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21st Century Curriculum Change Initiative: A Focus on STEM Education as an Integrated Approach to Teaching and Learning

Kimberly Barcelona*

Department of Defense Educational Activity, Fort Rucker Alabama, United States of America
*Corresponding author: kimbobkizzy@sbcglobal.net

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Abstract The objective of this paper is to apply Kotter's 8-Stage Process for Change in transforming traditional school organizationsinto models for 21st century instruction and explore research that suggests the change process was effectively implemented in order to improve student achievement. This paper is developed through inquiry and research that describes a course of action for a change initiative to enrich curricula and meet a vision for competency-based curricular reform. Two analyses were conducted including (1) review of literature and statistics driving the need for curricular reform and (2) a qualitative analyses of data collection from studies conducted on schools which instituted curricular reform to develop interdisciplinary curricula in the areas of science, technology, engineering and math (STEM). Analyzing and using the statistics and data from school systems in the state of Maine, which have made changes in their curricula and instructional methods, allows for critical review of the success of the change process. Results reveal that curriculum reform in the areas of STEM that creates a shift towards a more integrated approach in curriculum design has improved student achievement. Improving curriculum and instruction would be a hollow gesture without identifying and reviewing the research that suggests the use and application of the principles from John Kotter's 8-Stage Process for Change outlined in his book *Leading Change*was applied to deeply root successful change. Curriculum reform is a response to the growing need for educating future innovators that can continue to keep our world moving forward. Kotter's first step to creating change begins with a sense of urgency and currently we have a wealth of studies that are conducted that speak loudly to our society that we must focus on curriculum that involves students in problem solving challenges and innovative thinking activities to prepare them for the needs our society today and in the future. The educational system we have today is a product of the industrial age and was organized like an assembly line to produce a standardized product, which was considered the educated. At the time, it fit the needs of businesses. It is time that we begin asking what skills we will need our learners to know in the next twenty years. Engineers work in teams to solve large, complex problems and educational systems lack necessary skill building activities to foster what industries will need for the future success of our global society (Senge, 2014). As our economy moves from a manufacturing-based economy to, an information and service-based economy, the demand for a workforce well educated in science, technology, engineering and math (STEM) is growing. Unfortunately, the number of students who choose STEM fields continues to decline (US Bureau of Labor Statistics, 2009; Galloway, 2008; National Research Council Committee on Science, Engineering Education Reform, 2006; Mooney & Laubach, 2002). As such, there is a great need to spark interest among our K-12 youth in STEM, and to develop and facilitate quality engineering experiences for K-12 students (National Science Board, 2003; Frantz, DiMiranda & Siller, 2011) (Table 1).

Keywords: *21st century learning, curriculum, STEM education, problem solving, teaching*

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1. Introduction

The urgency for a focus on integrated curriculum in the areas of science, technology, engineering and math has been made clear by research studies conducted in our educational systems today (Table 1). Many school systems have invested in the need for curriculum reform to bring about change to meet the needs of what our students will face in the global world and work force. Supporting research indicated that integrative approaches to teaching and learning improve students' interest and advancement in STEM learning skills. STEM learning experiences prepare students for the global economy of the 21st century (Cachaper, 2008; Cullum, 2007; Hynes & Santos, 2007) and students need a solid STEM knowledge to become ready for college and employment. According to the U.S. Department of Education (2007), 75% of the fastest growing occupations require significant science or mathematics training (Table 1). The importance and value of STEM education has resulted in the need for significant national reform in K–16 education and curriculum (Becker & Park, 2011). The U.S. Department of Education (2007) also notes that one of the federal STEM education goals for K–12 education, in order to avoid the declining STEM pool of human resources in the U.S., is “to prepare all students with the science, technology, engineering, and math skills needed to succeed in the 21st-century technological economy, whether in postsecondary education or the workforce; and graduate students with the capability and motivation to become STEM professionals, educators, and leaders”.

In response to the urgency for preparing our students to be knowledgeable in the job opportunities of the future, school systems have begun to look closely at curricula and drive change in their schools to improve student achievement in science, technology, engineering and math.

