need there for children to have some experiences that touch their heart and their spirit. It always distressed that it seemed like public schooling was made for one type of student, and that there were other students who were gifted but perhaps not in the same way of the academic. I had a nephew who dropped out of school because his talents were not tapped into—was not recognized. No one looked for the gift in him, and that was, again, in a different state. I moved to Virginia with my son, when he was seven. And in this school division, there is a very strong caring about the children. And again still, a strong academic track, but I had a child when I was an elementary principal, I had a student—he wasn’t my child but a student there who had a learning disability. He had dyslexia for reading—so reading was his disability. However, he was also gifted and he invented a potato digger in the second grade, so at seven years old. That, to me was a spark, where I saw—there are children who have gifts. And I am very passionate about the school division, because the school division cares more than just about the grades. It cares about the children, not say that we don’t have things to change. Also we had another student that—when he was in fifth grade, he was a struggling reader. He did not do work. People had him pretty well pegged as he just didn’t care. And we worked with him and we loved but we could not turn him on to anything. I saw him again when he was one of the leaders in one of the CTE programs, and he did a presentation, and he spoke brilliantly. He had invented some things that created a new line of business for his family, and it was because of the CTE program. It was the CTE program where he found his niche in education. So, I have been a classroom teacher of English and then I worked with students who were English learners. So I worked with who English was their foreign language, or second language. I moved here and was principal of an elementary school. I was there for six years and then was moved here to the central office as the coordinator of professional development. Then was promoted to director of school improvement, testing, and accountability. So I worked with all schools in all those areas, and then last year, I had the opportunity to be moved into this position because I had a love for middle and secondary, and I love career and tech too. And so I was named in this position. So, I have been in this position less than a year. So, a lot of the growth and the reason I can brag on this program is—because it’s from me and my efforts. It’s because of the gentleman down the hall, Dr. Mark Burnette. And it was his leadership and that of the schools and the teachers in the schools that made this program what it is. So it’s very easy for me to brag on it because I had nothing to do with it. I can just be the cheerleader.

I Well, but a very effective cheerleader [laughter]

P12 [laughter] Thank you.

I Thank you. Well, I’m really glad that the opportunity arose because I have absolutely enjoyed talking to you.

P12 I have enjoyed it too. Thank you so much.

I Some wonderful insights into what CTE is. I wouldn’t—if you hadn’t told me you had been here for less than a year, I would have said maybe you are a veteran.

P12 Oh thank you. That makes me feel good. That makes me feel good.

I Thank you. Thank you. [laughter and handshakes] It was an absolute pleasure. It was well worth the waiting to talk you.

P12 Well, great. I’m so glad. Thank you for considering us to talk to.

Appendix G: Transcript with Codes and Issues

| Ln# | P | Text | Code | Issue |
|---|---|---|---|---|
| 1 | I | Good afternoon, and once again, I am really grateful for this opportunity to have this | None | Preliminaries |
| 2 | | interview which is in connection with my studies. Just for record purpose, tell me your | None | Preliminaries |
| 3 | | name and your job title. | None | Preliminaries |
| 4 | P6 | Okay. It's Christopher Martini, and I am the Director of Career, Technical and Adult | Being the Director of Career, Technical and Adult Education | Preliminaries |
| 5 | | Education for Arlington Public Schools. | None | Preliminaries |
| 6 | I | As director, what activities occupy your office in a typical week in a year? | None | Duties |
| 7 | P6 | We have all kinds of activities. What we are supposed to do is we are supposed to oversee | Overseeing the curriculum in CTE | Duties |
| 8 | | the curriculum in each of career and technical education programs. That also includes | None | Duties |
| 9 | | making sure that we have equipment and the equipment is running for all of our programs. | Making sure there is equipment; and the equipment is running | Duties |
| 10 | | Making sure that there are books, making sure there is staff development, we are complying | Making sure there are books, there is staff development | Duties |
| 11 | | with what has to be done in Virginia. We are reporting out to the State. We need to make | Complying with VA requirements; Reporting to the state | Duties |
| 12 | | sure that our competencies are being taken care of. We also make sure—doing our state | Making sure competencies are being taken care of | Duties |
| 13 | | approved testing at the end for certifications, also licensures and those type of things. So, in | Doing state approved testing; Doing licensures | Duties |
| 14 | | a typical week we may be running a staff development, we'd be collecting information on | Running staff development | Duties |
| 15 | | what materials or equipment teachers would be needing for the next year. We'd be | Collecting information for the following year | Duties |
| 16 | | looking at possibly new technologies that are coming down in each of the different areas to | Looking at new technologies | Duties |
| 17 | | make sure we are up to date, and those kind of things. So that is kind of a typical week. | Being up to date | Duties |
| 18 | I | Okay. If all factors were under your control, which issues do you think that your office | None | Duties |
| 19 | | should be attending more than the others. Where would you place your priorities? | None | Duties |
| 20 | P6 | Well, I think would place my priorities on staff development, and also making sure that | Prioritizing staff development | Duties |
| 21 | | teachers had—or have the knowledge and skills they needed to be able to reach all of our | Making sure teachers have the necessary knowledge and skills | Duties |
| 22 | | students with the curriculum. I think we provide a very important curriculum and I think | Providing important curriculum | Duties |
| 23 | | that it would be important—it's really important that our teachers are able to present that | Presenting in a differentiated way | Duties |
| 24 | | in a differentiated way so all our students are able to succeed in their classes. | Succeeding in classes | Duties |
| 25 | I | My interest in this study is in linkages between CTE and STEM education. From the STEM | None | Definition |
| 26 | | perspective, it means all sorts of things to different people. In your opinion, what should | None | Definition |
| 27 | | we take STEM education to be? | None | Definition |
| 28 | P6 | I consider STEM—I like to have it as integrated STEM education. I take STEM | Having it as integrated STEM education | Definition |
| 29 | | education as science, technology, engineering and math. And I don't see those as individual | Seeing STEM as individual letters | Definition |
| 30 | | letters. I see those as working all together for a common—common practice and for our | Working together for common practice | Definition |
| 31 | | students to have an understanding that science isn't just science education. There is a | Understanding that science isn't just | Definition |

