Education Link Report

August 2010

DRAFT

Linking STEM business needs to evidence-based educational strategies in order to make Florida a national leader in market relevant STEM talent development and retention

Florida Center for Research in Science, Technology, Engineering, and Mathematics

We would like to thank members of the **STEM***florida* Business Steering Council, under the direction of Dr. Jimmy Davis, Jr., for their guidance during the yearlong process that led to the creation of this report. We are grateful to the businesses that generously agreed to host the Business Roundtables: Florida Power and Light, Gulf Power Company, The Haskill Company, Lockheed Martin, and the Tampa Bay Regional Planning Council. Much appreciated financial support allowed business leaders, educators, and policymakers to meet, share, and discuss ideas during the 2010 **STEM***florida* Education Conference. Charitable sponsors included: Employ Florida Banner Center for Secondary Career Academics, Florida Power and Light, Helios Education Foundation, Monster, and the St. Joe Company.

We would like to specifically thank the other members of the **STEM***florida* Implementation Team, under the direction of Mary Chance and the Consortium of Florida Education Foundations. Pam Tedesco provided insightful project management. Paula Waller and Frank Fuller were valuable contributors during all components of the project. This report is the result of the efforts of many members of the Learning Systems Institute team, including Tia Bolívar and Meghan Hauptli. We are grateful for their contributions.

Most importantly, we are indebted to the members of the community who shared their time, ideas, and enthusiasm. This report would not have been possible without the support and feedback from the business community, educators, and policymakers in Florida. Thank you.

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PREPARED BY FCR-STEM

FUNDED BY Workforce Florida, Inc.

LEAD PARTNER CFEF Consortium of Florida Education Foundations

STRATEGIC PARTNER eFlorida Enterprise Florida

What is STEM?

"***Science*** is the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—scientific inquiry—that generates new knowledge."

"***Technology*** comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves."

"***Engineering*** is both a body of knowledge—about the design and creation of human-made products—and a process for solving problems. This process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include such things as time, money, available materials, ergonomics, environmental regulations, manufacturability, and repairability."

"***Mathematics*** is the study of patterns and relationships among quantities, numbers, and shapes. Specific branches of mathematics include arithmetic, geometry, algebra, trigonometry, and calculus."

All of these STEM fields are interdependent.

Figure 1. A description of STEM fields and their relatedness (Katehi, Pearson, & Feder, 2009, p. 17)

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OVERVIEW

In early 2010, a series of five roundtable discussions were hosted around the state to engage business leaders in a dialogue about STEM (Figure 1) business needs in Florida. Reports from these roundtables can be found on the **STEM***florida* Website. During the roundtables, business leaders identified important outcomes for improved STEM performance in Florida. The Florida Center for Research in Science, Technology, Engineering, and Mathematics (FCR-STEM) compiled these outcomes (Figure 2) and the business leaders' recommended strategies for realizing them. FCR-STEM also identified key variables related to improvements in STEM teaching and learning (Figures 3 and 4) and additional information relevant to achieving the desired outcomes. This information, reviewed and approved by attendees at the 2010 **STEM***florida* Business and Education Conference, is included herein, with additional feedback from conference attendees.

OUTCOMES DESIRED

1. **Increase the percentage of graduates at each level (high school, undergraduate, graduate) who have STEM knowledge and skills, defined by the business community to include:**

   - **Capable of successfully conducting real-world STEM projects and inquiry, some of which might involve measurement, scaling, computer literacy, financial and higher mathematics, using innovative approaches and strategies;**
   - **Capable of working productively with others, engaging in collaborative problem solving;**
   - **Proficient in integrating skills from different domains within STEM;**
   - **Proficient in reading, writing, and communicating in English; and**
   - **Proficient in reading, writing, and communicating information in a language other than English.**

2. **Increase the quality and quantity of K-12 STEM Educators.**
3. **Increase the number and strength of business-education partnerships.**
4. **Increase the percentage of graduates at all levels who are knowledgeable about and interested in STEM careers. Knowledge should include current, accurate information about career availability, wages, requirements, and pathways.**

Figure 2. STEM Outcomes identified by Florida's Business Leaders. After reviewing the above outcomes, attendees of the 2010 **STEM***florida* Business and Education Conference consistently indicated that Outcome 2 was necessary to achieve Outcome 1, and that both Outcomes 1 and 2 were the highest priorities. Outcome 4 was reported to be the lowest priority, although still considered important.

SYNTHESIS

The outcomes listed in Figure 2 guide the organization of this report. In order to provide information on strategies to achieve outcomes, it was important to consider the major variables affecting the outcomes, and how those variables interact. Figures 3 and 4 show the key variables that influence improvement of STEM teaching and learning. Although it is recognized that family and society play a critical role in student success, these figures contain only the variables that can be strongly influenced by businesses, educators, and policymakers.

In the following sections, the outcomes are explored in greater depth. For each outcome described by the business community, a series of business-recommended strategies are listed. These outcomes and strategies were compiled based on information provided by business leaders during the Business Roundtables. Additional information relevant to the development of a statewide strategic STEM plan was assembled by FCR-STEM and is included for each outcome. This information includes both causal and correlational research findings, along with assessments of the strength of the findings in each area.[1] This information is not exhaustive, but was provided to address specific questions and comments received from business leaders, educators, and policymakers. For further depth on specific topics, please refer to works cited within the text.

[1] For an overview of the levels of evidence associated with each causal and correlational findings, see Appendix A.

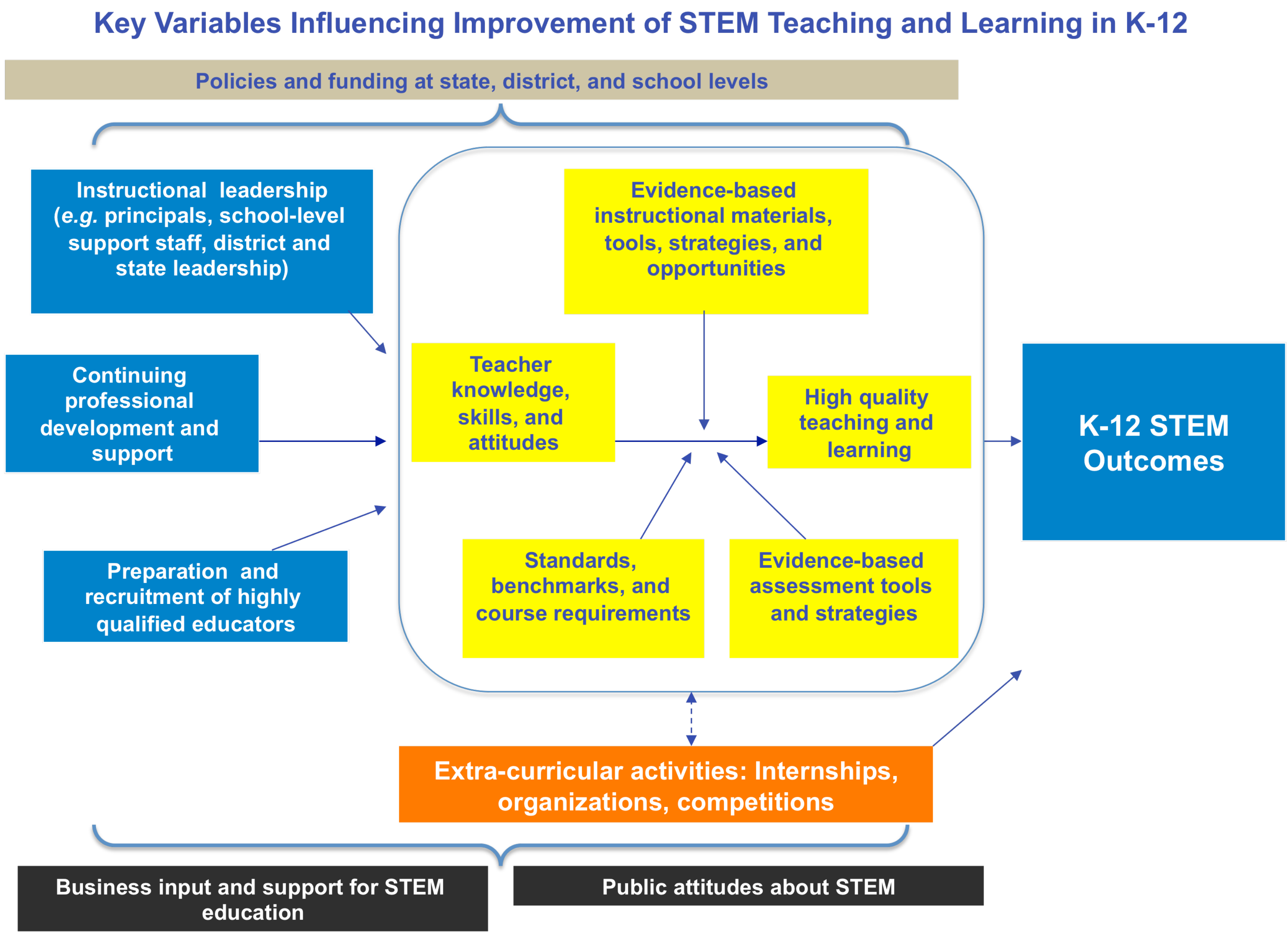

Figure 3. Key variables influencing improvement of STEM teaching and learning in K-12 have been identified by research. By considering all of the variables, and systematically strengthening each component, improved outcomes are more likely to be realized.

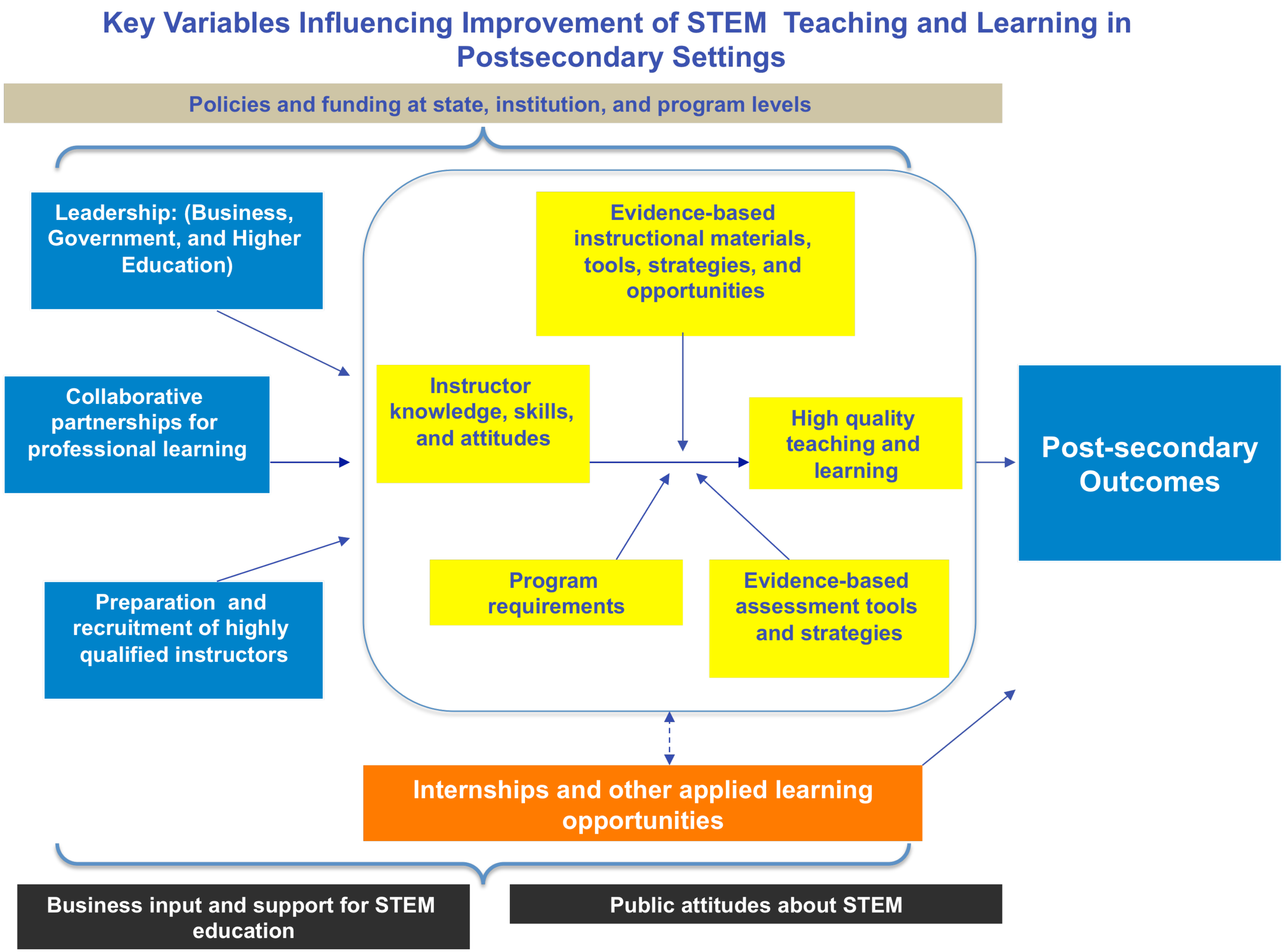

Figure 4. Key variables influencing improvement of STEM teaching and learning in postsecondary settings have been identified by research. By considering all of the variables, and systematically strengthening each component, improved outcomes are more likely to be realized.

OUTCOME 1

Increase the percentage of graduates at each level (high school, undergraduate, graduate) who have STEM knowledge and skills, defined by the business community to include:

- **Capable of successfully conducting real-world STEM projects and inquiry, some of which might involve measurement, scaling, computer literacy, financial and higher mathematics, using innovative approaches and strategies;**
- **Capable of working productively with others, engaging in collaborative problem solving;**
- **Proficient in integrating skills from different domains within STEM;**
- **Proficient in reading, writing, and communicating in English; and**
- **Proficient in reading, writing, and communicating information in a language other than English.**

BUSINESS RECOMMENDED STRATEGIES

1. Sequence the curriculum to promote maximum student learning so that concepts build on one another as students progress.
2. Provide educators and learners with curriculum and materials to support inquiry learning.
3. Assess learners in a manner that encourages proficiency in applying STEM skills and content knowledge.
4. Provide teachers with *current, accurate* STEM curriculum and resources.
    a. Provide classrooms with inquiry-based curricula.
    b. Provide high quality virtual manipulates, games, and technology that have clear learning objectives.
    c. Provide teachers with appropriate resources to teach *current, accurate* STEM curriculum that involves students in real-world STEM projects and inquiry.
    d. Ensure that curricula contain *current, accurate* STEM content in both core and elective classes.
        i. Regularly update elective classes in which students apply STEM knowledge and skills as the needs of business change.
5. Provide student internships as an integral component of STEM education.
6. Increase the opportunity for students to participate in dual enrollment.
7. Incentivize student enrollment/achievement in STEM fields at the college and university levels.

FOR CONSIDERATION: ADDITIONAL EVIDENCE, RESEARCH-BASED STRATEGIES, AND INFORMATION

I. Teaching and Learning

The desired skills and knowledge identified by the business community in Florida share many commonalities with the:

- 21st Century Skills identified by the National Research Council (NRC, 2010a) in conjunction with members of the Partnership for 21st Century Skills (http://www.p21.org/);
- Strands of science proficiency (Duschl, Schweingruber, & Shouse, 2007);
- National educational technology standards and performance indicators for students, identified by the International Society for Technology in Education (2007);
- General principles for K-12 engineering education (Katehi et al., 2009); and
- Process standards identified by the National Council of Teachers of Mathematics (NCTM, 2000).[2]

These skills require that people learn and creatively transfer that learning, applying it in novel and social contexts. Recent research in a variety of fields, including neuroscience, anthropology, and cognitive, developmental, and social psychology, shed light on how humans learn and develop cognitively. A series of publications by the National Research Council (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000; Donovan & Bransford, 2005a, 2005b; Duschl et al., 2007; Kilpatrick, Swafford, & Findell, 2001) compile the findings relevant to education and explore their significance for:

- teachers and teaching,
- learning environments, and
- learners and learning.

Learning research consistently indicates that a **learner must understand, or make sense of, the new topics in connection with that learner's prior knowledge**. For new knowledge to be used effectively, teachers must ensure that the knowledge is organized and connected to important concepts, with appropriately associated context, and that the learner is able to apply that knowledge creatively, not simply recall information (Bransford et al., 2000).

Research on learning during childhood indicates that young children have greater capacity to learn than commonly recognized. Young **children are apt learners** who are inclined to make sense of their world. They are active in developing their knowledge; they naturally reason, solve problems, generate questions, and monitor their knowledge development. Importantly, **children enter school with a wide range of prior conceptions and misconceptions about the world**. Adults can guide learning, "promoting children's curiosity and persistence by directing children's attention, structuring their experiences, supporting learning attempts, and regulating the complexity and difficulty of levels of information for them." (Bransford et al., 2000, p. 234)

Methods for guiding learning vary according to the context, learner, teacher, and knowledge to be gained, but sufficient overlap exists in the context of STEM fields to identify common elements of effective instruction (Banilower, Cohen, Pasley, & Weiss, 2008; Bransford et al., 2000; Carpenter, Fennema, Franke, Levi, & Empson, 1999; Donovan & Bransford, 2005a, 2005b; NCTM, 2000; NRC, 1996).

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[2] See Appendix B for a full listing of each of these skills, strands, standards and principles.