2. Current Research

In 2011 Kurt Becker and Kyungsuk Park conducted a study that synthesized the findings from existing research on the effects of integrative approaches among STEM subjects on students’ learning. Twenty-eight studies were selected and thirty-three effect sizes were calculated to examine the effects of integrative approaches among STEM subjects (Table 9). With respect to the grade levels, the effects of integrative approaches showed the largest effect size at the elementary school level and the smallest effect size at the college level. Regarding the types of integration, STEM, the integration of four subjects, presented the largest effect size. In addition, concerning the achievement through integrative approaches, STEM achievement showed the highest effect size and mathematics achievement showed the smallest effect size. The results of this preliminary meta-analysis reveal that integrative approaches among STEM subjects have positive effects on the students’ learning.All of the studies used the integrative approaches among STEM subjects, and the seven forms of integration were examined with the effect sizes for students’ achievement.

Becker and Park’s study sets the stage for further review of the urgent need for curriculum reform that can be connected with other research arenas. Between autumn 2012 and spring 2013 the Business and Industry Advisory Committee (BIAC) launched a survey of its national member and observer organizations’ priorities, perspectives and activities on education issues. BIAC received a high response rate from both BIAC members and observer organizations, suggesting that education and skills issues are important priorities for national business and employers’ organizations in our work force economies and beyond. The survey gathered both qualitative and quantitative data on the nature of collaboration and participation between private stakeholders and policy-makers, on education policy and reform. The survey results indicate that future needs for our global economy are educated students that are well-prepared for the work for in the areas of science, technology, engineering and math (Table 3).

Table 4 shows the respondents’ top priorities for education policy reform in pre-primary, primary and secondary schools. The most commonly selected priority is school curricula reform, closely followed by linking education to labor market needs and improving co-operation with employers. Improving teaching quality and training, including school leaders, is also a high priority for employers in many countries according to the Survey results. Given the attention attributed to curriculum reform, the Survey requested specific details from respondents about which elements of the curriculum should be strengthened in their respective countries. The results are shown in Table 4. According to the responses, it appears that employers most commonly believe that more emphasis is needed on science, technology, engineering and mathematics (STEM) in national curricula. This is closely followed by enhancing focus on core skills such as numeracy and literacy, as well as critical thinking and communication skills.

Another study conducted in 2004 by Levy and Murnane focused on the issue that the economy has become, not just more global, but also more knowledge based, the skill mix in the economy has changed dramatically. Results indicate that the proportion of workers in blue-collar and administrative support positions in the United States dropped from 56 percent to 39 percent between 1969 and 1999. Meanwhile, the proportion of jobs that are managerial, professional, and technical increased from 23 percent to 33 percent during the same period (Levy &Murnane, 2004). Skill demands within jobs are increasing too. Jobs that require routine manual or cognitive tasks are rapidly being taken over by computers or lower-paid workers in other countries, while jobs that require higher levels of education and more sophisticated problem-solving and communication skills are in increasingly high demand (Levy &Murnane, 2004).

At the elementary school level, the study by Barker &Ansorge (2007) and the study by Sullivan (2008) reported higher student achievement outcomes. Students who were exposed to integrative approaches demonstrated greater achievement in STEM subjects. Integrative approaches provide students with a rich learning context to improve student learning and interest (Riskowski et al., 2009). Students’ interest and their positive attitude toward STEM fields could help improve motivation in their future STEM careers (Sanders, 2009). Educators and policymakers throughout the United States continue to debate the international competitiveness of their students. The ability of the United States to thrive in the growing global economy is influenced by how well our students compete internationally. The ability to solve complex problems is central to science and engineering and STEM education and these studies conducted proved an increase in problem solving abilities among students being tested.

NCES initiated another study, in an effort to link the National Assessment of Educational Progress (NAEP) scale to the Trends in International Mathematics and Science Study (TIMSS) scale, so that states could compare the performance of their students with that of students in other countries. The study was conducted in 2011 with eighth-grade students in all 52 states/jurisdictions that participated in the NAEP mathematics and science assessments. Results from 2011 TIMSS (Foy, Martin, and Mullis, 2012) indicate how the performance of eighth-grade students in the United States as a whole compares with that of students in the other countries and subnational education systems that participated in the TIMSS assessment; it does not, however, provide results for individual U.S. states. NCES conducted the NAEP-TIMSS linking study to provide each state with a way to examine how their students compare academically with their peers around the world in mathematics and science.

NCES coordinated efforts across the NAEP and TIMSS assessment programs to conduct the 2011 NAEP-TIMSS linking study. The National Assessment Governing Board and NCES modified the NAEP assessment schedule so that eighth-graders in all 50 states, the District of Columbia, and Department of Defense schools could be assessed in mathematics and science in 2011.

The NAEP-TIMSS linking study used states' NAEP scores to predict performance on TIMSS. Nine states participated in 2011 TIMSS at the state level. In the linking study, their actual TIMSS scores were used to validate their predicted results.