| | | | | |
|---|---|---|---|---|
| | | | science education | |
| 32 | | connection to math, there is a connection to technology and there is a connection to | Understanding connections to M, T, & E | Definition |
| 33 | | engineering with that. And if they take it only in the context of science, they're really not | Taking it in context | Definition |
| 34 | | seeing the broad—breadth of what actually can happen when they get out into the real world | Seeing the breadth of what is actually happening | Definition |
| 35 | | and how these subjects kind of intermingle and work together. That's kind of how I see it. | Intermingling of subjects | Definition |
| 36 | | I see it more as an interdisciplinary program of these. I get a little bit, I wouldn't say | Seeing it as interdisciplinary | Experiences |
| 37 | | upset, but I get—I think people started adding too many things to STEM. We're starting | Adding too many things to STEM | Experiences |
| 38 | | to see STEAM, we're starting to see all different types of things, and that's because, in my | Starting to see different types of things | Experiences |
| 39 | | opinion, they are getting on the band wagon to be able to pull funding because STEM has, | Getting on the band wagon | Experiences |
| 40 | | you know, is able to—may be provide some funding at this point but it's—it's kind of | Pulling funding | Experiences |
| 41 | | deluding I think, what STEM is or integrated STEM. | Deluding what STEM education is | Definition |
| 42 | I | So at state level, you would rather have everyone have a common definition of what STEM | None | Definition |
| 43 | | —because as you said, I have met STEM with an 'H' meaning health sciences, STEAM, and … | None | Definition |
| 44 | P6 | Yah, there's too many—I mean, everybody is trying to get on to—to jump onto the band | Jumping onto the band wagon | Definition |
| 45 | | wagon. I used to think that the 'T' and 'E' used technology education, and now it's | Thinking T & E meant technology education | Definition |
| 46 | | technology and engineering. So [laughter]—you know what I mean. I'm not—to say that | None | Definition |
| 47 | | it shouldn't be part of it. But I really think everybody is kind of jumping on it. And I wish | Jumping on it | Definition |
| 48 | | that we would have just a general understanding that—um like a said, I see it more as the | Having a general understanding | Definition |
| 49 | | integration, and I'm everybody doesn't see—you know, some people don't see it that way | Seeing it as integration | Definition |
| 50 | | but—I see it as an integration of those four subjects and how rich an educational | Seeing it as an integration of S,T,E&M | Definition |
| 51 | | experience it would be if we were able to connect those entities together. | Being able to connect entities | Definition |
| 52 | I | Okay. What have been your experiences as director with linkages between CTE and | None | Experiences |
| 53 | | STEM education? | None | Experiences |
| 54 | P6 | I think that varies, and I think it varies by our—each of our leaders of our individual school | Varying [experiences] | Experiences |
| 55 | | systems. I see, as an integral part of career and technical education. I think it should be a | Seeing [STEM educ] as an integral part of CTE | Experiences |
| 56 | | direct linkage to that. I think that sometimes when look at pure academics, we don't | Being a direct link | Experiences |
| 57 | | include the technology, and engineering to that. And I think that's—that's not the right | None | Experiences |
| 58 | | way of doing it. Um, let's see, when we, you know, I think sometimes we start looking | Looking towards science | Experiences |
| 59 | | more towards science or towards us the leaders of it, and see it as components. I really | Seeing it as components | Definition |
| 60 | | see the technology and the engineering bringing them all together. And I think that's why | Bringing [S,T,E,&M] them all together | Definition |
| 61 | | we're an integral part of it, and we can't be an outside part of it. And with career and | Being an integrap part of it | Definition |
| 62 | | technical education, I see that, kind of as the linchpin between the science and the math | Being the linchpin between science and math | Definition |
| 63 | | because we have that in all our courses. And I think we can show STEM connections in | Showing STEM connections in all CTE | Definition |
| 64 | | all of our career and technical courses. | None | Definition |
| 65 | I | Do STEM educators see that opportunity as well for linking with CTE? I see that there is | None | Experiences |
| 66 | | a lot of effort from CTE educators to integrate with academics in general, but STEM in | None | Experiences |
| 67 | | particular. Is it mutual? | None | Experiences |

| | | | | |
|---|---|---|---|---|
| 68 | P6 | I don't think it is all the time. I think it gets to be more mutual when the science and the | Getting more mutual | Experiences |
| 69 | | math teachers see what we are doing and what we have—what we teach in our curriculum | Seeing what we are doing | Experiences |
| 70 | | in our different areas. I will give you an example. We are working on a summer program | Giving example | Experiences |
| 71 | | where we are helping students to learn, or to enhance their math abilities and we are | Helping students to learn | Experiences |
| 72 | | doing that in the context of boat building and we have a technology education teacher and | Doing that in context | CTE'sContributions |
| 73 | | we have a math teacher working together. And the math teacher was looking at all these | Working together [with math teacher] | CTE'sContributions |
| 74 | | different components of what we need to learn to build a boat and seeing the | Needing to learn [to build a boat] | CTE'sContributions |
| 75 | | mathematical connections. And I think by her seeing those connections, it really starts | Seeing the connections [math teacher] | CTE'sContributions |
| 76 | | having them feel that we are a part of this, and should be a part of that. Before that, I | Having them feel they are a part | CTE'sContributions |
| 77 | | don't know if she would have thought that. | None | CTE'sContributions |
| 78 | I | So, generally, what contributions have CTE programs made to STEM education implementation? | None | Experiences |
| 79 | P6 | I think it's brought it to the fore front. I think it's um—I think it's really brought project- | Bringing [STEM] to the forefront | CTE'sContributions |
| 80 | | based learning to the fore front and now we are hearing a of project science. And I think | Bringing project-based learning | CTE'sContributions |
| 81 | | that's really because of the STEM. I think with math too. I mean there is a lot of | None | CTE'sContributions |
| 82 | | manipulatives and things like that. But I think that math is also looking at how they can | Manipulating things | CTE'sContributions |
| 83 | | make it more relevant to students and I think that 'relevancing' is really what helps the | Making it more relevant | CTE'sContributions |
| 84 | | student kind of have a broader understanding of things. You know, too many times we here | Broadening understanding of things | CTE'sContributions |
| 85 | | 'when am I ever going to use this math?' And in STEM you can start seeing that, and | Seeing where to use STEM | CTE'sContributions |
| 86 | | seeing when it can be used. | Seeing where to use STEM | CTE'sContributions |
| 87 | I | Um, other the initiative you have described about the boat building, are there others | None | Example_Positive |
| 88 | | which stand out as particularly successful in linking CTE and STEM education? | None | Example_Positive |
| 89 | P6 | We started with Math-in-CTE … | Starting with math-in-CTE | Example_Positive |
| 90 | I | Oh, okay … | None | Example_Positive |
| 91 | P6 | I don't know if you are familiar with that? | None | Example_Positive |
| 92 | I | I'm familiar with that. Yes, yes I am. | None | Example_Positive |
| 93 | P6 | We went through that whole process with Louisville. And that really I think helped show | Showing integration | Experiences |
| 94 | | that integration—we have moved a little bit off—we have used the same concept but we | Moving a little bit off | Experiences |
| 95 | | have also brought in the STEM. So we have brought in science teachers, and math | Bringing in STEM | Experiences |
| 96 | | teachers, and career and technical teachers to work together to come with integrated | Working together to integrate subjects | Experiences |
| 97 | | subjects—oh, integrated activities. And I think that really has helped get more people | Getting more people involved | Experiences |
| 98 | | involved and to have that understanding of STEM. | Understanding of STEM | Experiences |
| 99 | I | Has that momentum been sustained—which was generated by the Math-in-CTE … | None | Experiences |
| 100 | P6 | This summer is going to be out fifth summer that we are going to be doing it. But I will | Doing math-in-CTE | Experiences |
| 101 | | say it hasn't—it hasn't been just an—I mean we continually go out and promote to make | Promoting continually | Experiences |
| 102 | | sure that we can keep the momentum going, and it's really by word of mouth too. You | Keeping the momentum going | Experiences |
| 103 | | know, some of the teachers start saying, hey you know, this is what I did this summer. | Having done it in summer | Experiences |
| 104 | | This is how I'm working with the career and technical teacher and then they start to see | Working with the CTE teacher | Experiences |
| 105 | | what's going on and then also want to, kind of come on board. | Coming on board | Experiences |
| 106 | I | That was obviously a huge initiative—very successful, for that. But are there some | None | Experiences |
| 107 | | initiatives that you have attempted as a district to link CTE and STEM education which … | None | Experiences |