In order for a teacher to effectively guide a learner, the **teacher must be aware of the learner's thinking**, including the learner's:

- prior conceptions;
- strategies for investigating questions, solving problems, or designing; and
- organization of thoughts.

Understanding a child's thinking **requires a teacher to have much deeper content knowledge than the learners**, so that the teacher can anticipate, question, and appropriately direct learner thinking. In order for deep learning to occur, learners should:

- be motivated;
- be intellectually engaged;
- use evidence to critique claims, strategies, and designs;
- actively examine their own thinking;
- attempt to make sense of their new knowledge in the context of the larger framework. (Banilower et al., 2008; Carpenter et al., 1999; NCTM, 2000).

In typical classrooms in the United States today, the above approach to instruction is the exception rather than the rule. The teacher dispenses information to students; students are expected to memorize and apply this information deductively and appropriately, typically using it to solve routine exercises that are bountiful, similar, and chiefly involve the manipulation of numbers and memorization of procedures or definitions (Givvin, Jacobs, & Hollingsworth, 2006).

Research in STEM education suggests that **learners learn more deeply and more effectively when they are expected to creatively "learn by doing"** – to examine real-world, meaningful problems and phenomena; explore conjectures that may or may not be correct on the first try; justify and compare different solution methods and interpretations; and communicate ideas orally, in writing and using representations of concepts, such as graphs or manipulatives. The learner's underlying reasoning is most critical. Teachers can most appropriately assess learner knowledge in this system – not by eliciting and praising correct answers – but rather by encouraging learners' self-reflection regarding their thinking and reasoning and peer feedback (Bransford et al., 2000).

Models of instruction that encourage "learning by doing" are often based on the **learning cycle**, originally developed in the 1960s for use in elementary science classes. An example is the **5E model: engage, explore, explain, elaborate, and evaluate** (see Bybee et al., 2006). Learners are engaged and encouraged to actively explore their environment and ideas. During the explanation phase, students integrate their prior conceptions with observations made during the exploration phase and new concepts introduced by teacher. They subsequently are expected to apply this new knowledge in a variety of situations. These models may be used effectively in didactic instruction, in which learner exploration is largely a thought process, or during "hands-on" lessons; the critical components of learning remain largely the same.

Just as learning in an individual lesson is structured, **lessons themselves should be linked, so that learners are guided progressively deeper into subject matter, applying earlier learning**. Achieving linkage of lessons requires forethought about **content connectedness and the level of learner understanding. Both are ingredients of learning progressions**, "descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time (e.g., 6-8 years)" (Duschl et al., 2007, p. 214). Though some models of scope and sequence of learning in STEM fields exist, they typically take into account only content connectedness but not the findings about how children learn.

Learner exploration of concepts varies by field, but generally involves learning by doing: inquiring, designing, and solving. **Design**, the "engineering approach to identifying and solving problems" (Katehi et al., 2009, p. 4), is an "iterative" and "open-ended" method, which can provide "a meaningful context for learning scientific, mathematical, and technological concepts" and "a stimulus to systems thinking, modeling, and analysis" (Katehi et al., 2009, p. 56). **Inquiry** is defined by in the National Science Education Standards as "a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena" (NRC, 1996, p.214). In science education, inquiry instruction is a pedagogical model that requires learners to answer research questions through the analysis of relevant data (Bell, Smetana, & Binns, 2005). The level of inquiry, or amount of freedom given to, and required of, the learner in posing the question, designing methods, and discovering the solution, may vary with learner readiness, lesson content and time, supplies, and other practical constraints. Learners who conduct real-world STEM inquiry, which the business community indicated as a need, are engaging in open inquiry in which the learner poses the question, creates methods for exploring, and discovers and interprets results. As with any skill, the process of scientific inquiry is learned, with teachers guiding learners to pose researchable questions, develop viable methodologies, and interpret data in meaningful ways.

Unfortunately, there is a scarcity of high-quality research on the effectiveness of these pedagogical strategies due to (1) a lack of shared terminology and assessment strategies for inquiry instruction, (2) the challenges associated with controlling for variables in educational settings, (3) the lack of control or comparison groups, and (4) insufficient methodological rigor. Despite these limitations, a recent meta-analysis of the effects of inquiry instruction on student learning, using experimental, quasi-experimental and non-experimental research suggests that, although "the evidence of effects of inquiry-based instruction…is not overwhelmingly positive…." there is a "clear, positive trend favoring inquiry-based instructional practices, particularly instruction that emphasizes student active thinking and drawing conclusions from data" (Minner, Levy, & Century, 2010, p. 493). "**Teaching strategies that actively engage students in the learning process through scientific investigations are more likely to increase conceptual understanding than are strategies that rely on more passive techniques**" (p. 474). Schroeder, Scott, Tolson, Huang, and Lee (2007) find similar results when analyzing only experimental and quasi-experimental studies. As noted above, however, learners must learn how to do inquiry. Scaffolding, "strategic support that enables students to do scientific tasks with a higher degree of sophistication," is useful in guiding learners to inquire effectively as it can "structure students' interactions with one another or their thinking about a particular model, concept or practice" (Duschl et al., 2007, p. 273). Finally, inquiry is one, but not the only, component that may be included in instruction. Without guidance to place the newly gained concepts into the framework of other knowledge (the Explain and Elaborate phases of the 5E model), learning is limited.

Learner thinking is evident **through communication**, both oral and written, between the student and learner, between individual learners, and to outside audiences. Communication is highlighted as critical in the standards, processes, and 21st century skills necessary for each STEM field (Appendix B) and in the desired outcomes defined by the business community of Florida.

The teacher's ability to pose **appropriate and well-timed questions** fosters communication. With such questions, a teacher may elicit **the thinking of a learner, and guide the learner to a deeper conceptualization of subject matter**. For example, in mathematics, learners grow in their knowledge by understanding and being able to construct relationships. When teachers ask questions that focus students' attention on these relationships, they nudge learners toward a deeper conceptual understanding of mathematics (Carpenter et al., 1999).

To openly communicate, learners must understand that it is appropriate, and expected, for them to respectfully critique thinking: theirs, their peers', their teacher's, and earlier thinkers'. "A focus on student thinking requires classroom norms that encourage the expression of ideas (tentative and certain, partially and fully formed) as well as risk taking. It requires that **mistakes be viewed not as revelations of inadequacy, but as helpful contributions in the search for understanding"** (Donovan & Bransford, 2005a, p. 20). In communities of learners, cooperative problem solving and argumentation fosters cognitive development. This benefit applies to any intellectual community, including a **learning community of teachers** working together to develop their professional knowledge and practice. Indeed, "teachers must be enabled and encouraged to establish a community of learners among themselves" (Bransford et al., 2000, p.25) in which they explore learning central to their profession: content knowledge, pedagogy, and student thinking (Smith, 2001).

The separation between STEM and language learning, often seen in educational settings, does not reflect this view of learning in which learners are expected to work together and refine their thinking through communication. Although limited, evidence [3] suggests that integrating science and literacy instruction can improve student performance in both areas, specifically science content knowledge, scientific inquiry skills, vocabulary acquisition and writing fluency. Additionally, communication skills required in STEM fields differ from those traditionally taught in language arts classes. According to Snow (2010) "a major challenge to students learning science is the academic language…designed to be concise, precise, authoritative. To achieve these goals, it uses sophisticated words and complex grammatical constructions that can disrupt reading comprehension and block learning. Students need help in learning academic vocabulary and how to process academic language if they are to become independent learners of science" (p.450). Literacy is essential to success in STEM fields, as the ultimate goal is to enable learners to independently assess and guide their own thinking and learning.

It should be noted that **no one pedagogical model and learning environment is always better than another**. Using video observations of 638 eighth-grade mathematics lessons, randomly sampled from seven countries, Givvin et al. (2006) confirm earlier observations that "teachers across countries with high-achieving students may teach in very different ways (Hiebert et al. 2003a; Hiebert et al. 2003b; Stigler and Hiebert 2004)"[4]. Though diverse in pedagogical style, **classrooms in the highest-performing countries shared most of the following features: focus on learner thinking, high-quality content, connection of concepts, and application of learning in novel situations.**

II. The Standards

The highest performing nations on international math and science assessments[5] consistently had high-quality standards to which students were held accountable. In the United States, national legislation requiring standards-based education was enacted in 1994 with the reauthorization of the Elementary and Secondary Education Act (ESEA), continued with No Child Left Behind (NCLB; 2001), and is strongly encouraged through incentives under the current administration (e.g., Race to the Top). Standards-based education typically includes both **content standards** ("subject matter descriptions of what students should know and be able to do;" NAE, 2009, p. 1) and **performance standards** (as assessed on tests such as the Florida Comprehensive Assessment Test, FCAT). The National Academy of Education (2009) provides a summary of the history, rationale, barriers, and future of standards-based education, in addition to reviewing the research on the effectiveness of past standards-based education reform to improve student achievement. They note that:

[3] Reviewed by Pearson, Moje, and Greenleaf (2010). See Appendix C for programs included in review.
[4] Givins et al., an online publication. Quoted material can be found at: http://www.nctm.org/eresources/view_article.asp?article_id=7396&page=7
[5] For more information about these assessments, see *A Snapshot: The State of STEM in Florida (FCR-STEM, 2010)*.

> "A fair conclusion from all of these studies might be to say that, since 1992, **the era of test-based accountability has been associated with increasing student achievement, but improvements have not been as clear-cut or dramatic as had been hoped** and cannot be attributed solely to accountability policies. Although the trend continues to be positive, the intensification of pressures since NCLB has not produced commensurately greater gains" (p. 2-3).

Unintended, negative effects of accountability associated with performance standards include the decreased time that students spend in subjects not tested and increased "emphasis on rote drill and practice" (p. 3), which is not associated with greater student learning (NAE, 2009). **High-quality standards are associated with greater learning. Just as important is how those standards are interpreted and put into practice in schools and classrooms.**

Adopted in 1996, Florida's first standards, the Sunshine State Standards (SSS), like those in many other states, were criticized as "a mile wide and an inch deep" with many topics per grade level and a high degree of repetition across the grade levels. In 2005, mathematics content standards of the 50 states were graded by the Thomas B. Fordham Institute in terms of clarity, content, reason, and negative qualities. At that time, Florida's standards received an "F" (Carmichael, Martino, Porter-Magee, & Wilson, 2010). According to a large-scale international study, curriculum standards in the highest performing countries have the opposite characteristics: few topics per grade level and little repetition across the grades. This study indicates that it is **not the adoption of curriculum standards per se that is important, but rather the focus and coherence of those standards that is most critical to student achievement** (Schmidt, Wang, & McKnight, 2005).

In revising its standards and adopting the current **Next Generation Sunshine State Standards[6], Florida moved toward more focus, greater coherence, and alignment of topics with the world's highest performing nations**. The numbers of topics and repetitions have been reduced substantially, particularly in the early grades, and the NGSSS emphasize mastery of the most important concepts at each grade level. In the recently released *The State of State Standards* by the Thomas B. Fordham Institute, **Florida received an "A" for its mathematics standards**. Four other states received an "A" and three received an "A-"[7]. Science standards were not graded (Carmichael et al., 2010).

Recently, states have joined efforts to create a national, common set of standards under the Common Core State Standards Initiative (CCSSI)[8]. **When compared to Florida's current NGSSS, the Common Core standards for mathematics were approximately equivalent** in terms of general organization, clarity and specificity, and content and rigor (Carmichael et al., 2010). Carmichael et al. report:

> "With some minor differences, Common Core and Florida both cover the essential content for a rigorous, K-12 mathematics program. Florida's standards are exceptionally clear and well presented and they are easier to read and follow than Common Core… On the other hand Common Core excels in the coverage of arithmetic, and includes some details – particularly those that address the development of fractions – that are missing in Florida" (p. 94).

[6] The NGSSS were adopted in 2007 for Mathematics and 2008 for Science. For a complete listing of the Next Generation Sunshine Standards in Health Education, Mathematics, Physical Education, Reading/Language Arts, Science, and Social Studies, see http://www.floridastandards.org/index.aspx.

[7] Including the District of Columbia. Those who received an "A" were California, District of Columbia, Florida, Indiana, and Washington. Those who received an "A-" were Georgia, Michigan, and Utah.

[8] The standards are available online at: http://www.corestandards.org/the-standards/mathematics.

On July 27, 2010, **Florida adopted the newly developed Common Core standards for mathematics** and for English language arts. **Over the next four years Florida will be transitioning, fully implementing them**.[9] A similar process is underway to create new standards in science. As the new standards are implemented, new assessments are also being developed and administered. **Appendix D contains information about the schedule for developing and administering the revised FCAT and the newly created end-of course exams**.

Although technology and engineering standards are somewhat integrated into the NGSS Standards for Mathematics and Science, **no stand-alone set of technology or engineering standards exist for Florida**. Technology and engineering standards, in general, are more recent than math and science standards, and lack the extensive review process the others have undergone.[10]

III. Increasing Rigor and Expectations

The State of Florida requires high school students to complete four mathematics courses and three science courses (two with a laboratory component) as a requirement for graduation. To date, only Algebra I has been specifically required. In view of the increasing academic skills demanded in college and the workforce, Florida enacted legislation in 2010 (CS/CS/SB 4) that, over time, will ramp up the rigor of coursework students take to fulfill these requirements. Beginning with students entering grade 9 in the 2010-2011 school year, students must take both Algebra I and Geometry. Beginning with students entering grade 9 in the 2011-2012 school year, one of the three credits in science must be Biology I, and beginning with students entering grade 9 in the 2013-2014 school year, the three required science courses must include Biology I, Chemistry or Physics, and an equally rigorous third course.

High school graduates who complete higher level mathematics and science courses, such as Calculus, Chemistry and Physics, are more likely to obtain high test scores, enroll in college and perform at higher levels in college science and mathematics courses than graduates who did not take advanced courses (NCES, 2007). Also, students who take Algebra in the 8th grade have higher math skills in later years (Smith, 1996 cited by Loveless, 2008). In response to this association between course-taking and student outcomes, some states and districts have considered or adopted policies requiring Algebra for all 8th graders and increasing the number of science and mathematics courses required for high school graduation.

Several research findings suggest caution in the crafting of these policies:

- The association between student course-taking and outcomes, described above, could be explained by student self-selection. Students with higher motivation and prior achievement are more likely to enroll in advanced courses; also schools in wealthier and more educated communities are more likely to offer them.

- Some states rank high in 8th grade mathematics, despite relatively low percentages of students enrolled in advanced math classes (Algebra I, Geometry, and Algebra II). For example, in Vermont and North Dakota, ranked 3rd and 4th on the 8th grade NAEP Mathematics in 2007, only 21% and 26% of 8th graders, respectively, took advanced courses compared to 45% of 8th graders in Massachusetts, the top-ranked state (Loveless, 2008).

[9] As of August, 8, 2010, thirty-four other states and the District of Columbia adopted the Common Core. For a map of adopting states, please see http://www.edweek.org/media/2010/08/06/37standards-c1.jpg.

[10] For information on technology and engineering standards, including sources for more information, see Appendix B.

- The average NAEP scores of 8th graders in advanced mathematics courses declined between 2000 and 2007, while the national average was rising. As the number of 8th graders taking advanced classes increased, so did the number of struggling math students enrolled. The lowest scoring 10 percent of students in advanced classes performed on average at the second grade level. They were predominantly Blacks and Hispanics in high-poverty schools and in classes taught by teachers less likely than the average 8th grade teacher to have a mathematics major, teaching experience, or a formal teaching credential. Students in advanced classes scoring at the 20th, 30th and 40th percentile also performed at levels significantly below grade level (Loveless, 2008).

The Consortium on Chicago School Research (CCSR) concluded that **course requirement policies *by themselves* are not likely to increase student learning in mathematics and science and may produce unintended negative consequences unless they are accompanied by strategies to improve student engagement and the quality of instruction** (Montgomery & Allensworth, 2010). In 1997, the Chicago Public Schools adopted a policy mandating a college-prep curriculum, including three years of science, for all entering ninth graders. A comparison of 9th grade cohorts before and after this mandate indicated that the policy was successful in increasing science course taking, but not in increasing student learning. After the new science requirements went into effect, five out of six students averaged a C or lower in science, standardized test scores showed little to no improvement, nor did college enrollment and retention improve. Graduation rates declined initially but began to rebound in 3 years. Although 90% of graduates completed all of the required science courses, only half of entering ninth graders did so because of the high dropout rate.

Chicago's college-prep curriculum also required Algebra I for all ninth graders followed by Geometry and Algebra II. As expected, the policy was effective in increasing Algebra enrollment, particularly for low-ability students who, unlike their higher-achieving peers, had been taking remedial math. However, both average and low-ability students had poorer outcomes after the policy went into effect. Math grades declined and absenteeism increased. The policy had the most adverse effects on low-ability students, who increased their Algebra I failure rate by 7.4 percentage points (Allensworth & Nomi, 2009).

The implication of these studies is *not* to abandon higher expectations, but rather to view these policies as one component of a broader strategy to improve teacher instruction and student achievement. In short, increasing academic rigor cannot be the only focus of high school reform. Many high schools are missing other important characteristics: "a foundation built on youth development principles, engaging learning, connection to the adult world, and strong underlying supports to meet individual students needs" (Lerner and Brand, 2006, p. 4).