The 38 countries and 9 subnational education systems from various countries that assessed eighth-graders in 2011 TIMSS are all referred to as "education systems" in this report. Results in mathematics and science are reported as average scores on the TIMSS scale (0–1,000, with an average of 500).

Beginning in 1995, with the most recent cycle of assessments taking place in 2007, TIMSS uses multiple-choice questions to assess learning of the science and math content commonly found in most countries' school curricula in particular grades. Students in the United States perform better on TIMSS than on PISA, coming in 9th place in 8th grade math and 11th place in 8th grade science in 2007 (Quek et al., 2008), in part because not all of the higher-performing industrialized countries participate in TIMSS, and also because American students are used to multiple-choice tests that ask them to reproduce curriculum content. However, when the United States' TIMSS performance was compared with that of only the most developed nations in 2003, it ranked below the average of the 12 countries (Ginsburg, Leinwand, Anstrom, & Pollock, 2005).

The most widely used global student measures are the PISA assessments from OECD, which began in 2000 measuring performance in 43 countries and subsequently grew to include 60 countries and 5 non-national systems in its 2009 surveys. Together, these countries constitute 90 percent of the global economy. In 2009, a number of provinces in mainland China took part in the PISA surveys for the first time, and India is planning to participate in future surveys. PISA truly has become a global education report card.

The PISA assessments, given to 15-year-olds, differ from TIMSS in that their goal is not primarily to measure subject matter knowledge but to determine how well students near the end of compulsory schooling apply their knowledge to real-life situations. The emphasis is therefore on understanding of concepts, mastery of processes, and real-world problem solving. PISA reports the average score for students in each country and identifies the top performers (levels 5 and 6) and poor performers (levels 1 and 2).

3. How does the United States Measures Up in National Assessments?

The most recent United States performance on PISA (OECD, 2010b) is disappointing, to say the least; in all three subject areas (Table 6).

In science, U.S. students ranked 17th among OECD member countries in 2009 (23rd among all nations and provinces taking the test). The U.S. score of 502 is average among OECD members. However, 18 percent of U.S. students did not reach level 2, considered the baseline level for being able to use science and technology in everyday life. This was an improvement from 24.4 percent in 2006. At the top end of performance, the United States has roughly the same proportion of high scorers as in 2006, with 10 percent of students reaching levels 5 and 6. Compare this figure with 28 percent in Shanghai, China, and 22 percent in Finland.

In math, the United States ranked 25th among OECD member countries (31st among all nations and entities taking the test). The U.S. score of 487 is below the average for OECD member countries, with 23.4 percent of students not reaching baseline level 2. Only 12 percent of American students reach level 5 or 6, compared with 50 percent in Shanghai, China, and over 30 percent in Singapore and Hong Kong, China.

The United States is not among the top performers in any of the three subjects tested by PISA. Despite some improvements in science, U.S. performance is average at best and largely flat. While small differences in scores on the PISA scale matter little, the performance gap between the United States and top-performing nations is huge. American students lag a full year behind their peers in the countries that score highest in math. Factoring into the U.S. performance are large variations in scores by region and by socioeconomic status. In other nations, large enough samples of students take the test to enable comparisons among states or provinces. The United States' sample size is not commensurately large, but the sample does enable approximate regional estimates that show that states in the Northeast and Midwest do better than states in the West or South. U.S. average performance is also strongly affected by the high proportion of students achieving scores at the bottom two levels. This continuing class- and race-based achievement gap means that we are failing to prepare large numbers of our young people, especially those in our minority communities, for postsecondary education or training. But we also lack a high proportion of students who reach the top skill levels that are critical for innovation and economic growth. Even our best and brightest are not achieving the way they should be.

In sum, the results from the world's global education report cards show that American students are not well prepared to compete in today's knowledge economy. A host of developed nations are surpassing us in education. These results are especially disturbing in light of the fact that the United States reports the world's second-highest per-pupil expenditure.

Mathematics

- Average scores for public school students in 36 states were higher than the TIMSS average of 500.

- Scores ranged from 466 for Alabama to 561 for Massachusetts.
- Massachusetts scored higher than 42 of the 47 participating education systems.
- Alabama scored higher than 19 education systems.

Science

- Average scores for public school students in 47 states were higher than the TIMSS average of 500.
- Scores ranged from 453 for the District of Columbia to 567 for Massachusetts.
- Massachusetts and Vermont scored higher than 43 participating education systems.
- The District of Columbia scored higher than 14 education systems.