| | | | | |
|---|---|---|---|---|
| 108 | P6 | Which haven't worked? | None | Example_Negative |
| 109 | I | …which, which you are not very pleased with? | None | Example_Negative |
| 110 | P6 | I think there's probably always some those, [laughter] unfortunately. I would say, um | Having some [unsuccessful initiatives] | Example_Negative |
| 111 | | we've been working with children's engineering—design engineering. I'm not sure if | Working with children's engineering | Example_Negative |
| 112 | | you're familiar with that at all. But we are working with one school, and it's been a little | Working with one school | Example_Negative |
| 113 | | bit more difficult for the teachers to grasp that concept because it was more of 'you need | Grasping [children's engineering] concept | Example_Negative |
| 114 | | to do this', as opposed to showing them and them wanting to do that. So I think it just | Showing them [what to do] | Example_Negative |
| 115 | | depends on how it's introduced and how teachers embrace it. Whether it's successful or not | Depending on how its introduced | Example_Negative |
| 116 | | —because the mandating that you need to do that hasn't been as successful as some of the | Mandating that you need | Experiences |
| 117 | | school we have gone into that said, hey we have a group of teachers that's interested in | Going into schools | Experiences |
| 118 | | doing this, and we brought the training in, and we've done the training and it's grown and | Training; Growing | Experiences |
| 119 | | blossomed. So, I think that's kind of the key—is really having the teachers buy-in to do it. | Having the teacher buy-in; Blossoming | Experiences |
| 120 | | To do an integration type of an activity. Does that kind of … | Doing an integration type of activity | Experiences |
| 121 | I | Yah, yah, yah. | None | Experiences |
| 122 | P6 | Okay. | None | Experiences |
| 123 | I | Because—especially that you have a shining example with the Math-in-CTE. I think | None | Example_Positive |
| 124 | | maybe strategies would have been similar to children's engineering … | None | Example_Positive |
| 125 | P6 | Yah. | None | Example_Positive |
| 126 | I | How can the contributions of CTE towards STEM education be made more visible, and | None | Recognition |
| 127 | | acceptable too to not just CTE educators, but other educators as well? | None | Recognition |
| 128 | P6 | I think you need to promote. I'm not sure if we are good at promoting some of things that | Promoting some of the things we do | Recognition |
| 129 | | we do. You know, getting the word out. Getting it out to different venues to be able to | Getting the word out | Recognition |
| 130 | | highlight it—I think that's really how we can go ahead and spread that. Um, getting more | Getting more parents involved | Recognition |
| 131 | | parents involved and having them spread the word that way. I always thought too that—I | Having them spread the word | Recognition |
| 132 | | know that in Maryland, one of the things that they have done is that they have made it a | Making it [STEM course] a requirement | Recognition |
| 133 | | requirement—that students have to take a technology—a technology education component. | None | Recognition |
| 134 | | But then everybody started to—you know, that helps kind of spread the—technology | Spreading technology education | Recognition |
| 135 | | education anyway, part of the STEM. But then people started connecting technology and, | Connecting [STEM] to technology education | Recognition |
| 136 | | like music or technology and this and kind of watering down really what the purpose of the | Watering down [STEM education] | Recognition |
| 137 | | law was. So, you know, I really do think though that promotion and getting people to see | Getting people to see | Recognition |
| 138 | | what we're doing and the connections that we're doing is the best advertising and the best | Advertising [what we are doing] | Recognition |
| 139 | | way to promote and to spread STEM. | Spreading STEM | Recognition |
| 140 | I | Do you subscribe to the view that CTE is still fighting the stigma that it's for the weak students? | None | Recognition |
| 141 | P6 | Yes. | None | Recognition |
| 142 | I | It still is the case? | None | Recognition |
| 143 | P6 | I think it's still the case. You know, we are starting to call it college and career readiness, | Starting to call it college and career readiness | Recognition |
| 144 | | but we still have that college or. I always try to say, it's career and college because if you're | Having college OR | Recognition |

| | | | | |
|---|---|---|---|---|
| 145 | | not going to college for a certain career path, you're just gonna flounder and you're not | Going to college | Recognition |
| 146 | | going to have a focus on getting all the way through. But I do still think that there is that | Focussing on getting all the way through | Recognition |
| 147 | | stigma. Um, and I think people are starting to see that it's more of a benefit. But it's still | Starting to see the benefits | Recognition |
| 148 | | —there is still a lot of work to done. | Having a lot of work to be done | Recognition |
| 149 | I | Were you upset with the Secretary of Education, two years ago when they increased | None | Recognition |
| 150 | | education budget but reduced CTE budget because CTE hadn't proved itself. Were you | None | Recognition |
| 151 | | disappointed with that? | None | Recognition |
| 152 | P6 | Oh yah. I am. I think that we're always seeming to have to prove ourselves. I think when | Proving ourselves | Recognition |
| 153 | | you start looking at some of the certifications that students are getting as they are going | Getting certifications | Recognition |
| 154 | | through and we are preparing them for those, as they are getting some of the industry | Getting industry certification | Recognition |
| 155 | | certifications that typically people do once they've been in industry. As we start seeing some | Seeing some of the data | Recognition |
| 156 | | of the data—I think the other thing that we need to do a little bit more is really track some of | Tracking some of the students | Recognition |
| 157 | | our students, in a good way, not track them in classes but see where they go and where they | Seeing where they [students] go | Recognition |
| 158 | | are two, four, six years after high school and seeing how successful they are. Because I | Seeing how successful they are | Recognition |
| 159 | | don't think we promote that as well either. I mean, I have seen a few studies here and there | Promoting as well | Recognition |
| 160 | | where it says, you know, they are more successful if they have gone through a career and | Going through CTE | Recognition |
| 161 | | technical course and gone on to college. But I really think we need more data like that to | Needing more data | Recognition |
| 162 | | hold up and say hey, our students are well prepared for a career, for post-secondary | Preparing for career | Recognition |
| 163 | | education—whichever they want to go, however they, you know, wherever their career | Preparing for post-secondary | Recognition |
| 164 | | takes them. | None | Recognition |
| 165 | I | Okay. What policies would you recommend that would mutually enhance the goals of | None | Policy |
| 166 | | CTE and the goals of STEM education? | None | Policy |
| 167 | P6 | Um, I would recommend that we had a career and technical course that everybody— | Recommending CTE course for all | Policy |
| 168 | | career and technical courses that everybody would be taking a part in, and I would also | Taking part in it | Policy |
| 169 | | promote that we would have a common planning period for math, science, technology, | Planning perod | Policy |
| 170 | | engineering teachers so that they could have common opportunity to develop activities | Having common opportunities | Policy |
| 171 | | that could be cross curricula and working with students cross 'curricularly'. So that's kind | Working with students cross "curricularly". | Policy |
| 172 | | of what I would like to see. More of a planning time when we could get a group of those | Getting a group of teachers together | Policy |
| 173 | | type of teachers together and also to have a project-based approach to those subject areas. | Having a project-based approach | Policy |
| 174 | I | Okay. But you already have—Virginia as state there is the policy already that every | None | Policy |
| 175 | | student should have a CTE elective, isn't it? | None | Policy |
| 176 | P6 | It's either fine or practical art … | None | Policy |
| 177 | I | It's not mandatory? | None | Policy |
| 178 | P6 | A fine or practical art. So that fine or practical arts could be a music program, it could be | None | Policy |
| 179 | | an art program. | None | Policy |
| 180 | I | Alright, I get you. | None | Policy |
| 181 | P6 | So they don't necessarily have to take a career and technical course. | None | Policy |
| 182 | I | Okay. | None | Policy |
| 183 | P6 | They also have one that says that they have to have industry certification. But it doesn't | Having industry certification | Policy |