IV. Curricula

Recently, a best-evidence synthesis was conducted to compare the effectiveness of programs designed to improve the mathematics achievement of middle and high school students (Slavin, Lake & Groff, 2009). This synthesis compared the effect sizes of studies meeting rigorous methodological criteria, such as use of randomly assigned or well-matched treatment and control groups, with treatment group students participating in the program of interest and the control group students participating in an alternative or "business-as-usual" approach. After an extensive search of the existing research literature, only 100 studies met these criteria. The programs studied were in the following three categories:

- **Mathematics curricula**, including *innovative approaches* based on the NCTM standards and focused on problem solving, alternative solutions, and conceptual understanding; *traditional commercial textbooks*, also based on the NCTM standards but with a more traditional balance among procedures, concepts and problem-solving; and *back-to-basics textbooks* emphasizing step-by-step mathematical procedures.

- **Computer-assisted instruction (CAI)**, including *supplemental programs* such as Jostens/Compass learning, in which students work on computers for a relatively small period of time each day to strengthen areas of weakness, and *core programs*, such as Cognitive Tutor, which deliver instruction, assessment, and feedback via computer based on individual student performance, with the teacher in a facilitator role.

- **Instructional process programs**, which emphasize teaching strategies and include extensive professional development for teachers on how to use these strategies effectively.

Most of the programs studied had insufficient evidence of effectiveness, i.e., they were not found to produce student learning outcomes superior to outcomes of the control or comparison group. Only two programs (IMPROVE and STAD) - both instructional process programs - had strong evidence of effectiveness. Student Teams-Achievement Divisions (STAD) combines cooperative learning, assessment and rewards. Teachers follow a schedule of instruction, student teamwork, and individual assessment. Each team of four students receives certificates and other recognition based on members' average quiz scores. IMPROVE combines cooperative learning, mastery learning, metacognitive strategies, and assessment. After the teacher's instruction on concepts, students work together asking each other questions to deepen their understanding. For example, they may explain their approaches to solving a mathematics problem and compare and contrast their different solutions. Students who do not meet the mastery criterion on each unit receive additional instruction.

With the exception of one curriculum (Prentice Hall course 2), all of the curricula were either in the limited evidence or insufficient evidence category, meaning that none offered a comparative advantage in terms of student learning. Computer-assisted instruction also did not offer much of a comparative advantage. To improve student achievement in Grade 6-12 mathematics, the authors concluded that **"programs that affect daily teaching practices and student interactions have more promise than those emphasizing textbooks or technology alone"** (Slavin, Lake & Groff, 2009, p. 839).

The What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/), currently operated by Mathematica Policy Research, Inc. with funding from the Institute of Education Sciences, evaluates research on interventions designed to increase student achievement and other outcomes. Based on studies that meet WWC evidence criteria, interventions are rated as positive, potentially positive, mixed, no discernible effects, potentially negative, or negative. The rating of effectiveness takes into account the quality of the research design, the statistical significance of the findings, the size of the differences between participants in the intervention condition and the comparison condition, and the consistency of the findings across studies.

Since 2007, WWC has reviewed research studies on 123 mathematics curricula (73 elementary; 50 middle school curricula). Results are summarized in the Tables 1 and 2.

Table 1. Elementary mathematics curricula reviewed by What Works Clearinghouse

Elementary math curricula	
Bridges Mathematics	Studies not sufficient to draw conclusions
Odyssey Math	Potentially Positive Effects: evidence of a positive effect with no overriding contrary evidence
Everyday Mathematics	Potentially Positive Effects: evidence of a positive effect with no overriding contrary evidence
Houghton Mifflin Mathematics	No discernible effects on mathematics achievement
Investigations in Number, Data, and Space®	Studies not sufficient to draw conclusions
Kumon Math	Studies not sufficient to draw conclusions
Progress in Mathematics© 2006	No discernible effects on math achievement
Saxon Elementary School Math	No discernible effects on math achievement
Scott Foresman–Addison Wesley Elementary Mathematics	No discernible effects on math achievement

Table 2. Middle school mathematics curricula reviewed by What Works Clearinghouse

Middle School math curricula	
Accelerated Math	No discernible effects on math achievement
Cognitive Tutor® - Algebra I	Potentially positive effects on math achievement
Connected Mathematics Project	No discernible effects on math achievement
Destination Mathematics	Studies not sufficient to draw conclusions
I CAN LEARN pre-algebra and algebra	Positive effects on math achievement
Mathematics in Context	Studies not sufficient to draw conclusions
MathThematics	Studies not sufficient to draw conclusions
Odyssey Math	Studies not sufficient to draw conclusions
PLATO	No discernible effects on math achievement
Saxon Math	Mixed effects on math achievement
Singapore Mathematics	Studies not sufficient to draw conclusions
The Expert Mathematician	Potentially positive effect on math achievement
Transition Mathematics	Mixed effects on mathematics achievement
U Chicago School Mathematics Project, Algebra	No discernible effects on math achievement

V. Class Size

Class size is a popular strategy to improve student achievement. In fact, when a nationally representative sample of adults was recently asked how they would want their community to spend any extra money they received for schools, reducing class size was chosen most frequently (33%), compared to improving math and science education (27%), paying teachers more (20%) and providing preschool for all children (15%) (Johnson, J., Rochkind, J., & Ott, A., 2010).

The first large-scale study on class size examined the impact of Tennessee STAR, a state-funded program operated in 1985-89, which randomly assigned students entering kindergarten to regular classes of 22-26 students, small classes of 13-17 students, or regular classes with a teacher's aide. Students remained in these classes for four years. The evaluation indicated that for K-3 students, being in a smaller class of 13-17 students (versus a larger class of 22-26 students) improved student achievement by about a fifth of a standard deviation (equivalent to raising average student performance from the 50th to the 58^{th} percentile). The benefits of the smaller class size were evident by the end of first grade, were sustained for many years, and were greater for minority students (Brewer, 2005).

California's experience about a decade later provides insights into the challenges of taking class size reduction to scale, particularly in a large state. In 1996, the California legislature instituted a program to reduce class size in grades K-3 to 20 students, a significant reduction compared to the existing average class size of 28. Although the program was voluntary, most districts implemented the policy that had strong educator and parental support and provided $650 per student in a "small" class. The result was a dramatic decline in teacher qualifications statewide, as districts tried to fill the demand for more teachers. Also, there was evidence of reallocation of resources away from other programs and services to pay for the cost of the program, which over a 5-year period totaled more than $8 billion (Brewer, 2005).

The rationale behind class size reduction is that teachers will be able to provide students more individual attention and have more time to improve their instruction. Subsequent research has shown, however, that regardless of class size, teachers seem to use the same strategies, rather than change the content or methods of their instruction. Although there is some evidence that teachers may spend more time on individualized instruction and less time on disciplining students in small classes, **"Overall the weight of the evidence tilts strongly toward a conclusion that reducing class size, by itself, does not significantly affect the instructional activities that occur in classrooms"** (Ehrenberg, Brewer, Gamoran, &Willms, 2001, p.23).

Florida's constitutional amendment passed in 2002 limits class size in the core subjects in Florida schools to 18 students in grades K-3, 22 students in grades 4-8, and 25 students in grades 9-12. Through a phase-in process, the caps initially applied to the district class size average, then the school class size average and, by 2010-2011, to every classroom in the state. Florida's class size policy went beyond the existing research in two ways. First, it reduced class sizes not only for grades K-3, but also grades 4-12. Second, it did not lower class sizes to the level having an effect in the STAR study (below 17).

Over the first seven years of implementation (2003-04 to 2009-10), the Florida Legislature appropriated $15.7 billion for operating and capital costs associated with the class size amendment. These costs are expected to rise to $20 billion by 2010-2011, when the caps are currently scheduled to take effect at the school level (Florida Department of Education, 2009c). All districts receive the same *per-student* allocation for class size reduction regardless of whether they were already in compliance: for example, $180 in 2004, $365 in 2005, $565 in 2006 - and $790 in 2007 when compliance started to be measured at the school level (Chingos, 2010).

A recent study of class size reduction in Florida compared trends in math and reading achievement for two groups of districts: (1) those that were mandated to reduce class size and (2) those already in compliance and able to use the resources for other purposes (Chingos, 2010). Using an interrupted time series design and regression analysis, Chingos compared how math and reading FCAT trends changed from the three years prior to the new policy (2001 to 2003) to the four years after the policy went into effect (2004 to2007). He found that **mandated class size reduction had minimal to no effects on student achievement as measured by the FCAT, or on non-cognitive outcomes, such as absenteeism and suspensions**. This analysis was limited to grades 3-8, because of the availability of annual test data and the even number of districts in the two groups of districts in these grades.

Chingos strongly questions whether class size reduction at a large scale is a productive use of limited resources. After reviewing the class size research in the context of Florida's class size amendment, Dominic Brewer, then Director of RAND Education, advised a close look at the cost-effectiveness of class size reduction:

> The main issue for Floridians, however, should probably be what alternatives there are to class size reduction. Given the high costs associated with small classes…it seems likely that there are more cost-effective strategies of achieving equivalent gains in student achievement (Brewer, 2005, p. 76).

In 2010, the Florida Legislature passed a Joint Resolution, which, if approved by 60% of voters in November 2010, would apply the constitutional limits to the school average and allow more flexibility on the upper limit for individual classrooms beginning in the 2010-2011 school year:

- **PreK–Grade 3:** The maximum number of students who could be assigned to each teacher in an individual classroom would be 21, but the average number of students assigned per class to each teacher within each public school could not exceed 18 students;
- **Grades 4–8:** The maximum number of students who could be assigned to each teacher in an individual classroom would be 27, but the average number of students assigned per class to each teacher within each public school could not exceed 22 students; and
- **Grades 9–12:** The maximum number of students who could be assigned to each teacher in an individual classroom would be 30, but the average number of students assigned per class to each teacher within each public school could not exceed 25 students.
  (The Florida Senate, 2010, see SJR 2 — Class Size Requirements for Public Schools)

VI. Comprehensive School Reform Models

A wide variety of high school reform models have been designed and implemented over the past several decades in U.S. schools, primarily with funding from the U.S. Department of Education and private foundations, such as the Bill and Melinda Gates Foundation. At this point, the body of evidence is limited in quality and quantity regarding the effectiveness of these models in terms of improved student achievement, graduation rates, postsecondary outcomes and workplace success (Fleischman & Heppen, 2009; Comprehensive School Reform Quality Center, 2006). However, based on reviews of studies with strong (experimental and quasi-experimental) research designs, some models appear to be more promising than others.

We define a model as "a set of specified practices or ideas that have been, or are intended to be, replicated widely," typically with a "group of coherent elements, driven by an expectation that these elements – when well-executed – will accomplish a desired goal, such as reduce dropouts or improve student achievement" (Fleischman & Heppen, 2009, p. 106).

Most models include instructional, structural and governance elements, but emphasize one more than the others. Models emphasizing *instruction* primarily seek to improve the content and delivery of instruction through curriculum changes, professional development and supports to improve the quality of teaching. Models emphasizing *structure* primarily seek to organize schools in ways that are expected to mobilize improvements in teaching and learning. Examples include reducing school or class size, extending the school day, instituting block scheduling, or offering dual enrollment. Models emphasizing *governance* primarily seek to improve teaching and learning by changing the way that schools are operated and managed. Examples include the creation of charter schools or the hiring of third-party management organizations to manage schools (Fleischman & Heppen, 2009).

Models also vary in their targeted outcomes, assumptions, and specific strategies for change, all of which should be considered by decision-makers when choosing an approach to implement in a local context. First and foremost, decision-makers should start with models that show the most promise of achieving desired outcomes, then choose among them considering local factors likely to affect their successful implementation. In many cases, it may be necessary to combine one or more models (Fleischman & Heppen, 2009).

Comprehensive school reform (CSR) models, implemented in thousands of schools nationwide since the 1980s, offer a coherent, systemic approach to improving whole schools, ranging from staffing, curriculum, and instruction to management and parental/community involvement. Generally implemented in low-performing high-poverty schools in urban areas, these models usually have external developers, who can provide technical assistance, training, and support during implementation. The specific components of these models vary. The U.S. Department of Education, which has awarded competitive grants for comprehensive school reform, requires 11 components for its funded projects, such as use of research-based methods; high quality, continuous professional development; measurable goals and benchmarks; buy-in from teachers and administrators; shared leadership; high-quality external assistance and support; and integration of instruction, assessment, classroom management, professional development, parental involvement and school management (Borman, Hewes, Overman, & Brown, 2002).

In 2006, the Comprehensive School Reform Quality Center, funded by the U.S. Department of Education (USED) at the American Institutes for Research, published the first comprehensive review of middle and high school whole-school reform models. The focus was 18 models meeting USED's 11 criteria and implemented in at least 3 states and 40 schools. The models were rated in terms of the quality, number, and positive findings of studies. Those rated highest are summarized in Appendix E based on descriptions provided by CSRQ Center reviewers.

Most comprehensive school reforms take three to five years to implement (CSRQ Center, 2006). **Those in place more than 5 years have the strongest effects** (Borman et al., 2002). Extensive, ongoing professional development is required for school and district staff – plus time must be devoted in the initial years to secure buy-in from teachers and the community, establish new organizational structures, and put new systems in place for planning and progress monitoring, instruction, summative assessment, and school management.

Comprehensive school reform models may be a good fit for local schools and school districts, particularly those that serve high percentages of low-performing students or lack the in-house district-level expertise to support and guide major reform efforts. In these cases, models with the strongest evidence of effectiveness, such as those referenced above, would be a good place to start. However, in cases where schools and districts already have reform efforts underway, educational leaders may prefer to add to or strengthen specific components (see below), rather than begin anew. To help inform such decisions, Quint (2006) at MDRC examined student and teacher surveys, student records, field research, and other evaluation data from three of the above comprehensive reforms – Career Academies, First Things First, and Talent Development High Schools - to arrive at "reasoned conclusions about which particular aspects of the reforms made them effective" (p. ES-3). Her conclusions are summarized below.

- Small learning communities appear to play an important role in making students feel known and cared about by their teachers and in increasing attendance, persistence and on-time promotion. However, they are not sufficient by themselves to improve student achievement.

- Intensive "catch-up courses" combined with double-block schedules appear to help low-achieving students succeed in the regular curriculum and earn course credits in high school, but are not sufficient to keep the *lowest* achieving students - those who repeated ninth grade - from dropping out of school.

- Teachers are likely to benefit from existing well-designed curricula and lesson plans, combined with high quality training and coaching. In general, they lack the time and expertise to develop their own curricula or to integrate themes into their lesson plans.
- Improving instruction should involve not only small learning communities but also academic departments so that teachers have access to improved teaching methods as well as content expertise.
- Teachers engaging in professional learning communities, to discuss and improve their instruction, shows promise of positive effects on student achievement. However, to be productive, these meetings must focus on instruction – a condition more likely to occur when administrators provide guidance on how to use the time productively and sit in on the meetings.
- Career academies have strong impacts on earnings of graduates. Young men in career academies earned over $10,000 more than their randomized control group peers during the 4-year period following graduation. This positive outcome appears to be related to career awareness activities and work internships during high school.
- Strengthening the academic component of career academies will be necessary to improve postsecondary outcomes. Students in career academies did not have higher academic achievement, graduation rates, or postsecondary enrollment and completion rates than their control group peers. This finding was not surprising because academy instruction in the core subjects remained similar to that in the rest of the school.
- Partnerships between high schools and employers work best when they are formally structured and when schools have a full-time staff liaison working with employers.

VII. High School Acceleration Programs

Apart from increasing high school course requirements, another option to increase academic rigor and engage students is to allow high school students to take college-level courses for credit. Florida currently offers a range of acceleration programs that are designed to **"**shorten the time necessary for a student to complete the requirements … of a high school diploma and a postsecondary degree, broaden the scope of curricular options available to students, or increase the depth of study available for a particular subject" (Section 1007.27(1), *F.S.*). These include Advanced Placement (see VI.A., below), International Baccalaureate, Advanced International Certificate of Education, dual enrollment (see VI.B., below), career academy opportunities (see Outcome 4), and courses that lead to national industry certification. The Credit Acceleration Program (CAP) was added by the legislature in 2010 as means for secondary students to obtain high school credit for courses, without enrolling in those courses, as long as they achieve a passing score on a statewide, standardized end-of-course assessment (The Florida Senate, 2010, see CS/CS/SB 4).

The opportunity to earn college-credit is offered in four of these acceleration programs: Advanced Placement, International Baccalaureate, dual enrollment and the Advanced International Certificate of Education. Beginning with the 2011-2012 school year, each high school will be required to offer at least one of these options: an International Baccalaureate Program, an Advanced International Certificate of Education Program, or a combination of at least four courses in dual enrollment or Advanced Placement, including one course each of the following subjects: English, mathematics, science, and social studies. Under certain conditions, school districts may provide these courses virtually (The Florida Senate, 2010, see CS/CS/SB 4).

Overall, the research on the impacts of these types of programs is thin. In a review conducted by the American Youth Policy Forum (Lerner & Brand, 2006), relatively few programs had been evaluated – and those rarely had evaluations that were scientifically rigorous, conducted by an independent third party or included outcomes beyond the students' opportunity to earn college credit (Lerner & Brand, 2006).

VII.A. Advanced Placement

The College Board's Advanced Placement (AP) program offers high school students the opportunity to take courses that qualify for college credit if the student passes the subject-specific AP exam. The Florida Legislature has invested in the AP program through incentives and supports for both teachers and students. The state funds AP exam fees for students and financial incentives for AP teachers (up to $2,000 per year) based on student AP exam scores (1011.62(1)(o), *F.S.*). The state also supports AP course instruction, professional development for AP teachers, and free PSATs/National Merit Scholarship Qualifying Tests for all tenth graders, which are intended to help school staff identify students ready or in need of preparation for AP coursework.