Document report findings from the Curriculum Reform Project, which conducted case studies of educational reforms in nine middle and senior high schools across the United States, prepared a cross-site analysis of the cases and identified implications for policy, practice, and research. The focus of this 4-year research project has been curriculum reform, with specific attention to the three areas of science education, mathematics education, and high order thinking across the disciplines. The literature review found that proponents of higher order thinking favor the constructivist learning approach, which requires students to be active builders of their own knowledge and which requires a change in teaching strategies and teachers' roles (Anderdson, 2000).

4. Discussion

The study conducted by Catherine Scott (2012) examined the characteristics of 10 science, technology, engineering and mathematics (STEM) focused high schools that were selected from various regions across the United States. In an effort to better prepare students for careers in STEM fields, many schools have been designed and are currently operational, while even more are in the planning phase. Data collected, analyzed and documented in this report included websites, national statistics databases, standardized test scores, interviews, and published articles. A comparative case design was used to identify key components of STEM high school designs. Results from this study indicate that students who attend STEM-focused high schools outperformed their peers at similar institutions. Although programs varied, a common theme that emerged from these schools was a focus on more rigorous course requirements with electives centered on STEM content and application. Students who attended STEM schools were engaged in real-world problem solving and completed internships and/or a capstone projects to fulfill graduation requirements. Most students attending STEM schools in this study were admitted based on a lottery system while two out of the ten schools admitted all applicants. The student population was comprised of a higher number of minority students compared to other schools in the United States. The findings in this study are significant because they indicate that many students, when given the opportunity and support, are able to successfully complete rigorous STEM academic programs that go beyond the basic graduation requirements (Table 9).

Research shows that integrative approaches improve students' interest and learning in STEM. STEM learning experiences prepare students for the global economy of the 21st century (Cachaper et al., 2008; Cullum et al., 2007; Hynes & Santos, 2007) and students need a solid STEM knowledge to become ready for college and employment. According to the U.S. Department of Education (2007), 75% of the fastest growing occupations require significant science or mathematics training. The importance and value of STEM education have resulted in the need for significant national reform in K–16 education and curriculum.

5. A Curriculum Change Initiative in a School System

These reports support the importance of integrated instruction that focuses on Science, Technology, Engineering, and Mathematics, which continues to be a high priority in K-12 education. It is clearly evident that the jobs of tomorrow are rooted in STEM (Science, Technology, Engineering and Math) fields. Integrated STEM education creates critical thinkers, increases literacy, and empowers the next generation of innovators. Innovation leads to new products and processes that sustain our economy. Innovation and literacy depend on a solid knowledge base in the STEM areas, and most jobs of the future will require a basic understanding of the sciences, technology, engineering and math.

The big message here is that integrated curriculum is not just for engineers, scientists or school laboratories. It carries the big ideas that are informing our philosophers and transformative thinkers. The lesson for us as educators is to realize that school subjects need to connect and not be taught in isolation from each other. Students must be able to transfer all learning across curricular areas and make connections that can increase levels of academic achievements.The urgency is clear and many school systems have invested in the need for curriculum reform. United States has become a global leader, in large part, through the genius and hard work of its scientists, engineers and innovators. Yet today, that position is threatened as comparatively few American students pursue expertise in the fields of science, technology, engineering and mathematics (STEM). President Obama has set a priority of increasing the number of students and teachers who are proficient in these vital fields and school leadership has acted to create a vision to move our students forward to be successful in global society.

By following Kotter's eight step process (Appendix B), school curriculum can become enhanced to support and encourage learning by giving rise to developing 21st century skills through STEM.

Curriculum reform, that pushes instruction towards a greater focus on integrated STEM education, has a large guiding coalition in the United States. Present Obama has implemented initiatives to address the urgency of 21^{st} century instruction to strengthen 21^{st} century skills in our students. This, in turn, has begun to filter down to school systems that have joined in the movement towards integrated curriculum to give greater focus on problem solving, innovative thinking and higher order thinking skills.

The educational research community has begun to conduct longitudinal studies focusing on STEM education and school districts have begun to create a vision and mission for their schools to address the urgent needs of preparing students for the global work force in STEM fields.