| | | | | |
|---|---|---|---|---|
| 184 | | say how they get that industry certification, you know. The best way that we are trying to | Getting industry certification | Policy |
| 185 | | promote it is they should take a sequence of career and technical courses that will lead to | Promoting sequence of CTE courses | Policy |
| 186 | | a certification, but the law doesn't state that. It doesn't go that far. | Having the law state it | Policy |
| 187 | I | How about at the curriculum level, what would you like to see to strengthen linkages | None | Curriculum |
| 188 | | between CTE and STEM education—curriculum as well as classroom practice? | None | Curriculum |
| 189 | P6 | Um, let's see, curriculum wise, I would like to see working together with subjects to have a | Working together with subjects | Curriculum |
| 190 | | common curriculum. In the course work, or the classes, I think like I said, I think that | Having a common curriculum | Curriculum |
| 191 | | there should be common activities that they are doing where students can actually see how | Having common activities | Curriculum |
| 192 | | everything kind of fits together. The example we are looking at—we are looking at | Seeing how everything fits together | Curriculum |
| 193 | | building a new elementary school, so we sat down with the architect. They're talking of | Building a new elementary school | Curriculum |
| 194 | | having cisterns to catch the rain water off of the roofs. We start looking at that. But how | Catching rain water off the roofs | Curriculum |
| 195 | | can we then also show or have places where students can monitor how much rain—how | Monitoring amount of rain | Curriculum |
| 196 | | much is in the cistern, how much comes off on the rain? Have them figure those things | Figuring things out | Curriculum |
| 197 | | out. How do we enhance math and science curriculum to be able to tie all of that together? | Enhancing math and science curriculum | Curriculum |
| 198 | I | Um, other than what I have asked, are there are issues about connections between CTE | None | Experiences |
| 199 | | and STEM education that you would wish to let me know about? | None | Experiences |
| 200 | P6 | I think, I don't know if—I try to stay on top of some of the newer things that are coming | Staying on top of newer things | Experiences |
| 201 | | up. I think that are ever changing—you know, and there is a lot of new … | Changing all the time | Experiences |
| 202 | I | In a positive way, I hope? | None | Experiences |
| 203 | P6 | Right. In a positive way. I mean, I think it might be kind of interesting to see [gathering | Being interesting to see | Experiences |
| 204 | | thoughts]—if there is—I'm not sure quite how to do it, but possibly, I don't know— | Being sure how to do it | Experiences |
| 205 | | maybe podcasts or things like that to kind of, to be able to enhance STEM education so | Enhancing STEM education | Experiences |
| 206 | | people understand what STEM education is all about. I think the general public—you say | Understanding what STEM education is about | Experiences |
| 207 | | that there are so many different definitions. I think if you asked the public as well what | Differing definitions | Definition |
| 208 | | STEM education is you're going to get a lot of different definitions. | Getting different definitions | Definition |
| 209 | I | A lot of parents very proud to say, oh, I was poor myself [laughter] | None | Experiences |
| 210 | P6 | That's right. That's right. So, somehow trying to—maybe get a common definition so | Getting a common definition | Definition |
| 211 | | people have a common understanding of what it is and what it should like. Because I | Having a common understanding | Definition |
| 212 | | don't know if people know when they are going into a school—what should it look like? | Going into a school | Definition |
| 213 | | I don't know if—I have an idea of what I think it looks like. But how do we get that out to | Having an idea what it looks like | Definition |
| 214 | | everybody. | Getting that out to everybody | Definition |
| 215 | I | Finally, just a little more about yourself—your educational background, your work background. | None | Bio |
| 216 | P6 | I was—I went to school for Industrial Arts. So that's what my college degree was in. From | Going to school for industrial arts | Bio |
| 217 | | there I worked in the woodworking industry for about ten years before I came into | Working in the woodworking industry | Bio |
| 218 | | working as a teacher. In the woodworking industry, I got to see really a lot of changes in | Seeing a lot of changes | Bio |
| 219 | | equipment and how things were done, and processes. I learnt a lot about different types of | Learning different types of things | Bio |
| 220 | | woodworking and construction and that type thing, and then I got into teaching, and I | Getting into teaching | Bio |
| 221 | | taught in a high school—taught electricity, electronics. I taught material and process, I | Teaching electricity | Bio |
| 222 | | taught drawing classes, and then in the middle school, I taught each of the 6th, 7th and 8th | Teaching drawing classes | Bio |

| | | | | |
|---|---|---|---|---|
| 223 | | grade programs which was intro to engineering—oh, intro to technology, inventions and | Teaching intro to engineering | Bio |
| 224 | | innovations in technological systems. So, and then I became a technology education | Becoming a technology edication supervisor | Bio |
| 225 | | supervisor. So I did supervising—then I became director for technical and adult education. | Supervising | Bio |
| 226 | I | Talking of Industrial Arts, before I came to Virginia Tech—back home in Zambia we still | None | Experiences |
| 227 | | have Industrial Arts and the teachers of Industrial Arts were lobbying that the subject be | None | Experiences |
| 228 | | changed to Design and Technology. I wasn't into CTE then. But the sense I got was that | None | Experiences |
| 229 | | they really wanted change of name, but not change of anything else. | None | Experiences |
| 230 | P6 | Yah. | None | Experiences |
| 231 | I | If you were there with the meeting of teachers, what would you advise them to be their | None | Experiences |
| 232 | | priority concern as they advocate for the change of name from Industrial Arts to … | None | Experiences |
| 233 | P6 | I think they have to—it's easy to change a name. It's hard to change content. And I think | Changing name | Experiences |
| 234 | | that as they look at it, it's really looking at how you can change content so that students | Changing content | Experiences |
| 235 | | have a better understanding and a better ability of where they could be. I always—I | Ungerstanding where they could be | Experiences |
| 236 | | myself, always like to look at—I never like to do the same thing over and over and over | Doing the same thing over and over | Experiences |
| 237 | | year after year after year. I was always looking for something new or something different | Looking for something new | Experiences |
| 238 | | to do. And I found it very refreshing when I was also work with colleagues. And I think | Working with colleagues | Experiences |
| 239 | | that's what STEM integration gets you to do—is to really, and a case in point, you know, I | Getting you to do | Experiences |
| 240 | | would do a hot air balloon with my students. So we would build the envelop for the hot air | Building the envelop | Experiences |
| 241 | | balloon and we would fly the hot air balloon. And as I started working with that, I started | Working with hot air balloons | Experiences |
| 242 | | learning a little bit more about the atmosphere, and about it being a fluid, and I started | Learning about the atmosphere | CTE'sContributions |
| 243 | | learning a little bit more science but if I had a little more connection with my science | Having a more connections with the science teacher | CTE'sContributions |
| 244 | | teacher, then I would have been able to enhance that more for my students and myself | Enhancing [learning] of students | CTE'sContributions |
| 245 | | because I was limited. I think that, I think we still have that—even with some of the | Being limited | Experiences |
| 246 | | people when we go to our technology education associations, there still people that say I | Going to TE conferences | Experiences |
| 247 | | want to do my wood shop, and I'm not going to do anything else. But really, that's not | Doing my wood shop | Experiences |
| 248 | | opening students' eyes and really giving them an opportunity to really go as far as they can. | Opening students' eyes | Experiences |
| 249 | | I think that's where we need to be looking—is how can we give a student an opportunity | Giving students an opportunity | Experiences |
| 250 | | to really grow and go further than we did. And if we don't change the way we do things, | Changing the way we do things | Experiences |
| 251 | | if we just change a name, we don't change we way we're doing things, we are still | Changing the way we do things | Experiences |
| 252 | | limiting our students. | Limiting students | Experiences |
| 253 | I | Well that's all I had. Again, I'm really grateful for this opportunity. I know time is | None | Pleasantries |
| 254 | | precious—for everyone is busy. But so, thank you very indeed. | None | Pleasantries |
| 255 | P6 | You're welcome. I have a question for you. | None | Pleasantries |
| 256 | I | Yes please. | None | Pleasantries |
| 257 | P6 | So how are you going to change them? How are you going to change the—from | Changing them | Curriculum |
| 258 | | Industrial Arts to …. | None | Curriculum |
| 259 | I | [laughter] Well. I support the desire to change. But as you said, their focus should be on | Focusing on new things | Curriculum |
| 260 | | what new things do they want do they want to do, rather than what new name do they want. | None | Curriculum |
| 261 | P6 | Right. | None | Curriculum |