Overall, Florida has one of the highest AP participation and pass rates in the nation. In 2009, about 40% of high school graduates took one or more AP exams (across all subjects), compared to 27% of high school graduates nationally. In Florida and seven other top-scoring states (MD, NY, VA, MA, CT, CA, CO), 20% or more graduating seniors earned a score of 3 or above on one or more AP exams (College Board, 2010a). The state also has made progress in increasing the AP success of Hispanic students. In 2009, the percentage of Florida Hispanics scoring 3 or above on an AP exam (28%) exceeded their representation among Florida's high school graduates (22%) (College Board, 2010b).

As of 2009, fewer graduating seniors in Florida had taken an AP exam in math (11.3%) or science (13%) compared to English (21%) and social sciences (29%). **About 5% of Florida's graduating seniors passed a mathematics and/or science exam with a score of 3 or higher (College Board, 2010b)**. Results by ethnicity are not reported for specific subject areas.

Focusing exclusively on math, science and English, the Texas Advanced Placement Incentive Program (APIP), developed by AP Strategies™, has shown promising results in increasing the course participation and exam pass rates of high school students, including traditionally underrepresented students. With the aim of improving college readiness, the program targets schools serving primarily minority and low-income students. Key components of the Texas program include teacher professional development conducted by the College Board, a pre-AP curriculum preparing middle school students to take AP courses in high school, vertical teams of teachers with a lead teacher providing training for other AP teachers, and financial incentives for teachers and students based on student performance on AP exams. Financial incentives, funded by private donors, vary by school district, but can be substantial. For their extra work, salary supplements are paid to Pre-AP teachers ($500 to $1,000 per year) and lead AP teachers ($3,000 to $10,000 – plus a bonus of $2,000 to $5000 based on AP exam results). For each AP exam score of 3 or higher, AP teachers receive $100 to $500; students receive $100 to $500 (Jackson, 2010).

A longitudinal study (1994-2004) estimated impacts of the Texas Advanced Placement Incentive Program (APIP) by comparing student outcomes of APIP-participating high schools with those of high schools scheduled to implement the program by 2008, adjusting for changes in student demographics. The study found an immediate increase after program adoption in the number of students taking AP and International Baccalaureate (IB) exams, with the baseline (18%) increasing to 22% by Year 2 (a relative increase of 23%). The increase was driven primarily by Hispanic and African-American students. A 21% increase in AP course enrollment (relative to baseline) followed after 3 years. Also, there was a 33% increase in the number of students scoring above 1100 on the SAT or 24 on the ACT by Year 3 and an 8 percent increase in the number of students who enrolled at a college or university in Texas. Because there were no increases in high school graduation rates or the number of students taking college entrance exams, the researcher concluded that APIP seems to benefit primarily higher achieving students, rather than those who may drop out of high school or never pursue college (Jackson, 2010).

In 2008-09, the National Math and Science Initiative (NMSI), with funding from ExxonMobil, competitively awarded 5-year grants to non-profits in six states (AL, AR, CT, KY, MA, VA) to replicate the Texas program. During the first year (2008-09), the number of AP exams passed at participating high schools in the three subjects increased by 52% relative to baseline (compared to a 5.2% increase nationally) and by 72% for African American and Hispanic students relative to baseline (compared to a 13% increase nationally). A new cohort of high school students will be added during each year of the project (see www.nationalmathandscience.org).

States are making concerted efforts to expand the AP program to more high school students in the interest of providing more equal opportunity to high quality, rigorous coursework and admission to postsecondary institutions (Klopfenstein & Thomas, 2009). Providing impetus to this movement are studies finding **AP course taking highly correlated with success in college. These correlational findings, however, do not take into account that students with higher achievement and other advantages are more likely to self-select into AP classes.** Even sophisticated regression models cannot totally control for preexisting differences between AP and non-AP students because many important factors, such as motivation or parental encouragement, are not measured. Also, some researchers have argued that these regression models have omitted the non-AP courses that students have taken in high school (for example, highest level of math course taken, participation in honors courses). Once these are added to the regression model, the power of the AP experience to predict college success, as measured by second year retention and first-semester GPA, is much weaker (Klopfenstein & Thomas, 2009). In short, "Once other rigorous high school courses and demographic and school characteristics are considered…students typically do well in college regardless of their AP experience" (p. 887).

In general, as more students are encouraged to complete AP courses and take the exams, the percentage of students passing declines. The Texas APIP program is no exception. Although the raw number of students passing exams increased relative to baseline (as described above), the number passing did not keep pace with the number of students taking the exam (Jackson, 2010). Large numbers of students not passing could indicate a weak AP programs or enrollment of students in AP courses without adequate preparation to succeed in those classes (Dougherty, Mellor, & Jian, 2006). The same pattern exists in Florida. **While the *number* of high school students enrolled in acceleration programs (including AP) has increased in Florida, the *percentage* of students qualifying for college credit through these programs (by passing AP/IB exams or meeting other criteria) decreased from 71% in 2002 to 64% in 2007 (OPPAGA, 2009).**

Although many students earn postsecondary credit through high school acceleration programs such as AP, they are less likely to do so in math and science. In a recent survey, the majority (75%) of students at UF, FSU, UCF and USF, reported that they generally were able to use their acceleration credits to meet university degree requirements, allowing them to graduate on average with 12 fewer excess hours than other students. Of the 25% who did not use their acceleration credits at the university, most (8 in 10) elected to retake math and science courses "to improve their understanding of the subject matter, to increase their GPAs, or because their universities recommended that they take these courses as a part of a sequence of courses" (OPPAGA, 2009, p. 1).

VII.B. Dual enrollment

Dual enrollment programs allow students to enroll in and earn credit for college courses while in high school. Generally, these courses are taken on college campuses and are taught either by college professors or high school teachers certified as adjunct faculty (Karp, Calcagno, Hughes, Jeong, & Bailey, 2008).

Offered in all of Florida's 67 school districts through partnerships with colleges and universities, dual enrollment courses were taken by about 33,000 Florida high school students in 2007-08 (OPPAGA, 2009). Enrolled students are exempt from the payment of registration, tuition, and laboratory fees (1007.271, *F.S.*). To be eligible, students must pass placement tests (such as the SAT/ACT or College Placement Test) required for admission to the postsecondary institution and have a 3.0 unweighted grade point average (GPA) to earn credit toward a college degree, a 2.0 unweighted GPA to earn credit toward a career certificate (Florida Department of Education, 2007).

The underlying assumption of dual enrollment is that it will increase the academic rigor of the high school curriculum, raise student aspirations, help students make a successful transition to college without the need for remediation, and reduce the cost of a postsecondary education. Although dual enrollment was offered in 42 states as of 2006, little is known about whether these programs are effective in improving postsecondary outcomes, such as persistence in college and completion of degrees (Lerner and Brand, 2006).

The most rigorously conducted studies on dual enrollment, using the best methods short of random assignment, generally found small positive effects on student outcomes, such as secondary enrollment, persistence, credits earned, and GPA (Lewis & Overman, 2008). These studied tracked outcomes for large numbers of students using administrative data from Florida and New York (Karp et al., 2008) and Minnesota (Kotamraju, 2005). **The longitudinal study of Florida's 2000-01 and 2001-02 high school graduates found a generally consistent positive relationship between dual enrollment participation and short- and long-term outcomes.** For example, dual enrollment students - generally and in career and technical education - were more likely than their non-participant peers to enroll in a 4-year postsecondary institution and persist in college. They also earned higher college GPAs and more college credits three years after high school graduation. Although these findings are encouraging, the researchers note the study was unable to control for all of the preexisting differences between students who participated in dual enrollment and those who did not. The former were more advantaged, i.e., more likely to be White, less likely to be poor or limited English proficient and have relatively higher high school GPAs. While some of these preexisting differences could be controlled using demographic and other data from administrative datasets, others (e.g., self-motivation, parental encouragement) could not (Karp et al., 2008).

Historically, dual enrollment programs have been offered to high achieving, college-bound students, but increasingly they are being viewed as an option to increase the rigor of high school instruction and college access for middle - and low-achieving students (Bailey & Karp, 2003; Karp et al., 2008).

Acceleration programs take a variety of forms that vary in intensity (Bailey & Karp, 2003):

- **Singleton programs** offer stand alone, college-level courses at a high school or college campus. The primary goal is offering the opportunity to earn college-credit mainly to students who meet academic qualifications. Examples are Advanced Placement and dual enrollment.
- **Comprehensive programs** give qualified students the opportunity to complete their last two years of high school taking college-level courses on a high school, college or university campus. The primary goal is earning college credit, although some college experience may be gained indirectly. An example is the International Baccalaureate program.
- **Enhanced comprehensive programs** aim to prepare students academically and socio-emotionally for

college. They generally encompass the entire high school curriculum and include courses for high school and/or college credit, combined with support services, such as counseling, academic assistance, and mentoring. An example is Early College High Schools (described below).

Although less common, the enhanced comprehensive programs appear to have the most potential to improve postsecondary enrollment and success for middle and low-achieving students (Bailey & Karp, 2003). For example, Early College High Schools, an initiative launched with funding from the Bill and Melinda Gates Foundation in 2002, offer students underrepresented in postsecondary education the opportunity to earn an Associate's degree or a maximum of 2 years of college credit toward a bachelor's degree while completing a high school diploma. The ECHSs are located on either high school or college campuses, primarily campuses of 2-year colleges. A variety of supports are offered, such as formal tutoring, support classes during the school day, informal counseling, peer and faculty mentoring, college tours, college preparation courses, career awareness opportunities such as internships, and early identification and intervention for students who are falling behind academically. Involving or reaching out to the middle grades also is a core principle of operation. Intermediary organizations provide technical assistance and support to participating sites (AIR and SRI, 2008).

The assumption underlying Early College High Schools is that "improved high school instruction and curriculum tied to the incentive or earning college credits will motivate students…thereby increasing their interest in an access to additional postsecondary education" (AIR and SRI, 2008, p. 1). Preliminary results of an evaluation of the ECHS initiative, conducted by the American Institutes for Research and SRI International (2008), indicated that **ECHSs were serving the target population and were showing positive signs on outcomes**, such as scores on state assessment in reading and math and the number of college credits expected to be earned by graduation. However, **a major area in need of improvement was the level of instructional supports**, such as (1) a clear purpose and rationale for lesson activities, (2) clear standards for judging achievement of learning goals, (3) informative feedback to help students improve, (4) opportunities to engage in elaborated communication about concepts, and (5) modeling use of discipline-specific tools, frameworks, or language (AIR and SRI, 2008). In mathematics, 71 percent of observed lessons were rated high on opportunity for rigor, but only 45% of mathematics lessons were high on both rigor and instructional support. Also, only 6% of mathematics lessons were high on relevance, as exhibited by drawing on students' prior knowledge, discussion topics related to students' daily lives, content related to students' career goals, and alternating between theories and everyday phenomena they explain (AIR and SRI, 2008). **These findings reinforce the importance of attending not only to content, but also how that content is taught in the classroom**.

VIII. STEM at the University Level

VIII. A. The Meyerhoff Scholarship Program

The Meyerhoff Scholarship Program was created in 1988 at the University of Maryland-Baltimore County (UMBC) in response to the observation that underrepresented minority students were not performing as well in college as their previous performance would predict, and were generally underrepresented at the graduate levels, particularly in STEM fields. Multiple studies have reported the success of this program in increasing student grade point average, increasing graduation rates in STEM fields, and increasing acceptance into graduate programs of Meyerhoff students relative to comparison samples of students (for a program review see Gordon & Bridglall, 2004). The program is academically demanding, with strong scholastic, financial, and social infrastructure, including peer, family, and faculty commitment and support. The highest achieving students are recruited and supported through challenging programs that include an introduction to college life and studies, and multiple research experiences. The program received the 1996 Presidential Award for Excellence in Science, Math, and Engineering Mentoring and "both internal and external evaluations show that Meyerhoff students are nearly twice as likely to persist and graduate in mathematics, engineering, and the sciences than their peers who declined offers of admission to the program and enrolled at other universities" (Gordon & Bridglall, 2004, p. 38-39).

In their independent evaluation of the Meyerhoff Scholars Program, Gordan and Bridglall (2004) report that the program "systematically and deliberately" combines research-based strategies to encourage success, monitors and evaluates program effectiveness, and modifies strategies accordingly. Program strategies include the following:

- Recruit a population of under-represented students of color who strive to achieve. By creating a culture of academically and socially supportive peers, the program seeks to avoid the isolation in which many students of color find themselves on college campuses.
- Require incoming freshman to participate in a Summer Bridge Program.
- Designate the most effective faculty and expect them to teach freshman courses.
- Help incoming students identify gaps in their knowledge and provide instructional support for addressing those gaps. Faculty are expected to "reinforce fundamental concepts while simultaneously exposing students to rigorous material that is challenging" (p. 41).
- Construct multiple support groups to address many areas of student academic and social life.
- Supply sufficient financial support, contingent on maintaining high achievement.
- Provide students with culturally relevant experiences.
- Monitor, mentor, and advise students before they arrive and throughout their undergraduate years.

Gordon and Brigdgall (2004) summarize the program effectiveness and the applicability of its components to other areas of STEM education:

> The Meyerhoff Scholars Program is clearly an exemplary model, not only for higher education but also for school systems and supplementary education services along the Prekindergarten through Grade 12 continuum. The components of the Meyerhoff Scholars Program are transferrable… (p. 43).

VIII. B. SCALE-UP

SCALE-UP (Student-Centered Active Learning Environment for Undergraduate Programs) is an initiative to transform traditionally large lecture science courses into small-group inquiry and discussion courses. Instructors pose questions and students, working in small groups, explore concepts through research and discourse. Originally designed for introductory physics courses at North Carolina State University (NCSU), the SCALE-UP model is now employed in more than 50 universities around the country for large courses in several STEM disciplines. This type of studio-based inquiry learning allows students to form social relationships with their peers and their teachers in a stimulating environment. Preliminary information, some of which is not yet peer-reviewed, suggests that the program can be highly successful in terms of content retention and concept learning. For program reviews, please see Beichner (n.d.) and Beichner et al. (2007).

Compared to traditional lecture courses, SCALE-UP courses show promise for increasing student gains, increasing student retention and motivation, and closing achievement gaps in STEM courses (Beichner et al., 1999; Beichner, n.d.).

Florida State University implemented SCALE-UP in General Physics courses for the first time in Spring 2008 and again in Summer 2008. Implementers reported that students showed normalized gains on the Force Concept Inventory (FCI) assessment of approximately 50% (for a description of the assessment, classroom setup, and equipment, and to view the classroom area, see http://scaleup.ncsu.edu/groups/adopters/wiki/48252/Florida_State.html). This gain is roughly two times higher than the 23% FCI pre-post test gain demonstrated by 6,000 students from around the country in traditional courses (Hake, 1998). Similarly, Florida International University (FIU) and University of Central Florida (UCF) reported that the average performance on the FCI by students in the studio-style physics course was roughly 2.5 times higher than the performance of students in traditional physics courses (taught at FIU and UCF, respectively; Beichner, n.d.; Beichner et al., 2007). While these results are very encouraging, student success may be at least partly attributable to other factors, including student self-selection and instructor attitudes and abilities.

Retention and student motivation was examined using drop, fail, or withdraw (DFW) rates:

At FIU, students were 75% less likely to drop, fail, or withdraw from the studio-based physics classes than the traditional physics courses. Additionally, recruitment of physics majors and minors was much higher in studio-based courses: between 10% and 20% of students chose to pursue physics minors or majors after taking the studio-based course. At Clemson, all freshman Calculus I courses were taught using the SCALE-UP model starting in Fall 2006; the DFW rate fell from 44% to 22% in courses that included almost 800 freshman students (Beichner, n.d.). Again, although promising, the influence of other factors explaining these results must be considered.

Female and minority performance improvements:

NCSU found that minority and female failure rates in SCALE-UP physics courses were four to five times lower than those for traditional physics courses (Beichner, n.d.).

OUTCOME 2

Increase the quality and quantity of K-12 STEM Educators.

BUSINESS RECOMMENDED STRATEGIES

1. Improve teacher pre-service programs.
    a. Increase the amount of STEM training received by teachers (of all grades).
    b. Increase requirements for graduation and placement.
    c. Recruit from outside the field of education.
2. Recruit top college students to fill teaching positions.
3. Provide high-quality, ongoing teacher professional development.
    a. Provide STEM-specific training for teachers of all grades.
    b. Provide teacher externships through STEM businesses.
4. Base pay on teacher performance.
5. Provide higher pay for high-demand STEM positions.
6. Rapidly remediate or remove low-performing teachers.

FOR CONSIDERATION: ADDITIONAL EVIDENCE, RESEARCH-BASED STRATEGIES, AND INFORMATION

Teachers help students learn by motivating them and guiding each student's thinking toward a more complete conceptual understanding of the subject matter. In order to do so, teachers must know the content and know how to teach the content. According to the Opportunity Equation (Carnegie Corporation of New York, 2009) "we need teachers who are knowledgeable, motivating, inspiring - and able to differentiate instruction to enable every student to achieve higher levels of math and science learning" (p. 35)

I. The Situation in Florida: STEM teacher recruitment, preparation, certification, and characteristics

Since 2001, Florida has faced a critical shortage in the number of teachers in middle and high school level science and mathematics and in technology education/industrial arts. In 2010-2011, the Florida Department of Education predicts that the state will need about 1,600 and 1,400 new mathematics and science teachers, respectively, and about 41 new technology education instructors. About 660 mathematics educators, 460 science educators, and 10 technology educators are expected to graduate from traditional teacher preparation programs in Florida in 2009-2010 – a number fall short of demand (see Appendix F; FL DOE, 2009b). **Of all critical shortage fields, the gap between school district needs and traditionally prepared teachers is the greatest in science, technology education, and foreign languages. In order to fill this gap, the state has one of the "highest growth rates in alternatively certified teachers and one of the most diverse set of alternative routes to certification"** (Sass, 2008b, p. 2).

In Florida, teachers can enter the profession by having one of two types of teaching certificates: a three-year, non-renewable temporary certificate, and a five-year, renewable professional certificate. There are currently nine pathways (Summarized in Appendix F, Table F.2) by which individuals may obtain a renewable, professional certificate to teach.

Historically, most teachers entered the profession by completing a degree in a traditional teacher preparation program, although the percent of teachers entering by this pathway has decreased substantially in the last decade. Community college and university Educator Preparation Institutes (EPI) programs, which now account for 16 percent of the new professionally certified teachers (2007-2008), are alternative certification programs specifically designed for non-education baccalaureate degree holders to enable them to meet educator certification requirements. District alternative certification programs, which vary by district, account for 18 percent. In general, to receive district certification, a teacher is required to pass the standard general knowledge and professional education certification exams and complete a competency-based alternative certification program. This certification usually involves an "initial assessment of skills, an individualized training plan, mentoring, a training curriculum that targets a set of 'accomplished teacher practices' and summative assessment that documents mastery of the practices. The training programs are frequently web-based, but some also involve collaborations with local community colleges or universities" (Sass, 2008b). **Both EPI programs and district alternative certification programs have had the greatest gains in the percent of new professionally certified teachers in recent years. Two-thirds or more of the teacher graduates in the core subjects of English, mathematics, science, and foreign languages enter the classroom via EPI and district alternative certification pathways** (FL DOE, 2009b).

II. Identifying High Quality Teachers: focus on output

Hanushek (2003) prefers an output-based measure of teacher quality, focusing on student performance instead of input measures focusing on characteristics of teachers and schools. High-quality teachers are ones who "consistently obtain higher than expected gains in student performance, while low quality teachers are ones who consistently obtain lower than expected gains." (p. F.90) Using this definition, it is possible to explore teacher characteristics, preparation pathways, and coursework in relation to student achievement, given that student achievement is accurately assessed. Recently enacted legislation (CS/CS/SB 4) related to end of course assessments (see Appendix D) will enhance researcher opportunities to explore these relations systematically and more specifically.

II.A. Impact of alternative and traditional certification on student achievement

Sass (2008b) used a "value-added" model of student achievement[11] to analyze the relative effectiveness of **4th through 8th grade mathematics and reading teachers in Florida** that entered the profession by each alternative and traditional teacher preparation pathways. He found "**little difference in the ability of alternatively certified and traditionally prepared teachers to promote student achievement**" (p.21). Additionally, he reported that "in some specifications alternatively certified teachers actually out-perform graduates of teacher preparation programs in boosting math achievement" (p. 21). He concluded that "the additional education coursework required in traditional teacher preparation programs either does little to boost the human capital of teachers or that whatever gains accrue from traditional teacher education training are offset by greater innate ability of individuals who enter teaching through alternate routes" (Sass, 2008b, p.1).

[11] Student achievement was based student performance on the FCAT-SSS (Florida Comprehensive Achievement Test- Sunshine State Standards) and FCAT-NRT (FCAT-Norm-Referenced Test, a version of the Stanford Achievement Test to which no accountability measures are tied).

This is consistent with results obtained elsewhere[12], although some studies suggest that certification may be important in some high school situations. For example, Clotfelter, Ladd, and Vigdor (2007) found that in North Carolina high school teacher certification in the subject or in a related subject being taught had a significant and positive relationship to student performance on end-of- course exams. Additionally Henry et al. (2010) report that in North Carolina, student achievement in grades 3-8[13] is similar for teachers who enter the classroom through traditional preparation and alternative pathways; however, in grades 9-12 mathematics, traditionally prepared teachers outperform teachers who enter through alternative pathways[14]. In science, students performed equally well at all grades, regardless of the pathway by which their teacher entered the profession, except for students of Teach For America (described on p. 35) teachers, who performed at higher levels than students of teachers entering by any other pathway.

After analyzing students achievement and teacher certification for elementary and middle grades throughout the United States, Kane, Rockoff, and Staiger (2006) conclude that our previous "emphasis on certification status may be misplaced." They find "little difference in the average academic impacts of certified, uncertified, and alternatively certified teachers" (p. 15). In combination with the research in the next section, this suggests that **teacher certification alone may not be an adequate indicator of a teacher's content knowledge or a teacher's ability to teach that content knowledge**.

II.B. Advanced degrees, characteristics of pre-service training, scholastic aptitude, experience

Using similar methods of analysis, Harris and Sass (2008) and Sass (2008a) report that for Florida mathematics and reading teachers (elementary, middle, and high school levels), none of the following teacher traits significantly increases the teacher's ability to improve student achievement: attainment of advanced degrees (except for middle grades mathematics teachers), pre-service undergraduate training, or scholastic aptitude. Teaching experience strongly enhances student achievement in the first years of teaching, but additional years of experience may not have a substantial impact.

The findings of Harris and Sass (2008) and Sass (2008a) vary to some extent from those of other researchers, as noted below:

- **Teacher coursework in mathematics is associated with higher student mathematics achievement** (Bachelors or Masters degree in mathematics: Goldhaber & Brewer, 1997, 2000; Coursework in mathematics: Monk & King, 1994).

- **Advanced degrees in other areas do not improve student achievement** (Clotfelter et al., 2007, Goldhaber & Brewer, 1997, 2000; Henry et al., 2010, Hanushek, 2003; Rivkin, Hanushek, & Kain, 2005). It should be noted that the majority of Master's degrees awarded to teachers nationally are either Masters of Arts in Teaching or a more general degree available to practicing teachers. According to Hill (2007) "descriptions of these offerings suggest that many are of low intellectual quality, are disconnected from classroom practice, and are often fragmented" (p. 113). However, many states mandate or strongly incentivize attainment of an advanced degree for teachers.[15]

- **Pre-service training in traditional education programs does not improve teacher performance** (Aaronson, Barrow, & Sander, 2003; Constantine et al., 2009; Henry et al., 2010 (except in grades 9-12 mathematics)).

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[12] e.g., Constantine et al., 2009; Goldhaber & Brewer, 2000; Hanushek, Kain, O'Brien & Rivkin, 2005; Kane, Rockoff, & Staiger, 2006

[13] In elementary only math and reading are measured, for all other grades, math, science, and reading are measured.

[14] With the exception of Teach for America (TFA, described below) teachers and visiting international faculty

[15] See Appendix F, Table F.2 for salary and degree levels of Florida teachers.

- **Teacher scholastic aptitude alone (as indicated by SAT scores or grade point averages) is not a predictor of student achievement** (Kane et al., 2006), although Clotfelter et al. (2006; 2007) and Hanushek (1997) have found that **teacher test scores in content area assessments are predictive of student achievement**. Clotfelter et al. (2007) note that this is particularly the case in mathematics, and also true for biology.

- **Student outcomes improve with increased teacher experience, particularly in the first years**. Teacher experience was not as likely to cause increased gains after the initial years. (Coltfelter et al., 2007; Hanushek, Kain, O'Brien & Rivkin, 2005; Rivkin et al., 2005)

- **Teacher performance during the first two years is the greatest indicator of future teacher performance** (Kane et al., 2006).

III. Teacher Preparation

What type of teacher preparation is most likely to produce the greatest gains in student achievement? Evidence for the effects of specific coursework is thin[16] but the research above and additional studies do suggest that the **aspects of teacher preparation listed below are associated with increased teacher effectiveness**.

- **Increased STEM coursework**
  Increasing the teacher preparation coursework in the STEM area can translate into student gains (e.g., Boyd, Grossman, Lankford, Loeb, &Wyckoff, 2009; research summarized in Floden & Meniketti, 2005). Additional studies (Ball, Hill, & Bass, 2005; Clotfelter et al., 2007; Hill, Rowan, & Ball, 2005) indicate that teacher content knowledge is linked to increased student gains.

- **Practice-based preparation**
  Various studies report that teachers greatly improve in the first one to two years of teaching (Coltfelter et al., 2007; Hanushek et al., 2005; Henry et al., 2010). Early research suggests that increasing the amount of supervised teaching during coursework may translate into greater student gains (Boyd et al., 2009) but more research is needed (NRC, 2010b).

Boyd et al. (2009) provide an analysis of specific coursework completed by teachers entering the teaching profession in New York City schools and the relationship to later student achievement. Though their results are "suggestive rather than clearly establishing cause" their work indicates that "**learning that is grounded in the practice of teaching- such as that proxied by the capstone project, studying curricula, and oversight of student teaching- is associated positively with student achievement gains in the 1st year, and content learning- as proxied by disciplinary coursework requirements- is associated positively with learning in the 2nd year**" (p. 433-434).

III.A. UTeach

Recently developed programs in Florida that emphasize both increased STEM coursework and focus on the practice of teaching include **FSUTeach at Florida State University and FloridaTeach** at the University of

[16] See National Research Council (2010b) for an overview.

Florida. Both programs are modeled after the successful UTeach program[17] and require that students take advanced STEM coursework, become competent in content-specific pedagogy, and complete rigorous internships. Important aspects of the UTeach program include:

- two free introductory UTeach courses offered to interested math and science majors;
- degree plans that allow most UTeach participants to graduate with their math or science degree and teacher certification in four years;
- professional development courses based on research in math and science teaching and learning;
- paid internships,
- familiarity and application of technology in the classroom through integrated technology benchmarks, and
- continued intensive field experiences[18].

Results to date suggest that UTeach graduates are retained in the classroom at much higher rates than non-UTeach graduates: retention of UTeach cohorts was above 80% after 5 years of teaching, while average teacher retention[19] was less than 70%.

III.B. Teach for America

Teach for America (TFA) is a national programs that recruits top college students, screens them for teaching ability, and places them in high-need districts. TFA graduates have been shown to be at least as effective as graduates of traditional teaching programs, even when accounting for lack of prior teaching experience. Additionally, the high turnover rates of TFA participants, given their two-year commitments, were similar to that of traditionally certified teachers (Kane et al., 2006). Because TFA is a highly selective program, however, TFA teachers constitute a very small (<1% portion of all teachers). It should be noted that the success of TFA teachers is not in contradiction with the findings of Sass (2008a, 2008b) and others that scholastic aptitude was not a predictor of teaching success, as TFA applicants are required to demonstrate both scholastic aptitude and teaching ability during the selection process.

Though much more research is needed on the specific elements of effective teacher preparation, the findings to date are consistent with research on learning in general (summarized in Outcome 1) and on effective teacher professional development, summarized below.

IV. Effective Teacher Professional Development

In order to retain certification, teachers in Florida are expected to complete a minimum of 120 hours of professional development, 6 semester hours of college credit, or the equivalent[20] within a 5-year period.

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[17] UTeach was developed in 1997 at the University of Texas at Austin through a grant from the National Science Foundation and has been replicated at universities around the nation, including Florida State University and the University of Florida, with funding from the National Math and Science Initiative and the Helios Foundation.

[18] Participants complete approximately 40 hours of field experiences during coursework and an additional 240 hours of field teaching.

[19] As sampled by the National Center for Education Statistics Schools and Staffing Survey (SASS) for cohorts in 1991, 1994, 2000, and 2004.

[20] See http://www.fldoe.org/edcert/renew.asp

Numerous studies show that U.S. teachers lack the content knowledge and content-specific pedagogy required to enable students to achieve world-class standards in mathematics and science (Ball, 2003; Darling-Hammond, 2007; Greenberg & Walsh, 2008; Stigler & Hiebert, 1999; Weiss, Pasley, Smith, Banilower, Heck, 2003). Likewise, evidence suggests major gaps in the mathematics and science content knowledge of Florida teachers. For example, baseline data from ten district Math and Science Partnership (MSP) projects (Meisels & Howard, 2008) showed that only 47%of participating teachers felt well-prepared in science content knowledge, with physics and Nature of Science being weakest for elementary teachers and physics and space science being weakest for secondary teachers. .

In a review of more than 1,300 studies potentially addressing the effect of teacher professional development on student achievement in reading, mathematics, and science, only nine met What Works Clearinghouse evidence standards, attesting to the scarcity of rigorous studies that directly examine the link between professional development and student achievement (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007) Additionally, all nine studies focused on elementary students and teachers. They found that **teachers who received sufficient amounts of professional development did have moderate positive effects on student achievement**. On average, the time spent in the professional development was 49 hours; teachers receiving under 15 hours of professional development showed no significant impact on student achievement. However, as the professional development in the nine studies was fairly similar, it was impossible to discern which characteristics of the professional development affected student outcomes. Professional development in most of the studies was time-intensive, involved follow-up after the initial professional development, and was delivered directly to the teachers rather than through a “train the trainer” model.

The similarity of the programs is not coincidental; their components are grounded in research on learning. Experts in the field typically suggest that professional development be of **sufficient duration, content-focused, aligned with teachers’ real work experiences (curriculum and standards; school, district, and state policy), focused on student thinking, and involve active learning and peer collaboration** (e.g., Desimone, 2009; Scher and O’Reilly, 2009). Available studies support these suggestions; as described in the above paragraph, however, there are few rigorous studies from which to draw strong conclusions. To explore more deeply the relationship between characteristics of teacher professional development and student outcomes, Scher and O’Reilly (2009) performed a meta-analysis of 18 methodologically robust experimental or quasi-experimental studies that analyzed the impact of professional development on student achievement. They find support for the idea that professional development should extend beyond a “one shot” experience to an intensive intervention occurring over one or more years. Additionally, they report that **programs focused both on content and pedagogy had a larger positive impact on student achievement than did programs that focused only on one component.**

Overall, research indicates that job embedded, STEM content-focused professional development with content-specific pedagogy should increase teachers’ ability to positively impact student achievement.

V. Research Experiences for Teachers

As mentioned in Outcome 1, “learning by doing” is a powerful way of increasing learner knowledge. By directly participating in scientific research, teachers may increase their understanding of STEM fields, which may translate into improved instruction and increased student achievement and interest in STEM careers. Silverstein, Dubner, Miller, Glied, & Loike (2009) examined the impact of research experiences for teachers on student achievement within New York City schools. The Columbia University Summer Research Program (CUSRP) includes middle- and high-school science teachers in scientific research as visiting scholars. For 16 weeks over the course of two summers, teachers are paired with a STEM faculty member and participate in authentic research. The program additionally includes weekly, one-day-long professional development seminars on science teaching materials and methods, data-driven instruction, and how to transfer science concepts and technologies into classroom instruction. Teachers receive a $6000 summer stipend and may request up to $1000 per year for conference travel and transfer of classroom and/or lab supplies and equipment to their classroom. In the first 2 years after the program, average pass rates for students of CUSRP teachers was 10.1% higher than for students of non-CUSRP teachers . This difference grew to 15.5% by the end of 4 years after program entry. An estimated $297,845 was saved by increasing teacher retention and student pass rates on the Regents science exam. Return rates hovered between $1.14 in immediate- and $10.27 in long-term economic benefits per $1.00 invested by CUSRP's sponsors (Silverstein et al., 2009).

In addition, significant changes occurred in the CUSRP teachers' instruction and classroom environment: 96% reported more hands-on classroom activities and new laboratory exercises, and 93% designed new or altered their lesson or laboratory plans. The students of CUSRP teachers reported that their teachers more often encouraged them towards careers in math and science and required them to reflect on their assignments and use primary sources to study science compared to students of non-CUSRP teachers (Silverstein et al., 2009).

These results are promising, although more research is needed to establish that these effects are generalizable to other settings and to determine what specific characteristics of the research experience are most likely to enhance teacher and student performance. Research experiences for teachers can take a variety of forms, but typically are offered in the summer, provide teacher stipends, and last for at least six weeks. The National Science Foundation is the largest funder of Research Experiences for Teachers (RETs), with similar programs funded by industry groups, the Department of Energy, the National Institutes of Health, NASA, the Howard Hughes Medical Institute, and educational nonprofits.

For a State-by-State listing of RET opportunities, please see http://www.retnetwork.org/ret_programs.php. This list contains programs in and outside Florida available to Florida teachers. As of 6/28/2010, 11 such programs were listed for Florida teachers, including programs through Embry-Riddle Aeronautical University (http://www.retnetwork.org/ret_programs_detail.php?p=392), the Office of Science Teaching Activities at Florida State University (http://bio.fsu.edu/osta/RET/), the National High Magnetic Laboratory (http://www.magnet.fsu.edu/education/ret/), and Scripps Research Institute Florida (http://www.scripps.edu/florida/edprograms/flteacher.html).

VI. Remediation or Removal of Ineffective Teachers

Kane et al., (2006) found "large, observable differences in teacher effectiveness" within the first two years that were strong indicators of future teacher success. With improvement of teacher effectiveness measures, school leaders could assess teacher performance and suggest methods for remediation, as is done in formative assessment elsewhere in education.

As the "average value-added among the top quartile of elementary school math teachers is…almost 10 times the magnitude of any difference associated with initial certification status….selectively retaining the most effective teachers appears to be a…promising strategy" (Kane et al., 2006, p.2).