| | | | | |
|---|---|---|---|---|
| 262 | I | What do they want their students to be able to do which is different from what they are | Doing different things | Curriculum |
| 263 | | doing now. But that aspect of the discussion, I didn't pick any of it. | None | Curriculum |
| 264 | P6 | Okay. It seems like it's going to be a—well it's been a challenge for us. I mean, we are still … | Being a challenge | Curriculum |
| 265 | I | Oh in UK, it's now called this—we also [laughter]. Yah | None | Curriculum |
| 266 | P6 | Yah, it is to change name. | Changing name | Curriculum |
| 267 | I | Because with that, I'm sure they would be advocating for professional development as | Advocating for professional development | Curriculum |
| 268 | | well because it would a new concept. | None | Curriculum |
| 269 | P6 | Yah, that's right. | None | Curriculum |
| 270 | I | So, I didn't hear much of that. Maybe in my absence the discussion could have changed. | Changing discussion | Curriculum |
| 271 | P6 | I found that the design briefs were very helpful, and I'm not sure if, you know, you're | Finding design briefs helpful | Curriculum |
| 272 | | doing that at this point. | Doing [design briefs] | Curriculum |
| 273 | I | Yah, I did some with Mark Sanders. | None | Curriculum |
| 274 | P6 | Okay, oh yes. But I see that's kind of a different way of looking at things. And what I | Looking at things differently | Experiences |
| 275 | | really like about that, is when you give it to students—they come up with all different | Coming up with different ideas | Experiences |
| 276 | | ideas and some things that you don't think about. I think that's really neat because it's not | Being neat | Experiences |
| 277 | | a yes or no. It's not, 'this is the right way to do it'. There's really many right ways of | Having many right ways | Experiences |
| 278 | | doing it, and how can you come out with a solution from that. So … | Coming out with a solution | Experiences |
| 279 | I | It gives students more ways to succeed in their own way. | None | Experiences |
| 280 | P6 | That's right. That's right. | None | Pleasantries |
| 281 | P6 | Well, thank you. | | Pleasantries |

Appendix H: Compilation of Codes for the Issue “CTE's Contribution to STEM Education Implementation”

| | | |
|---|---|---|
| P6 | P7f | P7m |
| Advertising [what we are doing] | Advertising | Acknowledging industry certification |
| Connecting [STEM] to technology education | Beginning to change | Basing on what 'building' thinks |
| Focusing on getting all the way through | Being not weighted | Being a higher requirement that SOL |
| Getting certifications | Branding CTE | Being a much higher level [of standards] |
| Getting industry certification | Dispelling old vocational education | Being an excellent point |
| Getting more parents involved | Doing public relations | Being extremely hard |
| Getting people to see | Doing something | Being significant |
| Getting the word out | Figuring their GPA | Changing their image |
| Going through CTE | Flooding the market | Fighting perception |
| Going to college | Flooding the market with information | Getting the distinction of Governor's academy |
| Having a lot of work to be done | Getting data out | Giving credibility from outside |
| Having college OR | Getting higher GPA | Giving credibility to our programs |
| Having them spread the word | Giving the a higher GPA | Giving distinction of Governor's academy |
| Making it [STEM course] a requirement | Having image issue | Giving final exam |
| Needing more data | Having to be NATEF certified | Giving validation |
| Preparing for career | Hurting their GPA | Having different perception |
| Preparing for post-secondary | Making a sustainable change | Having governor's STEM academy |
| Promoting as well | Marketing a new product | Having huge enrolments |
| Promoting some of the things we do | Marketing it [CTE] | Having internal and external audiences |
| Proving ourselves | Marketing your program | Having small enrolments at some big schools |
| Seeing how successful they are | Publicising what students are | Having weighted classes |

| | | |
|---|---|---|
| | doing | |
| Seeing some of the data | Signing up for weighted classes | Lacking belief in [CTE] programs |
| Seeing where they [students] go | Taking a class | Lacking understanding |
| Spreading STEM | Taking weighted class | Passing [industry standard exams] |
| Spreading technology education | Talking at schools, to parents | Perceiving the academic level of the class |
| Starting to call it college and career readiness | Thinking it's for kids not going to college | Realizing programs incorporate math |
| Starting to see the benefits | Thinking vocational education | Realizing the standards they are being held to |
| Tracking some of the students | Weighting | Running it like you used to |
| Watering down [STEM education] | Working to change the perception | Running through CTE |
| | | Seeing today's classes |
| | | Signing up [for weighted CTE class] |
| | | Stepping up |
| P9 | P12 | Stepping up teacher training |
| Assuming being effective | Being a very strong program | Stepping up the curriculum |
| Being difficult to prove efficacy | Being rigorous | Taking the same test |
| Being made visible | Doing dual enrolment | Teaching curriculum |
| Dealing with high school kids | Dumping ground | Using other techniques |
| Demonstrating what students are doing | Following closely industry certification | |
| Doing it building by buiding | Getting high school and college credit | P8 |
| Going through a number of CTE electives | Giving [newsletter] to all schools | Being not as bad |
| Highlighting what's going on in classrooms | Having two programs of study | Bringing kids along |
| Increasing visibility | Helping them develop too | Doing our best to accommodate |
| Inviting teachers into classrooms | Involving more students in CTE | Getting all kids exposed |
| Leaving hall way open | Making aware of efforts | Getting involved as early as elementary |
| Lobbying organizations optimistic | Making our high school shine | Getting representation |
| Making classroom work more public | Offering courses | Getting students involved |
| Making them visible | Offering courses | Having 600 kids |

| | | |
|---|---|---|
| Proving effectiveness | Showing CTE was no dumping ground | Having more staff dev., resources & funding |
| Proving efficacy of CTE may be impossible | | Having programs that interest kids |
| Reinstating the shortfall in Perkins | P11 | Having to do with funding and resources |
| Seeing what's going on | Being aware [of STEM activities] | Having to work |
| Supporting what CTE is accomplishing | Connecting with STEM | Lacking funds and staff |
| Trying small effort | Doing all through their classes | Lacking resources |
| Waxing and waning | Doing research | Needing more staff resources and funding |
| | Emphasizing STEM concepts | Offering programs kids desire |
| P3 | Incorporating different strategies | Pressuring school board |
| Advisory council | Letting teachers [explore] | Requesting it |
| Asking about making CTE visible | Realizing that they are doing | Serving a portion of students |
| Asking about making CTE visible | Relating [to STEM] | Setting up programs early |
| Coming fron all around the area | P4 | Taking back seat to core subjects |
| Make STEM work | Incorporating technologies | Taking high tech classes |
| | Lending themselves to promoting STEM | |
| P10 | Promoting CTE activities | P2 |
| Continuing education and PD | Promoting the STEM work that is going on | Planning |
| | Seeing all CTE as promoting STEM | |
| P1 | P5 | P2 |
| Adding industry certifications | Being in position for 22 years | Avoiding cut in funding |
| Appreciating CTE | Being longest serving superintendent | Being able to force the horse |
| Being a lab someone might do | Being meaningful data | Being a mindset |
| Being a real supporter of CTE [SoE] | Being noticed [efforts] | Dealing with someone's best |
| Being for those other kids that can’t achieve in the high school | Being rigorous | Doing better than those with bachelors' degrees |