VII. Performance Pay for Teachers

Performance pay, or merit pay, rewards individual teachers, teacher teams, or whole schools with monetary bonuses for achieving work-related performance goals. The rational for performance pay is often presented in contrast to the traditional single salary schedule. A key difference between the single salary schedule and performance pay lies in the traditional model's reliance on "inputs" (e.g., years of experience and advanced degrees), whereas performance pay is more closely tied to teacher quality "outputs" such as student achievement and teacher evaluations (Hanushek, 2003).

Performance pay is primarily intended to influence teacher effectiveness via improved instructional practice and ultimately to impact student achievement outcomes. Policy experimentation with performance pay gained traction in the mid 1980s after the release of *A Nation at Risk* (The National Commission on Excellence in Education, 1983). More recently, with an era of accountability created by *No Child Left Behind*, performance pay policies endeavor to reward teachers whose students perform well, through a traditional performance model, or demonstrate growth, through value-added models, on state assessments. Even though it has been recommended in the literature that performance pay plans should be structured to include a spectrum of performance standards (Koppich, 2005; National Institute for Excellence in Teaching, 2007), plans that rely primarily on student achievement data from state accountability tests are common. Other student outcome measures might include course completion data, attendance, graduation rates, grade point averages, school-wide achievement, etc. (Eberts, Hollenbeck, & Stone, 2002).

Evidence to suggest the effectiveness of performance pay is mixed. The National Mathematics Advisory Panel's Task Group on Teachers and Teacher Education (2008) reviewed fourteen quantitative studies, but none of these studies meet the criteria for *gold standard*, scientifically based research, and the authors note that the methodologically strongest studies were conducted in developing countries. Based on this same body of evidence, a 2009 RAND Policy Brief concluded, "Overall, there is insufficient evidence to support claims that pay-for-performance will improve achievement in the United States" (Hamilton & Li, 2009, p. 1). Even more recently, the National Center on Performance Incentives at Vanderbilt University published the year three evaluations of Texas' GEEG and TEEG programs (Governor's Educator Excellence Grants and Texas Educator Excellence Grants, respectively). A key policy point included in the TEEG report states: "**No strong, systematic evidence of a TEEG treatment effect on student achievement was found**" (Springer, Lewis, et. al, 2009).

While research on the issue of performance pay is far from complete, federal policy-makers are encouraging the use of performance pay by requiring states to apply student achievement data to teacher compensation decisions if states wish to compete for federal grant programs like Race to the Top. Similarly, federal commitment to performance pay can be seen in the U.S. Department of Education's more than four-fold increase in funding to the Teacher Incentive Fund (TIF) this year (Education Commission of the States, 2010). In the midst of this push for performance pay, empirical questions such as the optimal size of bonuses and whether or not performance pay is more efficiently awarded at the individual, teacher team, or whole school level remain unanswered. Podgursky and Springer (2007), prominent researchers in this area, noted that while the research literature is thin, it is promising and they argued in favor of further policy experimentation. **Given the lack of conclusive results, it is important for Florida to attach rigorous evaluation components to the state's ongoing performance pay programs (e.g., the Merit Award Program and the Florida School Recognition Program) and any programs that may be introduced in the future**.

VIII. Principals as STEM Educators

VIII. A. Leadership and Student Achievement

Research indicates that principal leadership is a key variable in predicting school effectiveness (Hallinger, Bickman, & Davis, 1996; Hallinger & Heck, 1998) and, importantly, that leadership effects on student achievement appear stronger for relatively lower-SES schools (Hallinger & Heck, 1996). Reviews of studies conducted over the past twenty years concluded that principals' influences on student outcomes were primarily indirect, but measurable (Hallinger & Heck, 1996), and that the total direct and indirect effects of leadership on student outcomes account for approximately 25% of the total school effects, after controlling for individual student characteristics (Leithwood, Louis, Anderson, & Wahlstrom, 2004). Studies have shown that school leaders influence the quality of their schools and, more specifically, student performance, **through the creation of learning environments that foster achievement and by focusing improvement efforts on the practices most likely to result in improved student outcomes, including the development of teachers' instructional skills** (Brenninkmeyer & Spillane, 2004; Crow, Hausman, & Scribner, 2002; Leithwood, & Kington, 2008; Hallinger et al., 1996; Hallinger & Heck, 1996; Marks & Nance, 2007; Mulford, 2005; Nettles & Herrington, 2007).

Although research substantiates the importance of their influence, there is evidence suggesting that current principals are not uniformly well prepared to build supportive cultures that clearly tie adult learning to student learning. In fact, the more traditional, university-based preparation programs for school leaders have not proven to be effective at developing principals who impact student learning (Fry, O'Neill, & Bottoms, 2006; Hess & Kelly, 2005; Levine, 2005). Principals themselves indicate that their graduate preparation programs did not prepare them for the challenges they face in today's schools (Tucker & Codding, 2002). Our ability to address these gaps in principal preparation is limited by the relatively thin body of systematic knowledge related to effective professional development for principals, especially those leading low performing schools (Quint, Akey, Rappaport &Wilner, 2007).

Further complicating the current situation, **little is known about the specific content and pedagogical knowledge required for principals to influence student achievement** (Lang, Goldwyn, Schatschneider, Roehrig-Bice, & Johnson, 2007), and the extent to which these effects are mediated and/or moderated by other variables, such as teacher knowledge and practice (Goldwyn, 2008; Leithwood, Harris, & Hopkins, 2008; Leithwood, Louis et al., 2004; Nettles & Petscher, 2006; O'Donnell & White, 2005; Waters, Marzano, & McNulty, 2003). The relatively small number of related studies employing experimental designs have focused primarily on the direct effects of principal leadership on student outcomes, while studies of interventions that might explicate the relations among school leader knowledge and practice, teacher knowledge and practice, and learning are missing in the literature (Witziers, Bosker, & Krüger, 2003).

VII.B. Principals' Domain Knowledge in Mathematics and Science

Reform-oriented, standards-based instruction requires principals to have "leadership content knowledge" (Stein & Nelson, 2003), i.e., a sufficient level of subject matter knowledge and knowledge about how to teach that subject matter to enable them to observe instruction and supervise teachers effectively.

> Principals typically do not attend to mathematical thinking that is going on. When they observe standards-based mathematics classes they tend to continue focusing on behavioral features of the class but substitute a new set of behaviors for the old. Now they look for the presence of manipulatives, small group discussion, students explaining their problem-solving strategies, etc. These features tend to be easily observable, generic features that are independent of the mathematical thinking going on in the class. Such principals have not shifted their observation practices to look for

how teachers' use of these pedagogical tools gives their student the opportunity to do the hard work of making sense of the mathematical ideas at play in their classroom" (Nelson, Benson, and Reed, 2004, pp. 24-25).

P**rincipals often lack the knowledge of mathematics content and pedagogy to understand its complexities and demands** (Cobb, McClain, Lambert, & Dean, 2003). In response to a survey completed by 137 elementary principals, more than 50% reported that they were uncomfortable with mathematics (Reed, Goldsmith & Nelson, 2006). Perceiving mathematics teaching as relatively routine, principals tend to focus more on the results of high-stakes assessments than on the quality of instruction driving student outcomes (Printy, 2008). Not surprisingly, a recent study at the elementary level found the influence of principals on mathematics teachers' practices generally weak (Hamilton, Stecher, Russell, Marsh, & Miles, 2008).

VII. C. Principal's Role in Collaboration and Professional Development

Past practice has not included school leaders in mathematics and science content-focused professional development. Large-scale systemic reform in STEM has often viewed principals as "stakeholders", along with parents, teacher unions, and students, whose support and "buy-in" for the vision was sought by a "leadership team" without the principal (Weiss, Miller, Heck, & Cress, 2004). With the exception of the Florida PROMiSE Project, awarded in 2008, no other state includes a professional development component for principals in their U. S. Department of Education Math and Science Partnership grants. Florida was allowed to do so only after approval was obtained from the U. S. Department of Education's general counsel for the MSP program (T. Clark, personal communication, June 11, 2008). In most states, professional development is provided only for teachers. However, without ongoing support and mentoring from knowledgeable principals the likelihood that teachers will change their instructional practice is diminished (Nelson & Sassi, 2005).

While current practice does not typically acknowledge the importance of the principals' role in improving mathematics and science instruction, a number of researchers are systematically exploring the connection among principal leadership, teacher leadership, peer instructional collaboration, and changing teacher instructional practice (Lang et al., 2010). A recent mixed methods study conducted in 49 schools serving large numbers of high risk students suggested that **delivering professional development to principals was a first step in increasing professional development opportunities for teachers and in increasing principal engagement with teachers in efforts to improve instruction** (Quint et al., 2007)**.** Principals were more involved in teacher professional development when they had higher levels of participation in instructionally related professional development themselves. Increasing teacher participation in instruction-focused professional development helped to improve the effectiveness of their instruction, at least in reading. Importantly, in both reading and mathematics, higher instructional quality was related to higher levels of student achievement. Additionally, it has been shown (McGhee & Lew, 2007) that **principals' abilities to positively influence student performance can be heightened when principals target instructional issues**. If changes in instructional approaches and practices are called for, then changes in attitudes may be necessary (Ball, 1996). Inability to change attitudes has been cited as one of the obstacles to successful reform efforts in math and science (Raymond, 1997; Walker, 2007). One requirement of this change in attitude on the part of educators is a willingness to abandon strict adherence to procedural explanations for mathematics constructs Frykholm (1999). Additionally, Fink and Resnick (2001) offer the suggestion that educational leaders demonstrate a shift in attitude toward a stronger emphasis on providing intellectual leadership for development and improvement of teaching skills as a means to improved student academic performance. Further, **the role that districts play in principals' and teachers' learning must be considered, as it affects communities of practice outside the school building that will impact opportunities for both groups** (Stein & Coburn, 2008).

OUTCOME 3

Increase the number and strength of business-education partnerships.

BUSINESS RECOMMENDED STRATEGIES

1. Allow and expect more business input and funding for curriculum development, classroom resources, assessments, and information about STEM careers.
2. Designate points of contacts in schools and businesses to facilitate more effective and timely communication between the two.
3. Create a single, statewide website to link businesses and educators interested in collaborating, and for parents and students to view available programs in their areas.

FOR CONSIDERATION: ADDITIONAL EVIDENCE, RESEARCH-BASED STRATEGIES, AND INFORMATION

Empirical research on the efficacy of specific components of business-education partnerships is limited; however, several groups have conducted surveys, interviews, and focus groups to identify strategies for smoothly creating and maintaining business-education partnerships. Two such groups are the Daniels Fund and the Council for Corporate and School Partnerships.

I. Seven Strategies for Success, and Barriers to Avoid

The Daniels Fund, a private, non-profit foundation, reviewed websites, spoke with business leaders and partnership experts to "offer educators, business leaders and administrators practical advice about creating successful and lasting school-business partnerships." They compiled their findings, including strategies for success, best practices, success tips, and barriers to avoid, into the online report, "What Works?: Seven Strategies for Success" (http://www.danielsfund.org/sevenstrategies/). Their **suggested strategies** include the following:

- **Ensure student learning and achievement are the focus of every partnership.**

  "Schools and businesses should sit down together and discuss how the partnership will enhance student learning and how progress will be measured." Improving student achievement requires coordination and structure to the partnership and strong communication between partners. On-site school coordinators are helpful.

- **Develop a well-defined and well-managed program that supports school-based partnerships.**

  Successful partnerships typically contain:

  - formal structure
  - written guidelines
  - a partnership handbook
  - comprehensive databases
  - evaluation tools
  - recognition programs, and
  - specific policies in place for safety, confidentiality, etc.

  Samples of tools to develop the above components are provided at the above link.

- **Make strategic matches between schools and businesses that advance a school's improvement goals.**

  By conducting an inventory of schools' and businesses' needs, assets, and constraints prior to partnering, mutually beneficial partnerships are easier to create and sustain. "Strong support was voiced among business and district leaders for providing partners with a menu of options from which they could pick and choose. The more variety, the better."

- **Set clear expectations for schools and businesses.**

  "Defining roles and responsibilities, goals and measurements of success helps minimize problems that could materialize later due to lack of clarity." They caution, however, that the program should not create unnecessary paperwork and regulations that may deter involvement and curb enthusiasm.

- **Provide training for school staff and business employees.**

  Training can be useful to engage volunteers, open lines of communication, and clarify roles and expectations.

- **Create a meaningful process for communicating about the program and recognizing the contributions of business partners.**

  Effective communication and publication of efforts can serve to recognize business involvement, encourage ongoing excitement and collaboration, and recruit additional collaborators.

- **Regularly monitor and evaluate each partnership and the overall program.**

  Early in the partnership, collaborators should identify what will be evaluated and create "user-friendly, meaningful, and simple evaluations."

Also helpful are their **Barriers to Avoid** which include:

- **Businesses and schools operate differently and on different timelines**

  By addressing these differences upfront and recognizing the constraints and expectations of each system, frustrations may be avoided.

- **Time constraints of unpaid staff**

  Provide incentives and recognition to volunteers: performance pay, gift certificates or planning time.

- **Delays in background checks**

  Background checks are currently a requirement for all non-school district personnel visiting school sites. Advance planning can facilitate completion of these background checks in a timely fashion.

II. Guiding Principles for Business and School Partnerships

The **Council for Corporate and School Partnerships** interviewed about 300 board members and school administrators and 50 business executives, polling them for information about how to best structure, implement, and evaluate business education partnerships. Their findings are reported in the **Guiding Principles for Business and School Partnerships** (The Council for Corporate and School Partnerships, n.d.) and are reproduced in **Appendix G**.

Key points from the overall document include the following:

- Business-education partnerships, previously often philanthropic, are now more likely to be **mutually beneficial partnerships** based on shared values and needs.

- Businesses and schools come in a wide range of sizes with diverse needs and assets. Although frameworks and guidelines are helpful in structuring and implementing partnerships, they are not prescriptions for success. **Partnerships should be flexible to best benefit the collaborators** and partnership decisions should be made at the local level.

- It should be recognized that "**resources from school-business partnerships alone will not close the budget gaps** so prevalent in education – nor will partnerships supplant traditional sources of funding for education" (p. 2).

- Among the important findings of their opinion surveys:
  - Educators consider increasing **student motivation and providing students direction** in their future education to be the most valuable outcomes of partnerships.

  - **School administrators want to publicly recognize their business partners** and say that is it appropriate to do so.

  - Businesses value both the student results and benefits to the company.

- **Business executives stress the importance of structure and evaluation.**

OUTCOME 4

Increase the percentage of graduates at all levels who are knowledgeable about and interested in STEM careers. Knowledge should include current, accurate information about career availability, wages, requirements, and pathways

BUSINESS RECOMMENDED STRATEGIES

1. Expose students to STEM-positive attitudes, which emphasize relevance to students' lives, promote diversity, and do not limit the appearance of STEM professionals to traditional stereotypes.
2. Ensure that core STEM classes and elective classes in which students apply STEM knowledge and skills are viewed as relevant and high-status courses.
3. Increase the opportunity for students to participate in Career Academies.
4. Provide students the option of earning industry certification by the time they complete their coursework.
5. Promote the entrepreneurial aspect of STEM careers/ Combine STEM and business education coursework.

FOR CONSIDERATION: ADDITIONAL EVIDENCE, RESEARCH-BASED STRATEGIES, AND INFORMATION

Originating in the 19th century, vocational education historically provided training for jobs in factories, farms, and offices primarily for students considered unlikely to graduate from high school or pursue postsecondary education. Globalization in the 1980s and 1990s, the loss of U.S. manufacturing jobs, and the subsequent decline in vocational education enrollment spurred the education community to broaden its vision. The term, "vocational education", was replaced with "career and technical education" (CTE) with the aim of raising academic standards and increasing academic skills for CTE students, eliminating the stigma commonly associated with vocational education, and preparing students – not for specific jobs – but for careers in an increasing demanding and changing workforce (Castellano, Stringfield & Stone, 2003). This new vision involved three approaches (Stone, 2000, cited by Castellano et al., 2003)):

- **Education *through* work** –education that uses work as a context for developing broader general skills,
- **Education *about* work** - education that uses work as a context for teaching students the skills needed for long-term occupational and career success,
- **Education *for* work** – education that uses work as a context for developing occupationally specific skills.

In recognition of the changing economy, reauthorizations of the federal Carl D. Perkins Vocational and Applied Technology Education Act led to a number of new initiatives and reforms (Castellano et al., 2003):

I. Tech Prep Programs

Tech Prep was designed to raise student proficiency and ease high school students' entry to and success in community college by (1) integrating the academic and vocational curriculum through a coherent course sequence, and (2) aligning curricula for the last two years of high school and the first two years of community college through formal agreements between secondary and postsecondary schools. More specifically, it is "a planned sequence of study in a technical field that typically provides students the opportunity to earn postsecondary credit toward a technical certificate or diploma " (Lerner & Brand, 2006). Formal agreements aligning curricula of high school and postsecondary institutions specify the instruction that will be provided by both partners and the criteria students must meet to receive postsecondary course credit.

Although Tech Prep **has spurred desired changes in CTE**, such as greater cooperation between secondary and postsecondary teachers, increased use of contextual teaching, and broadening of the technical curriculum away from "job training" toward development of career skills (Hull, 2005), **evidence of its effectiveness in terms of student outcomes has not yet been demonstrated in research and evaluation studies**. The program experienced a variety of implementation problems, ranging from lack of clear guidance to state and local school districts on curriculum integration to the misgivings of parents and students about the strict course sequences, which were perceived as limiting admission to 4-year institutions (Castellano et al., 2003).