| | | |
|---|---|---|
| Being wrapped up in testing (SoLs) | Being significant | Doing through STEM education |
| Bringing recognition to the program | Being very respected | Finding a degree and a job |
| Completing the mandated requirements | Bringing all that together | Gaining employment |
| Fighting historical battle of being for 'those other' kids | Bringing attention [to CTE] | Getting college education at four-year university |
| Fighting image [all we do is bake] chocolate chip cookies | Having 28,000 students in CTE | Getting information to parents |
| Finding a job | Having no [secretly successful programs] | Getting right information to parents |
| Getting better paying jobs | Having room to tell the story | Giving [parents] the data |
| Having a shift in the pendulum | Having some really neat little things | Giving people the information |
| Having more dual enrolment courses than core areas | Hearing of best kept secrets | Going down a path |
| Looking at all the job openings | Leveraging STEM education | Going on to do great things |
| Looking at what business and industry want | Making me proud | Having exceptions to the rule |
| Looking at what the other options are | Making me proud | Having job openings that don't match parents' dreams |
| Looking for CTE skills | Seeing the open houses | Having to train and retrain |
| Making policy makers aware | Talking about partnership | Hosting career fairs |
| Moving CTE into an equal peer | Talking about what we are doing | Informing govt agencies how you are using money |
| Moving CTE out of the red-headed srep-child position | Tooting own horn | Involving them in what you are doing |
| Paying attention to economic need | Understanding how great it was | Letting govt officials know their dollars are well spent |
| Seeing results of their students [jobs] | | Making funding decisions |
| Seeming that policy makers do not know | | Making the best decisions |
| Starting to change | | Making the best decisions |
| Trying to jumping over those hurdles | | Matching earnings to degrees |

## Appendix I: Sample Memos

**September 18, 2013**

**Definition of STEM education**

Changed one category of definitions form “interdisciplinary teaching” to integrated teaching”

To follow up on Drake & Burns curriculum integration.

Interesting how most definitions are functional rather than textbook-based.

Cyrus stated that STEM was really a secondary education thing [not just CTE]. It’s advanced math, advanced science, engineering, technology and ultimately STEM would be a way to kind of weave those together to help students understand how they work together to provide career opportunities for students in those fields”. This definition has many aspects of Integrative STEM education except for the focus on T&E and intentionality.

Bryant: And if they take it only in the context of science, they’re really not seeing the breadth of what actually can happen when they get out into the real world and how these subjects kind of intermingle and work together. (Ln# 33-35] Can link this to definition 4.

**September 13, 2013**

**Results**

Having done the first part of the results, now wondering where results of the pilot study should go—Methods or Results. I think that since the pilot was part of ensuring quality and rigor, it should remain in Methods.

**September 13, 2013**

**Focus coding**

Need to locate the source for the four-point locale categorization: city, suburban, town, rural.

Great to talk by phone to Nancy Tsupros, author of the widely quoted STEM education definition. Publication to be posted today in the afternoon.

Demography: One director was less than a year in post but still had great insights; another director declined to participate for lack of experience.

**September 12, 2013**

**Focus coding**

Wondering how to organize results on duties of CTE director. Started off on a thematic basis, then changed to participant basis.

**September 10, 2013**

**Focus coding**

Battling with overlaps in focus codes, e.g. whether “managing CTE programs” should be a focus code or whether it is subsumed in other codes such as managing funds, managing curriculum and instruction (P6, P10).

**August 30, 2013**

**Recoding Interview 2**

“Focused coding means using the data most significant and/or frequent earlier codes to sift through large amounts of data (p.50). … “Through comparing data to data, we develop the focused code (p.60)”. Comparing data to data is made possible by having the codes adhering to data as closely as possible.

Charmaz (p.47/48) “Coding should stick closely to the data. Try to see actions in each segment of data rather than applying preexisting categories of the data. … to the degree possible, code data *as* actions. This method of coding curbs our tendencies to make conceptual leaps and to adopt exant theories before we have done the necessary analytic work”.

Seeing STEM education’s contributions to CTE (Ln#s 39-48, 78-81)

STEM education falling under CTE (Ln#s 87-91)

Industry credential for teachers a blessing and a curse (Ln#s 175-183)

**August 29, 2013**

**Focus Coding**

I could see the importance of adhering closely to the original data at coding. It is difficult to figure out what the issue was when the code was interpretive. This was very evident with Interview 1. Code-to-code comparison is made easier with action words arising directly from the data.

Re-coding Interview 1, e.g. … a math teacher presenting a concept on angles does not relate it at all to the CTE program: Code (Ln#42), “Stating weakness of STEM educators” → “Presenting [math] concept without relating to CTE”; … that we are providing STEM linkage with. So examples of that includes our motor sports (Ln#60): Code “Giving example of successful initiative linking STEM and CTE” → “Including motor sports”; … program. We are very very conscious and very excited about what we can do to improve STEM (Ln#62): Code “Expressing satisfaction at CTE's contribution to STEM education” →”Being conscious and excited about what can be done”.

I think that we are sometimes so wrapped up in test achievement, in our case SOLs in the state (Ln#110): Code, “Disapproving excessive regard for test achievement (SOLs)” → “Being wrapped up in testing (SoLs)”

… getting better paying jobs from the skills that they learn (Ln#117): Code: “Stating benefits of CTE” → “Getting better paying jobs”

… get loaded with so many things as it is. I don’t want it to be their responsibility but I would (Ln#125): Code: “Stating limitation” → “Getting loaded with many things”

**August 23, 2013**

**Secondary coding**

STEM education benefiting from the administrative structures of CTE, e.g. P2:57-61

**August 22, 2013**

**Literature review on coding**

Dey quoted in Charmaz (2006, p.48) “There is a difference between an open mind and an empty head”.

**May 1, 2013**

**Experiences from school visits**

Visiting CTE students on their teaching practice at Christiansburg High School gave me insights into the opportunities and challenges of integrating academics into CTE. Then I was wondering how I could use the insights from lesson observations in my dissertation given that the classroom experiences are a valuable window into the understanding the opportunities and challenges for integration of academic into CTE, and yet, my proposed data collection methods do not include lesson observations. I think that I can still use insights from the school visits as part of my reflexivity.

Some specific issues attracted my attention are the influence of curriculum materials, habits (writing related SOLs on lesson plans, only as it seemed, a ritual). Procrastination

**Reflections.** I was delighted that the response from the state director of CTE came just a day after making the request. I went to the Virginia Department of Education website to locate George Willcox so that in my acknowledging the information he sent me, I could address him by the correct title. I noticed that that the link to Career and Technical Education was via “Career and *College* Readiness”. It was important for to note that the “college” readiness role of CTE was taking center stage.

**04/16/2013**

**Task.** Chasing definition

**Activity.** I sent e.mail requests for definition of “District Director of CTE” to the Virginia state director of CTE, Ms. Linda Hall; and to the National Association for State Directors of CTE:

I am a graduate student from Zambia studying for a PhD in CTE at VT. I am planning a study on the experiences of school district directors of CTE with the contributions of CTE to STEM education implementation. In view of the centrality of school district directors to the study, I need to define “District Director of CTE”. I had taken it for granted and realized I can't find anything from the literature I have searched.

Considering that some 'small' districts might place the responsibilities for the local director of CTE under another office, e.g. Director of Curriculum and Instruction, I realized that the definition was important so that it is clear who can be in the sample, and who cannot.

I have searched the literature long enough without success. Please help. I need a clear statement on who a school district director of CTE is.

Thanking you in advance.

Appendix J: Duties of a School Division CTE Director

| **Credentialing** | **Procuring equipment and teaching resources** | **Managing funds** | **Marketing CTE** | **Managing curriculum and instruction** |
|---|---|---|---|---|
| P4-Administering tests | P4-Buying equipment | P4-Managing grant | P5-Being active with school business partners | P4-Providing professional development opportunities |
| P4-Credentialling | P4-Providing resources necessary for teachers | P4-Overseeing funding to CTE | P5-Being approachable, visible, and accessible | P11-Being in a classroom |
| P4-Picking credentials for use | | P4-Overseeing Perkins grant | P5-Being visible | P11-Engaging students |
| P11-Keeping up with competencies | **Firefighting** | P12-Tracking budget | P5-Communicating | P11-Enjoying [working with teachers] |
| P7f-Dealing with staffing, principals, equipment" equipment | P4-Dealing with various roles | | P5-Dealing with community and school partnerships | P11-Working with students |
| P8-Preparing students for industry certifications | P11-Being incharge of discipline & teacher duties | **Multi-tasking** | P5-Doing community outreach | P11-Working with teachers |
| **Managing program routines** | P11-Working on schedules | P11-Being building administrator | P12-Disseminating information | P5-Being most important factor in student learning |
| Hiring | P5-Being the screen and filter of directors | P11-Enrolling students | P1-Talking to stake holders | P5-Getting kids college and career ready |
| P7f-Managing day-to-day operations of CTE | P5-Doing the payroll | P11-Wearing dual hat | P9-Working with the public | P5-Giving students opportunities |
| P7f-Managing | P5-Handling | P5-Having macro and | | P5-Comparing |

| | | | | |
|---|---|---|---|---|
| implementation Finance course | situations in schools | micro level things to do | | program of studies with DOE |
| P8-Evaluating | P5-Having a hand in leadership of principals & staff | P5-Having opportunities to stretch skill sets | **Dealing with mandates and reports** | P12-Looking at STEM in relation to other areas |
| | P5-Meetings | P5-Supervizing stand-alone programs | P11-Compiling data | P12-Publishing program of studies |
| | P7m-Having huge variety of things | P2-Working on multifaceted and multi-disciplined tasks | P11-Dealing with reports | P12-Updating program |
| | P1-Attending to whatever occurs on that day | P2-Managing people | P11-Preparing for federal reviews | P6-Being up to date |
| | P1-Fighting fires of the day | P2-Taking care of people | P5-Reading reports | P6-Looking at new technologies |
| | P3-Dealing with behavioral issues for students | P12-Initiating programs | P12-Doing master record collection | P6-Making sure competencies are being taken care of |
| | P3-Trouble shooting things that are happening | P9-Hiring | P12-Looking at endorsements & stats | P6-Making sure teachers have the necessary knowledge and skills |
| | | P3-Wearing two hats | P12-Looking at reports | P6-Making sure there are books, there is staff development |
| | | | P6-Complying with VA requirements; Reporting to the state | P6-Presenting in a differentiated way |
| | | | P6-Doing state approved testing; Doing licensures | P9-Improving facilities |
| | | | | P9-Keeping up with industry standard |

| | | | | |
|---|---|---|---|---|
| | | | | P9-Mentoring teachers |
| | | | | P9-Working with program improvement |
| | | | | P3-Looking at pedagogical strategies |
| | | | | P3-Sitting on advisory committees |
| | | | | P8-Helping CTSOs participate in competitions |
| | | | | P8-Helping students' organizations |
| | | | | P7f-Managing implementation of STEM |

Appendix K: Participants, Codes, Categories, and Themes Regarding Definition of STEM Education

*Participants, Codes, Categories, and Themes Regarding Definition of STEM Education*

| **Participant** | **Code** | **Category** | **Theme** |
|---|---|---|---|
| Cyrus | Using S,T,E,&M in career fields | Application to work context | |
| Russell | Learning how to do wiring | Application to work context | |
| Russell | Becoming part of every occupation | Application to work context | |
| Russell | Using M,S,&E | Application to work context | |
| Russell | Looking to do | Application work context | |
| Layla | Applying to individual programs | Applying STEM disciplines | |
| Stephen | Developing a STEM program | Applying STEM disciplines | |
| Isobel | Encompassing an issue | Applying to problem solving | |
| Darell | Being one and the same [CTE and STEM education] | Applying to work context | Applying STEM disciplines to real world situations |
| Russell | Wiring a circuit | Applying to work context | |
| Darell | Having STEMH [including health care] | Being open to what STEM could be | |
| Darell | Including more than typical STEM programs | Being open to what STEM could be | |
| Gregory | Including health sciences | Being open to what STEM could be | |
| Bryant | Showing STEM connections in all CTE | Learning in context | |
| Robin | Exciting that all [STEM] areas been part of CTE for long | Application to work context | |
| Russell | Involving CTE | Learning in context | |
| Russell | Needing 100% | Learning in context | |
| Trevor | Infusing into the program | Learning in context | |
| Lauretta | Considering STEAM | Being open to what STEM could be | |
| Lauretta | Integrating STEM and the arts | Being open to what STEM could be | |
| Allison | Being in every curriculum | Integrating disciplines | |
| Allison | Doing STEM in every curriculum | Integrating disciplines | Curriculum integration |
| Allison | Integrating STEM | Integrating disciplines | |

| Participant | Code | Category | Theme |
|---|---|---|---|
| Bryant | Being able to connect entities | Integrating disciplines | |
| Bryant | Having it as integrated STEM education | Integrating disciplines | |
| Bryant | Intermingling of subjects | Integrating disciplines | |
| Bryant | Seeing it as an integration of S,T,E,&M | Integrating disciplines | |
| Bryant | Seeing it as integration | Integrating disciplines | |
| Gregory | Being bigger than people think | Integrating disciplines | |
| Lauretta | Having no silos | Integrating disciplines | |
| Russell | Involving S,M,E,&T | Integrating disciplines | |
| Stephen | Building integrations | Integrating disciplines | |
| Trevor | Infusing with STEM | Integrating disciplines | |
| Allison | Integrating STEM into any curriculum | Learning in context | Curriculum integration |
| Allison | Triggering students | Learning in context | |
| Bryant | Being an integral part of it | Learning in context | |
| Cyrus | Expanding students' understanding | Learning in context | |
| Darell | Being able to influence whole school division | Learning in context | |
| Darell | Including STEM across the curriculum | Learning in context | |
| Russell | Incorporating in every lesson | Learning in context | |
| Russell | Teaching as you go in CTE classes | Learning in context | |
| Stephen | Teaching in CTE is STEM-based | Learning in context | |
| Bryant | Working together for common practice | Applying to work context | |
| Allison | Doing STEM in every curriculum | Integrating disciplines | Applying integrated disciplines to problem solving |
| Cyrus | Weaving [S,T,E,&M] together | Integrating disciplines | |
| Isobel | Pulling together STEM to solve a problem | Applying to problem solving | |
| Lauretta | Ensuring students solve real life problems | Applying to real life problems | |
| Russell | Living-learning process | Being open to what STEM could be | |
| Isobel | Integrating STEM in a project-based curriculum | Integrating disciplines | |
| Stephen | Integrating program areas | Integrating disciplines | |

| | | | |
|---|---|---|---|
| Layla | Being multiple layered | Open to multiple definitions | |
| Bryant | Being the linchpin between science and math | Using technology/engineering to teach S&M | |
| Stephen | Relating to advanced manufacturing | Application to work context | Technology/ |
| Bryant | Thinking T & E meant technology education | Challenges of defining STEM education | engineering based |
| Stephen | Learning in technical settings | Learning in context | learning |
| Bryant | Understanding connections to M,T,&E | Using technology/engineering to teach S&M | |
| Stephen | Incorporating theoretical sciences technological areas | Using technology/engineering to teach S&M | |
| Stephen | Integrating between academic and technical areas | Using technology/engineering to teach S&M | |
| Trevor | Emphasizing engineering | Using technology/engineering to teach S&M | |

*Note:* Some participants' responses are reflected in more than one category because they gave extended responses which applied to all the marked categories.