II. Integration of vocational and academic curricula

The idea of integrating the academic and vocational curricula was consistent with the recommendation of the business community that high schools prepare students for the demands of the workplace and with research indicating that students learn better in real-world, engaging contexts (Brown, Collins, & Duguid, 1989; Castellano et al., 2003; SCANS, 1991;). Moreover, curriculum integration was viewed as a potential driver of high school reform by fostering teacher collaboration across disciplines and providing students with engaging academic courses that related to adult life and careers, regardless of whether students pursued a job or postsecondary education after high school (Castellano et al., 2003).

III. Promotion of work-related experiences

Workplace opportunities that are "coordinated and sequenced with learning at school" (Castellano et al., 2003, p. 249) were conceived a means of smoothing the transition from school to work. These experiences have taken a variety of forms: (1) co-op programs which provide training as part of a employer-paid job, (2) school-based enterprises, such as running a store or other business on or off the school site, and (3) youth apprenticeships, in which schools provide integrated academic and vocational education related to employment at a worksite (Castellano et al., 2003).

IV. School-to-Work

School-to-Work was authorized by Congress in 1994 through separate legislation, the School-to-Work Opportunities Act. The purpose of this Act was to stimulate states “to develop and implement comprehensive statewide systems to help all young people prepare for high-skill, high-wage careers, using workplaces as learning environments” (Castellano et al., 2003, p. 251). The program included three major elements: career awareness and exploration activities, work-based learning experiences, and school-based activities, including strong academics, linking school- and work-based learning. Many states incorporated program elements described in the section above in their menu of offerings. **A national evaluation found that these initiatives were including students across the achievement spectrum, as intended. However, student participation in the various program components was low. Evaluations, often lacking comparable control groups, yielded mixed or inconclusive results, although most students reported that the program helped them identify their career goals**. Federal support for School-to Work ended in 2001 (Castellano et al., 2003).

V. Career Academies

Career academies originated as a drop-out prevention strategy, then evolved into a **high school reform model** that proliferated nationally in the 1990s (Castellano et al., 2003). Career academies provide a **mix structural and pedagogical reforms** in three key features: 1) small learning communities - a “school within a school” - in which students usually share the same teachers across multiple years, 2) integration of academic, career, and technical curricula around a common career theme (such as STEM), and 3) partnerships with the local business community to supply students with authentic experiences in the workplace (Kemple & Willner, 2008).

A "career and professional academy" is defined in Florida Statutes as “a **research-based program that integrates a rigorous academic curriculum with an industry-specific curriculum aligned directly to priority workforce needs established by the regional workforce board**“ (Section 1003.493, *F.S.*). The two major elements of these academies are a rigorous standards-based academic curriculum integrated with a career curriculum and one or more partnerships with postsecondary institutions, businesses, industry, employers, economic development organizations, or other appropriate partners from the local community. Students graduating from these academies must receive a standard high school diploma, the highest available industry certification, and opportunities to earn postsecondary credit if the academy partners with a postsecondary institution.

A longitudinal randomized field trial, conducted by MDRC researchers (Kemple & Willner, 2008), provides **impressive evidence on the impact of career academies on labor market outcomes**. Students who applied for a place in one of nine career academies in the U.S. were randomly invited by lottery to enroll in the limited number of places available. The career academies were single programs within comprehensive high schools serving disproportionately high percentages of minority and disadvantaged students in or near urban areas (such as Miami; Baltimore; Pittsburgh; San Jose; and Washington, DC). The academies served students across a wide range of performance levels but primarily targeted students who were not engaged in school or at risk of dropping out. The study compared students invited to enroll (the treatment group) with students in the rest of the applicant pool who enrolled in regular high school programs (control group).

- **Career academy graduates earned an average of $2,088 (in 2006 dollars) more per year than their non-academy peers**. This difference is equivalent to an additional $16,704 in earnings during the 8-year period after scheduled graduation. There were **no statistically significant differences in earnings between students at high, medium or low risk of dropping out of school**.

- Young men who graduated from the career academies benefited most, earning $3,722 (in 2006 dollars) more per year on average than their non-academy peers (equivalent to about $30,000 more over the eight year period following graduation). **This effect for young men is comparable to the earnings premium that accrues from two full years of community college enrollment**.

There were **no differences between career academy and non-academy students on standardized math and reading test scores, graduation rates or postsecondary enrollment and completion**. The lack of impact on student academic outcomes was not surprising for two reasons: (1) instruction in the core academic subjects at each of the nine career academies remained similar to that in the rest of the school, and (2) academic and career-related curricula were not truly integrated (Kemple & Willner, 2008).

Currently, we have **limited understanding of the specific features or components of career academies that explain their effectiveness** (Elliott, Hanser & Gilroy, 2002), although focus groups and interviews offer some possible explanations**. Small learning communities** reportedly make students feel known and cared about by their teachers and appear to contribute to improved attendance, persistence and on-time promotion, but are not sufficient to improve student achievement, as demonstrated by the MDRC evaluation described above (Quint, 2006). Nevertheless, the nurturing environment they foster may still be an important factor in improving academic outcomes, such as 9th grade grade point averave and graduation, perhaps even more important than the career-oriented curriculum (Elliot, Hanser & Gilroy, 2008). The positive results on earnings in the MDRC study appear to be related to **career awareness activities and work internships** during high school (Quint, 2006). Developing a better understanding of the most critical components of career academies and how they work is a topic for future research.

Career academies involve both restructuring and pedagogical changes. However, studies of career academies in their first few years indicate that the former are easier to implement than the latter (Elliott, Hanser & Gilroy, 2008). At the heart of pedagogical change is integration of the academic and career/technical curriculum. In general, **curriculum integration has been slow and difficult** - not surprising given the traditionally low status of vocational education and the lack of contact between academic and vocational faculty (Castellano, Stringfield & Stone, 2003). Perhaps most problematic is the lack of consensus on what curriculum integration means and looks like (Alfeld, Pearson, Lewis, & Jensen, 2006).

All curriculum integration models depart from the traditional model of instruction, in which subjects are taught more or less in the abstract, in isolation from any context. In **context-based models**, teachers use CTE as a context for delivery of traditional instruction, for example, by using CTE “real world” applications in math or science problems. A **contextualized approach**, on the other hand, involves engaging students’ thinking about mathematical or science concepts as part of CTE instruction and helps students apply their thinking and learning in various contexts (Alfeld, Pearson, Lewis, & Jensen, 2006). The National Research Center for Career and Technical Education has been conducting three scientifically based research studies to determine whether the contextualized approach to integrating CTE courses with academic content can increase student achievement. The Math-in-CTE study, discussed below, was completed in 2005; the Authentic Literacy Applications in CTE study and the Science-in-CTE study are being launched in 2010.

Using a **randomized field trial, the Math-in-CTE study** (Stone, Alfeld and Pearson, 2009) **tested the effectiveness of a math-enhanced CTE curriculum and professional development model designed to prepare CTE teachers to explicitly teach mathematics concepts naturally occurring in CTE courses**. Working as communities of practice, CTE teachers within specific occupational areas (agriculture, auto technology, business and marketing, health, and information technology) - in collaboration with partner math teachers at their high schools - identified math concepts inherent in their CTE curriculum, then created lessons designed to “move students from the fully embedded example in CTE toward less contextualized and more abstract examples of the math concept.” (p. 771). The math-enhanced lessons were taught by CTE teachers. After students learned a math concept in the context of a particular application, CTE teachers presented additional contextual examples, and ultimately presented the concepts in abstract forms (e.g., an equation) as students would encounter them in a traditional math class or on a standardized test. Teachers assessed students’ understanding through activities and projects related to the lessons and on traditional quizzes and tests. Math teachers provided support to CTE teachers before and after their classes, so that lessons could be further developed and refined during the school year. **Students in the experimental classrooms randomly assigned to the one-year intervention performed significantly better than the wait-list control group on a traditional measure of high school mathematics** (TerraNova developed by CTB/McGraw-Hill) and on a test of college readiness in mathematics (ACCUPLACER ® Elementary Algebra test developed by the College Board). The math-enhanced curriculum had no adverse impact on measures of students’ technical training (both experimental and control groups performed the same on tests of technical skills). After the demonstration project ended, use of the lessons was sustained the following school year by 73% of CTE teachers in the experimental group. Also, 66% of the partner math teachers reported using applications from the CTE lessons in their teaching of mathematics courses.

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APPENDIX A: Levels of Evidence

The following information on the levels of evidence was described in FCR-STEM (2009).

> Educators are faced with a wide variety of options when choosing interventions to implement in their schools and classrooms. Before investing time and resources in a course of action, however, it is important to consider the weight of the evidence supporting an intervention's effectiveness. Some, despite widespread use, have not been tested at all. Others have been evaluated or researched but with varying levels of scientific rigor.
>
> According to the Coalition for Evidence-Based Policy (2003), **randomized controlled trials**, in which program participants are randomly assigned to treatment (intervention) and control groups, **provide the strongest evidence of effectiveness**. Random assignment maximizes our ability to eliminate factors other than the intervention as an explanation for a program's effect. It **gives us a high degree of confidence that the groups vary in only one respect -- the intervention** -- not in prior levels of achievement, demographics or other characteristics that we are not able to observe or measure. Without random assignment, it would be very difficult to separate the effect of the intervention from the characteristics of the participants.
>
> **Studies with well-matched comparison groups**, although not as conclusive, **can provide a moderate level of evidence**. For example, students in treatment and matched comparison groups might be matched on prior achievement, race, and socioeconomic status. Matching, however, cannot eliminate rival explanations of a program's effect that might be attributable to other factors or individual characteristics, such as personal motivation or family encouragement, that are difficult to measure.
>
> **Correlational research describes the direction and strength of a relationship between two variables**. For example, the number of advanced mathematics courses taken in high school is positively correlated with postsecondary success. High levels on the first variable are associated with high levels on the second. However, **correlation is not causation**. Higher student achievement could be due to factors other than course-taking. For example, advanced mathematics courses may tend to be offered in high schools where students' parents have high incomes and educational levels. Also, students encouraged or motivated to enroll in advanced mathematics courses are likely to be high achievers. **Correlational research can be used in the design of interventions that can be subsequently tested through causal research, but it cannot be the basis for cause-and-effect conclusions.**

APPENDIX B: Desired Skills and Knowledge in 21st Century STEM Fields

The following figures (B1-B5) provide information from the National Research Council, Partnership for 21st Century Skills, International Society for Technology in Education, and the National Teachers of Mathematics, on skills, standards, proficiencies, and performance indicators required for students to be considered proficient in STEM.

Preliminary Definitions of 21st Century Skills

1. Adaptability: The ability and willingness to cope with uncertain, new, and rapidly changing conditions on the job, including responding effectively to emergencies or crisis situations and learning new tasks, technologies, and procedures. Adaptability also includes handling work stress; adapting to different personalities, communication styles, and cultures; and physical adaptability to various indoor or outdoor work environments (Houston, 2007; Pulakos et al., 2000).

2. Complex communication/social skills: Skills in processing and interpreting both verbal and nonverbal information from others in order to respond appropriately. A skilled communicator is able to select key pieces of a complex idea to express in words, sounds, and images, in order to build shared understanding (Levy and Murnane, 2004). Skilled communicators negotiate positive outcomes with customers, subordinates, and superiors through social perceptiveness, persuasion, negotiation, instructing, and service orientation (Peterson et al., 1999).

3. Nonroutine problem solving: A skilled problem solver uses expert thinking to examine a broad span of information, recognize patterns, and narrow the information to reach a diagnosis of the problem. Moving beyond diagnosis to a solution requires knowledge of how the information is linked conceptually and involves metacognition—the ability to reflect on whether a problem-solving strategy is working and to switch to another strategy if it is not working (Levy and Murnane, 2004). It includes creativity to generate new and innovative solutions, integrating seemingly unrelated information, and entertaining possibilities that others may miss (Houston, 2007).

4. Self-management/self-development: The ability to work remotely, in virtual teams; to work autonomously; and to be self-motivating and self-monitoring. One aspect of self-management is the willingness and ability to acquire new information and skills related to work (Houston, 2007).

5. Systems thinking: The ability to understand how an entire system works; how an action, change, or malfunction in one part of the system affects the rest of the system; adopting a “big picture” perspective on work (Houston, 2007). It includes judgment and decision-making, systems analysis, and systems evaluation as well as abstract reasoning about how the different elements of a work process interact (Peterson et al., 1999).

Figure B1. Preliminary Definitions of 21st Century Skills, created during the May 2007 Workshop on Research Evidence Related to Future Skills Demands (National Research Council, 2008), reported in *Exploring the Intersection of Science Education and 21st Century Skills* (National Research Council, 2010a, p. 3).

NRC Strands of Scientific Proficiency

Strand 1: Know, use, and interpret scientific explanations of the natural world.

"This strand includes acquiring facts and the conceptual structures that incorporate those facts and using these ideas productively to understand many phenomena in the natural world. This includes using those ideas to construct and refine explanations, arguments, or models of particular phenomena."

Strand 2: Generate and evaluate scientific evidence and explanations.

"This strand encompasses the knowledge and skills needed to build and refine models based on evidence. This includes designing and analyzing empirical investigations and using empirical evidence to construct and defend arguments."

Strand 3: Understand the nature and development of scientific knowledge.

"This strand focuses on students' understanding of science as a way of knowing. Scientific knowledge is a particular kind of knowledge with its own sources, justifications, and uncertainties. Students who understand scientific knowledge recognize that predictions or explanations can be revised on the basis of seeing new evidence or developing a new model."

Strand 4: Participate productively in scientific practices and discourse.

"This strand includes students' understanding of the norms of participating in science as well as their motivation and attitudes toward science. Students who see science as valuable and interesting tend to be good learners and participants in science. They believe that steady effort in understanding science pays off—not that some people understand science and other people never will. To engage productively in science, however, students need to understand how to participate in scientific debates, adopt a critical stance, and be willing to ask questions."

"Evidence to date indicates that in the process of achieving proficiency in science, the four strands are intertwined, so that advances in one strand support and advance those in another."

Figure B2. The Strands of Science Proficiency reported in *Taking Science to School* (Duschl et al., 2007, p. 37)

The ISTE National Educational Technology Standards and Performance Indicators for Students

1. Creativity and Innovation
2. Communication and Collaboration
3. Research and Information Fluency
4. Critical Thinking, Problem Solving, and Decision Making
5. Digital Citizenship

Figure B3. National Educational Technology Standards Students (International Society for Technology in Education, 2007). Also see the Standards for Technological Literacy: Content for the Study of Technology (International Technology And Engineering Educators Association, 2000).

General Principles of K-12 Engineering Education

Principle 1. K–12 engineering education should emphasize engineering design.

"The design process, the engineering approach to identifying and solving problems, is (1) highly iterative; (2) open to the idea that a problem may have many possible solutions; (3) a meaningful context for learning scientific, mathematical, and technological concepts; and (4) a stimulus to systems thinking, modeling, and analysis."

Principle 2. K–12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills.

"Certain science concepts as well as the use of scientific inquiry methods can support engineering design activities. Similarly, certain mathematical concepts and computational methods can support engineering design, especially in service of analysis and modeling. Technology and technology concepts can illustrate the outcomes of engineering design, provide opportunities for "reverse engineering" activities, and encourage the consideration of social, environmental, and other impacts of engineering design decisions. Testing and measurement technologies, such as thermometers and oscilloscopes; software for data acquisition and management; computational and visualization tools, such as graphing calculators and CAD/CAM (i.e., computer design) programs; and the Internet should be used, as appropriate, to support engineering design, particularly at the high school level."

Principle 3. K–12 engineering education should promote engineering habits of mind.
"Engineering "habits of mind" align with what many believe are essential skills for citizens in the 21st century. These include (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations."

Figure B4. The general principles for K-12 Engineering Education as defined in Engineering in K-12 Education: Understanding the Status and Improving the Prospects (Katehi et al., 2009, p. 4-5)

NCTM Process Standards for Mathematical Proficiency

Problem Solving

- Build new mathematical knowledge through problem solving
- Solve problems that arise in mathematics and in other contexts
- Apply and adapt a variety of appropriate strategies to solve problems
- Monitor and reflect on the process of mathematical problem solving

Reasoning and Proof

- Recognize reasoning and proof as fundamental aspects of mathematics
- Make and investigate mathematical conjectures
- Develop and evaluate mathematical arguments and proofs
- Select and use various types of reasoning and methods of proof

Communication

- Organize and consolidate their mathematical thinking through communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Analyze and evaluate the mathematical thinking and strategies of others;
- Use the language of mathematics to express mathematical ideas precisely.

Connections

- Recognize and use connections among mathematical ideas
- Understand how mathematical ideas interconnect and build on one another to produce a coherent whole
- Recognize and apply mathematics in contexts outside of mathematics

Representation

- Create and use representations to organize, record, and communicate mathematical ideas
- Select, apply, and translate among mathematical representations to solve problems
- Use representations to model and interpret physical, social, and mathematical phenomena

Figure B5. Principles and Standards for School Mathematics as reported by the National Council of Teachers of Mathematics (2000, p. 402)

APPENDIX C: Integrated Science Literacy Initiatives

The following contains information about integrated science literacy initiatives and the evidence for effectiveness of each as summarized in Pearson et al., (2010).

CORI: Concept-Oriented Reading Instruction

CORI promotes literacy using science concepts and curricula through instructing reading strategies to teachers in professional development workshops, engagement of students in hands-on investigations and inquiry with text in teams to promote strategic thinking and writing to communicate and publish findings. Student motivation is also important in the CORI model. Students engaged in classrooms using the CORI method showed increased science concept learning, use of productive inquiry strategies, motivation, and text comprehension compared to students in classes without combined literacy and science instruction and/or instruction in reading alone.

http://www.cori.umd.edu/

Guided Inquiry supporting Multiple Literacies (GIsML)

GIsML involves the usage of a fictional working scientist's notebook as a model for students to use in inquiry-based investigations, attempting to make use of secondhand investigations (the notebook) to help students in firsthand (hands-on) investigations (Palincsar & Magnusson, 2001). Students use this scientist's notebook as a guide to reading and interpreting scientific texts and data during hands-on investigations to solve specific questions regarding a particular scientific concept posed by the instructor. A quasi-experimental design showed that students using the GIsML notebook on light learned more than students who used a considerate text.

http://www.umich.edu/~gisml/

Science IDEAS

In-depth Expanded Applications of Science (Science IDEAS) involves a 2-hour time period dedicated to concept-focused science learning embedded with literacy skills. Students engage in firsthand activities, directed by concept maps, to explore and learn the importance of scientific processes. Instruction also includes reading comprehension, journal writing, and discussion as integral components to Science IDEAS. Multiyear, longitudinal studies show that Science IDEAS students perform better on reading and science tests than students who receive separate literacy and science instruction.

http://scienceideas.org/about.html

Seeds of Science – Roots of Reading

Inquiry-focused reading, writing, and language activities as part of the Great Explorations in Math and Science (GEMS) model for K-8 forms the basis for Seeds and Roots, which is designed to use literacy skills to scaffolds knowledge and concept acquisition.

http://www.seedsofscience.org/

Reading Apprenticeship

Focusing on underprepared secondary and postsecondary students, Reading Apprenticeship teaches science instructors to evaluate how they themselves make meaning from scientific texts and then how to convey to their students sense-making and active inquiry with scientific texts. Teachers learn how to engage students through mentoring, promoting discussion of scientific texts, and supporting self-awareness of comprehension deficiencies and problem solving. Randomized experiments in high school biology teaching and learning showed statistically significant learning gains in English language arts, reading comprehension, and biology for students on state standardized tests.

http://www.wested.org/cs/ra/print/docs/ra/home.htm

APPENDIX D: Assessment in Florida

The following was reported on the Florida Department of Education website (http://www.fldoe.org/asp/k12memo/pdf/tngcbtf.pdf; FL DOE, 2010) as of August 17, 2010:

Computer-Based Tests: Grades and subjects which are optional by school in CBT or PBT are shown in ***bold, italic***; full CBT administration except for accommodations are shown in ***red, bold, italic, underlined***.

	2009-10	2010-11	2011-12	2012-13	2013-14
FCAT	Reading (3-10) Mathematics (3-10) Science (5, 8, 11), Writing (4, 8, 10) Reading & Mathematics Retakes (fall, ***spring***)	Science (5, 8, 11) Writing (4, 8, 10) Reading Retakes (fall, ***spring***) Mathematics (***10***) Mathematics Retakes (fall, ***spring***)	Writing (4, 8, 10) Reading Retakes (***fall***, ***spring***) Mathematics Retakes (***fall***, ***spring***)	Writing (4, 8, 10) Mathematics Retakes (***fall***, ***spring***)	Writing (4, 8, 10)
FCAT 2.0	Reading (3-10) (FT) Mathematics (3-8) (FT)	Reading (3-10) (B) Mathematics (3-8) (B) Science (5, 8) (FT)	Reading (3-6, ***7***, 8-10) (SS) Reading Retake ***(fall)*** Mathematics (3-8) (SS) Science (5, 8) (B)	Reading (3-6, ***7***, 8-9, ***10***) Reading Retake ***(fall)*** Mathematics (3-6, ***7***, 8) Science (5, 8) (SS)	Reading (3-4, ***5***, 6, ***7***, 8-9, ***10***) Reading Retake ***(fall)*** Mathematics (3-5, ***6-7***, 8) Science (5, 8)
End-of-Course	***Algebra 1*** (FT)	***Algebra 1*** (B) ***Geometry*** (FT) ***Biology 1*** (FT)	***Algebra 1*** (SS) ***Geometry*** (B) ***Biology 1*** (B) ***US History*** (FT)	***Algebra 1*** ***Geometry*** (SS) ***Biology 1*** (SS) ***US History*** (B) ***Civics*** (FT)	***Algebra 1*** ***Geometry*** ***Biology 1*** ***US History*** (SS) ***Civics*** (B)

Notes: Provision of end-of-course (EOC) assessments requires legislative action to allow use of EOCs instead of comprehensive assessments in high school.
The Geometry and Civics EOCs are being added to the FCAT 2.0 contract through a pending contract amendment.
FT – Field test administration only; EOCs will be field tested in a sample of high schools only.
B – Baseline administration; a scale score will be reported; no developmental scale score or achievement levels will be available.
SS – Standards set; developmental scores, achievement levels, and passing scores will be reported for the first time.

APPENDIX E: Summaries of highest rated Comprehensive School Reform models

(Comprehensive School Reform Quality Center, 2006)

America's Choice: The primary goal of America's choice is to prepare students to perform well on state and local assessments and to enter post-secondary education without requiring remediation. Middle and high schools are divided into small learning communities, such as career academies or "houses", with a team of teachers in the core subjects who stay with students through grades 6-8, 9-10 or 11-12.

The Core curriculum requires 3 years of math and science instruction in middle school and one laboratory science course, Algebra I and geometry in grades 9-10. America's Choice provides the curricula for reading, writing and mathematics (with one exception). "Ramp-up" math and literacy courses are provided for students more than 2 years below grade level. In grades 11-12, the program includes a combination of academies (four choices), Advanced Placement courses, a capstone project, and off-campus opportunities, such as technical training at a community college.

America's Choice trains local staff to provide teacher professional development, focusing on teaching the most important concepts, aligning instruction with standards, differentiating instruction, and establishing classroom routines. *Intensive* professional development is provided on implementing "ramp-up" courses and strengthening grade-level English and math courses.

The principal and a design coach at the school lead the implementation effort. Each school also has a reading coach, math coach, parent/community outreach coordinator, and an adult from the community who advises students (grades 11-12) on work and postsecondary education. Initial training, monitoring and feedback on progress are provided by America's Choice staff.

First Things First: The goal of First Things First (FTF) is to prepare all students for postsecondary education and careers. FTF is a K-12 model that focuses on "feeder schools" –for example, several middle schools whose students attend a particular high school. Schools are organized into small learning communities (SLCs) with teachers moving with students across the grades. Each small learning community is led by a coordinator. Teachers within SLCs have at least 3 hours of common planning time per week for training, technical assistance, discussion of instruction and student progress and planning future improvements. Transitional communities and/or opportunity centers, focusing only on core subjects (no electives), provide temporary (up to a year) learning environments with low class sizes for struggling students.

Schools have the option of using FTF literacy and math curricula, which include components targeted for struggling students. Regardless of whether schools choose to use FTF or other curricula, teachers are expected to align their curricula with state/district standards, individualize instruction based on student needs, and institute block scheduling. Through a Family Advocate System, each student is assigned a teacher who provides support from a caring adult across the grades. The advocate works with the student and his/her parent(s) on tracking progress and establishing a system of interventions.

The district is expected to designate a part-time point-person for the reform initiative, which is led at each school by a school improvement coordinator. School leaders, including the principal, provide coaching to classroom teachers. FTF provides benchmarks for implementation; special software for tracking student, teacher, and school progress; and onsite and off-site technical assistance that is especially intensive during the initial years.

School Development Program: Founded on principles of child and adolescent development, the School Development Program **(**SDP) is a K-12 school organization and governance model designed to mobilize schools and communities to improve the learning environment and students' academic success. The model requires a 5-year commitment from a district and at least four schools.

A district steering committee oversees implementation. Within each participating school, a school planning and management team, led by the principal, develops a comprehensive plan for curriculum, instruction, and assessment; coordinates daily activities; and monitors implementation. A student and staff support team addresses student issues and problems. A parent team develops strategies to involve parents in information sharing, school activities and decision-making.

The model does not offer a curriculum, but does provide curricular and instructional services, such as the (1) the *Balanced Curriculum Process*, designed to help schools plan and implement units of instruction, including formative assessments, aligned with state and local standards and (2) *Teachers Helping Teachers* designed to improve teachers' instructional practices through training, dialogue about teaching strategies, and observing each other's instruction.

SDP oversees professional development and technical assistance for participating districts and schools. Training is provided through institutes and workshops at Yale University or regional offices – primarily for principals and school team members, who in turn train staff or parents at their schools. SDP coaches the three school teams through onsite visits, phone, and email, while SDP demonstration schools provide opportunities to observe the model in practice.

Success for All-Middle Grades: Success for All – Middle Grades (SRA-MG) targets academic outcomes in reading, writing, science, and the humanities – and non-academic outcomes, such as attendance and discipline rates. Schools are advised, but not required, to organize students into interdisciplinary teams, with a teacher for each subject.

The "backbone" of SRA-MG is the Reading Edge Curriculum focusing on fluency, vocabulary development, word recognition, comprehension strategies and writing. Students are grouped for reading instruction based on initial assessments then moved into other groups as appropriate based on their progress. They also are given weekly individual feedback and expected to set personal learning goals and monitor their own progress. The science curriculum emphasizes the connection of science concepts to real-world problems, cooperative learning, observation, research and hands-on learning. The program also has a social-problem solving curriculum and a Humanities curriculum (but no specific math curriculum). Cooperative learning, classroom management and the improvement of literacy skills are integrated into all of the curricula. Teachers of all subjects are expected to address students' reading needs in their instruction.

A Success for All Foundation (SFAF) coach visits each school at least quarterly to observe classrooms, meet with school staff, and help with goal-setting. Each middle school designates an SFA-MG facilitator who observes teachers and provides feedback, organizes assessment data, and oversees implementation. The foundation provides professional development and technical assistance before and during implementation.

Talent Development High School: This high school reform model emphasizes a college-preparatory program with strong scaffolding to help struggling students succeed. Specific courses, with detailed curricular materials, are offered to students one or more grade levels behind in reading, writing and math. For example, a Freshman Seminar, emphasizing cooperative learning and team building, is designed to prepare 9th graders for the rigors of high school, by building academic and non-academic skills (such as career planning and study skills). During the first semester of each school year, students below grade level take a "double-dose" course (e.g., *Transition to Advanced Math* in 9th grade, *Geometry Foundations* in 10th grade and *Algebra II Foundations* in 11th grade) designed to prepare them to succeed in these core subjects in the second semester. *Strategic Reading* and *Reading and Writing in Your Career* are offered to students below grade level in grades 9 and 10, respectively; a college-preparatory reading and writing course follows in 11th grade for students who are still reading 2 years below grade level.

Schools are organized into a 9th grade success academy and career academies (grades 10-12). Instruction is delivered on a block-schedule, specifically four 90-minute periods per day focused on language arts, math, social studies/history/Freshman Seminar, and either science or an elective. Within classes, pre-test and daily assessments are used to guide instruction, form instructional groups and identify students in need of further assistance. Teachers within academies have common planning and lunch times to facilitate collaboration. A Twilight School, an alternative school offered from 3:00 to 7:00 p.m., serves students who have serious attendance or discipline problems or are re-entering school after incarceration or suspension.

An onsite school team, consisting of an organizational facilitator and three curriculum coaches (English, math and Freshman Seminar), leads implementation of the reform model. TDHS staff provides professional development and technical assistance before and during implementation, including training on the project components and organizational change, additional training for the onsite school team, four tiers of teacher support for each TDHS course, and consultation with instructional facilitators from Johns Hopkins University.

APPENDIX F: Florida's Educators

Table F.1 Metrics on teacher availability, teaching positions, and teacher certification for middle and high school mathematics and science, and for industrial arts/technological education (Source: FL DOE, 2009b)

	Number of teachers in Florida (Fall 2008)	Percent of teachers not appropriately certified (2008)	New hires as a percentage of all teachers (Fall 2008)	Percent of new hires hired out of field (Fall 2008)	Projected Florida education completers 2009-2010	Projected number of positions to be filled 2010-2011
Mathematics	11,188	3.0%	6.5%	4.5%	657	1585
Science	9,370	5.4%	8.2%	5.4%	462	1399
Industrial Arts/ Technological Education	597	NA	5.4%	25%	12	41

Table F.2 Salary, Degree Level, and Experience of Florida Teachers, 2008-2009. These values are the average values from all Florida school districts (Source: Fl DOE, 2009a).

	Number of Teachers	Average Years Experience	Minimum Salary	Median Salary	Mean Salary	Maximum Salary
Bachelor's	109,789	10	$34,606	$39,763	$43,745	$55,779
Master's	66,757	15	$37,006	$47,475	$51,064	$58,926
Specialist	4,901	17	$38,319	$55,451	$57,317	$60,567
Doctorate	2,478	15	$39,500	$54,900	$56,685	$61,994
Total	183,925	12		$42,670	$46,938	

Table F.3 Pathways by which teachers may be professionally certified in Florida (Adapted from Sass, 2008a)

	Certification Requirement Options
Graduate of a Florida Teacher Preparation Program	1. Initial Degree College Courses in Traditional Teacher Preparation Program
Course Analysis	2. Initial and After Degree Approved College Professional Training Option – Content Major & College Education Courses per Rule 6A-4.006; 3. After Degree – Professional Preparation College Courses per Rule 6A-4.006
Certified in Another State	4. After Degree – Full Reciprocity 5. After Degree – A valid NBPTS (National Board for Professional Teaching Standards; http://www.nbpts.org/) Certificate in the Subject Area
District Alternative Certification Program	6. After Degree – District Alternative Certification Competency-based Program
All Others	7. After Degree – A valid ABCTE (American Board for Certification of Teacher Excellence; http://www.abcte.org/) Passport Certificate in the Subject Area; 8. After Degree – Two semesters of successful college full-time teaching experience; 9. After Degree – (EPI) Education Preparation Institute Competency-based Program

APPENDIX G: Guiding Principles for Business and School Partnerships

The Council for Corporate & School Partnerships (n.d.) compiled Guiding Principles for Business and School Partnerships. The following is excerpted from their document:

THE FOUNDATION: Developing the partnership's core values

- School/Business partnerships must be built on shared values and philosophies.
    - Begin with an open and frank discussion about values, goals and needs.
    - Respect and reflect the culture and goals of both the education and business partners.
    - Support the core mission of the school.
    - Bolster the academic, social and physical well being of students.
    - Compliment the social values and goals of the school, business partner and the community.
- Partnerships should be defined by mutually beneficial goals and objectives.
    - Clearly define short and long-range goals.
    - Focus on collaboration to determine activities that meet the goals of all involved.
    - Partnership goals and objectives should be aligned with education goals of individual schools and/or district.

IMPLEMENTATION: Translating values into action

- Partnership activities should be integrated into the school and business cultures.
    - Partners should communicate frequently to respect and understand each other's cultures.
    - Partnerships should provide students, teachers, and business employees with opportunities to interact at school, community and business sites.
- Partnerships should be driven by a clear management process and structure.
    - Each school and school district should have a point person to manage partnerships to ensure quality and alignment with educational goals for students.
    - Partnerships should include written descriptions of roles and responsibility, accountability measures and guidelines for responsibilities of educators and business employees.
    - Partnerships should include training for all key personnel.
- Partnerships should define specific, measurable outcomes.
    - Partnerships should be guided by collaborative agreement on outcomes, benchmarks and measures of progress.

CONTINUITY: Sustaining the partnership over time

- Partnerships should have support at the highest level within the business and school and concurrence at all levels.

    - Superintendents, principals, school boards, CEOs and managers should articulate and demonstrate support for the partnership internally and externally.
    - Partnerships should be explicitly supported by teachers, employees and other constituents.
    - Communities should have the opportunity to review and contribute to partnerships.

- Partnerships should include detailed internal and external communications plans, which clearly illustrate expectations of all parties.

EVALUATION: Determining strengths, weaknesses and future directions

- Partnerships should be developed with clear definitions of success for all partners.

    - Measures for success should be established at the outset of the partnership.
    - Partnerships should be evaluated on a regular agreed-upon basis.
    - Evaluation should include collection and analysis of information to determine accomplishments, strengths and weaknesses of the partnership.

APPENDIX H: Additional Feedback from the STEM*florida* Business and Education Conference

The following are comments and suggestions recorded during the working lunch at the 2010 **STEM***florida* Business and Education Conference that were not already addressed in the body of the report.

- Guidance/career counselors need to be provided information/resources regarding STEM career opportunities.
- Take advantage of Web 2.0 (social networking) to reach younger audiences.
- Involve and increase STEM awareness of parents, community leaders, and policymakers.
- Be explicit that STEM is for ALL students.
- Ensure that Technology and Engineering components are treated as importantly as Science and Mathematics in this initiative.
- Refer to Sarasota County's STEM work plan as we create goals.
- It would be helpful to "tell a story" with the various research results. Summarize in 3-5 key findings and recommendations.
- Add a policy focus to the STEM plan.
- Stratify Bright Futures to pay full scholarships for STEM students.
- Create a link to the (desired) statewide, comprehensive STEM website to imbed on the Chamber of Commerce website.
- In order to increase business-education partnerships ask for time, not money.
- Inform students about the pay associated with STEM careers.
- How do we capture and measure teacher passion? That is truly important.
- Make it financially feasible for professionals in STEM careers to become teachers.
- Marketing is important and should not be ignored in the creation of a STEM plan.
- Specify which languages are most desired by business.