Appendix L: Participants, Codes, Categories, and Themes: Contributions of CTE Programs to STEM Education Implementation

| Participant | Code | Category | Theme |
|---|---|---|---|
| Andrew | Having higher enrolments | Motivation for Learning | Context for Learning |
| Bryant | Seeing where to use STEM | | |
| Layla | Having interest in | | |
| Stephen | Being interested | | |
| Bryant | Working together [with math teacher | Organizational structure | |
| Bryant | Bringing project-based learning | Pedagogy | |
| Bryant | Manipulating things | | |
| Gregory | Collaborating between theory and practice | | |
| Robbin | Having hands-on experience | | |
| Russell | Concentrating more on some skills | | |
| Russell | Getting your hands dirty | | |
| Russell | Piloting sustainable technology | Program development | |
| Gregory | Having benefits for STEM education | | |
| Layla | Being the heart of STEM | | |
| Layla | Taking computer and digital animation class | | |
| Stephen | Leading effort has been CTE | Program management | |
| Layla | Calling it the center for STEM education | | |
| Layla | Looking at programming | | |
| Andrew | Taking a lot more to be certified in car repair | Program structure | |

| Participant | Code | Category | Theme |
|---|---|---|---|
| Darell | Seeing what students are doing | | |
| Andrew | Having many more skills | | |
| Darell | Seeing STEM identified in some business areas | | |
| Layla | Giving kids multiple pathways | | |
| Layla | Having multiple program offerings | Occupational and/or career diversity | |
| Layla | Taking them into multiple pathways | | |
| Russell | Being a master brick layer | | |
| Russell | Having 21st century skills | | Multiple Pathways |
| Russell | Making students marketable | | |
| Russell | Teaching math for advanced manufacturing jobs | | |
| Trevor | Applying to career path | | |
| Layla | Being about marketing to kids | | |
| Layla | Having best opportunities for life | | |
| Layla | Making 25 dollars an hour | Opening opportunities | |
| Layla | Thinking about opportunities | | |
| Layla | Talking with students and parents | Outreach | |

| Participant | Code | Category | Theme |
|---|---|---|---|
| Andrew | Making CTE valuable to schools | | |
| Darell | Bolstering programs | | |
| Lauretta | Beginning to change | Boosting image | |
| Lauretta | Being [CTE] different now | | |
| Robbin | Becoming the popular educational phrase | | |
| Robbin | Bringing STEM to where it should be | | |
| Robbin | Improving STEM through CTE | | |
| Andrew | Running through CTE | | Platform for delivery |
| Darell | Being under the umbrella of CTE | | |
| Lauretta | Having two health sciences academies | Program management | |
| Lauretta | Having two STEM academies | | |
| Lauretta | Opening health sciences academies | | |
| Lauretta | Opening STEM academy | | |
| Robbin | Noting program completers | Program structure | |

Appendix M: Participants, Codes, Categories, and Themes Regarding Recognition of CTE's Contributions to STEM Education

*Participants, Codes, Categories, and Themes Regarding Recognition of CTE's Contributions to STEM Education*

| **Participant** | **Code** | **Category** | **Theme** |
|---|---|---|---|
| Andrew | Stepping up the curriculum | | |
| | Making it [STEM course] a requirement | | |
| Byrant | Spreading STEM | | |
| | Spreading technology education | Curriculum | |
| Isobel | Being rigorous | | |
| Stephen | Going through a number of CTE electives | | |
| Trevor | Getting involved as early as elementary | | |
| | Setting up programs early | | |
| Isobel | Finding the niche | | Curriculum and instruction |
| Lauretta | Figuring their GPA | | |
| Trevor | Bringing kids along | Individual needs | |
| | Doing our best to accommodate | | |
| | Getting all kids exposed | | |
| | Having programs that interest kids | | |
| Russell | Emphasizing STEM concepts | | |
| | Incorporating different strategies | Pedagogy | |
| | Letting teachers [explore] | | |
| | Realizing that they are doing STEM | | |
| Andrew | Stepping up teacher training | | |
| Gregory | Continuing education and PD | Teacher capacity | |
| Trevor | Having more staff dev., resources & funding | | |

| Participant | Code | Category | Theme |
| --- | --- | --- | --- |
| Byrant | Advertising [what we are doing] | | |
| | Having them spread the word | | |
| Darell | Getting right information to parents | Creating awareness | |
| Lauretta | Doing public relations | | |
| | Flooding the market with information | | |
| | | | |
| Robin | Making policy makers aware | Lobbying | |
| Stephen | Lobbying organizations optimistic | | |
| | | | |
| Layla | Talking about partnership | | |
| Stephen | Highlighting what's going on in classrooms | Marketing | Marketing CTE |
| | Increasing visibility | | |
| | Inviting teachers into classrooms | | |
| | | | |
| Byrant | Getting people to see | | |
| | Promoting some of the things we do | | |
| Cyrus | Promoting CTE activities | | |
| | Promoting the STEM work that is going on | | |
| Darell | Hosting career fairs | Promotions | |
| Isobel | Giving [newsletter] to all schools | | |
| Lauretta | Publicizing what students are doing | | |
| | Talking at schools, to parents | | |
| Layla | Talking about what we are doing | | |
| | | | |
| Byrant | Getting more parents involved | | |
| Darell | Involving them in what you are doing | Stakeholder involvement | |
| Trevor | Getting representation | | |

| Participant | Code | Category | Theme |
|---|---|---|---|
| Darell | Being a mindset | | |
| Isobel | Dumping ground | | |
| Lauretta | Dispelling old vocational education | | |
| | Thinking it's for kids not going to college | Lingering image | |
| Robin | Fighting historical | | |
| | Fighting image of chocolate chip cookies | | |
| Trevor | Taking back seat to core subjects | | |
| | | | |
| Andrew | Changing their image | | |
| Byrant | Preparing for career | | Rebranding CTE |
| | Starting to call it college and career readiness | New image | |
| Cyrus | Being rigorous | | |
| Robin | Moving CTE into an equal peer | | |
| | | | |
| Andrew | Getting the distinction of Governor's academy | | |
| Byrant | Connecting [STEM] to technology education | | |
| | Getting industry certification | | |
| Cyrus | Seeing all CTE as promoting STEM | Strategy for change | |
| Isobel | Doing dual enrolment | | |
| Lauretta | Having to be NATEF certified | | |
| Russell | Connecting with STEM | | |
| Trevor | Taking high tech classes | | |

| Participant | Code | Category | Theme |
|---|---|---|---|
| Byrant | Seeing how successful they are | | |
| Darell | Doing better than those with bachelors' degrees | | |
| | Gaining employment | | |
| | Going on to do great things | Achievements | |
| Isobel | Making our high school shine | | |
| Layla | Making me proud | | |
| Robin | Getting better paying jobs | | |
| | Seeing results of their students [jobs] | | |
| | | | Value of CTE |
| Andrew | Acknowledging industry certification | | |
| | Being a higher requirement that SOL | | |
| | Giving credibility from outside | | |
| | Passing [industry standard exams] | Credentials | |
| Isobel | Following closely industry certification | | |
| Robin | Adding industry certifications | | |
| | Looking at what business and industry want | | |
| | | | |
| Byrant | Tracking some of the students | | |
| Stephen | Assuming being effective | Evaluating CTE | |
| | Being difficult to prove efficacy | | |
| | Waxing and waning | | |