The state of Maine has become a model for looking closely at their change process as they progress through school curricula reform to move curriculum towards a rich inclusion of STEM education. Kotter's eight steps to driving change (Appendix B) are evident in the documentation of how the state has created movement in the direction of STEM collaboration. Maine has recognized the urgency of curriculum reform in their schools and implemented a movement towards a change initiative in classroom instruction. In order for a shift in curriculum focus to be successful it must begin with well-trained, energetic and willing teachers (Borrego & Henderson, 2014) that can become part of a guiding coalition. Because major change is so difficult to accomplish, a powerful force is required to sustain the process (Kotter, 2012, p. 53). Professional development and time for open discussion about the changes will allow teachers to share ideas and concerns about infusing project-based STEM learning into everyday activities.The behavior of the guiding coalition must be consistent with the vision or it can spoil all other communication. In addition, the leaders of curricular reform must provide opportunities for 2-way communication, which assists in addressing seeming inconsistencies that may undermine the initiative. The guiding coalition within each individual school system must also embrace community and global resources that support a richer curriculum in the STEM areas. Developing an effective vision that is focused enough to guide employees must be clear and efficient. Simplicity is essential (Kotter, 2012, p. 79). It is very important for all stakeholders to have high standards that will help achieve the vision (Kotter, 2012) and the vision must be presented clearly to the staff. The Maine STEM Collaborative was formed in 2007, and is a statewide partnership of education, research, business and industry, government and non-profit sectors who have come together to foster the improvement of STEM education in the state. It is overseen by a Steering Committee representing 17 organizations, and has a general membership representing 45 additional organizations. The Collaborative Vision developed is that Maine will have a strong educational foundation in science, technology, engineering, and mathematics that will propel the state toward economic prosperity. The Mission includes dedication to the Maine STEM Collaborative works to increase the quality of STEM education, aspirations, and awareness in the state through the integration, coordination, and promotion of efforts. The mission guides the coalition to focus on guiding students to become critical thinkers, as well as confident and successful life-long learners in a richly diverse society. Importance is placed on students becoming fluent in working together in order to grow and succeed together in the 21st century interconnected world.

In order to develop a positive school culture, communicating the change vision is essential to surface thoughts and ideas about the changes. Current programs and activities that Maine has implemented, to communicate the vision and mission, include STEM Summits (bi-annually), Support-cooperative programs between members and other state STEM efforts, and Commission landscape studies on STEM in Maine. Leaders have designed communication efforts nationally by creating brochure, newsletters, talking points, summit reports, landscape study summary and websites.Nothing undermines the communication of a change vision more than behavior on the part of key players that seems inconsistent with the vision (Kotter, 1996 as cited in Satchwell&Loepp, 2002). Through this change of culture, over time the school will develop a strong, professional culture that supports staff and student learning. Educational leaders in Maine recognized that current awareness and understanding levels about STEM vary widely and having very diverse target audiences means that they need different message versions and delivery mechanisms. K-20 students, parents, teachers, guidance counselors, administrators, general public, government, legislators, businesses and industries were all groups of focus when communicating the vision. The wider the dissemination of information, the better the outcomes are to assure that everyone understands the importance of the initiated changes.

During school level staff meetings, expectations must be addressed about what constitutes as best teaching practices and staff members will be given the opportunities to reflect and share their ideas. It will be important for the leadership team to believe in their teachers and trust in them to do their job, so they do not feel defeated. This will be accomplished by strengthening and recognizing those in the department who are making progressive changes and taking chances in their teaching. Educators must work collaboratively in order to improve their students' performance. The substantial body of research on learning should be the basis for making the vision for STEM instruction more effective. This research suggests that students learn by constructing their own meaning from experiences (Driver & Oldham, 1986; Sachse, 1989; Watson &Konicek, 1990) and schools must begin to develop effective ways to deliver instruction from an integrated curriculum.

Empowering employees for broad-based action is important in focus a school on working to create a culture that influences the way people think, feel, and act. When a school has a positive, professional culture one finds meaningful staff developments, successful curricular reform and the effective use of student performance data (Kotter, 2012). Learning thrives when there is a positive school culture. Several challenges to successfully implementing integrated STEM education programs can be overcome with specific attention to the program's design. The challenges associated with the change must have support from the administration, continuous staff development, and coaching programs that focus on the specific needs of teachers transitioning to a new way of teaching. STEM teachers' implementation of the integrative approaches highly depends on their individual characteristics when accepting a new instructional method, their perceptions toward the integrative approach, school context, delivery methods, and so on. That is, STEM teachers' decision to implement integrative approaches is associated with national curricula, educational trends, rewards, and supports within their specific school contexts

(Rogers, 2003; Sahin, 2006; Zubrowski, 2002). As Zubrowski (2002) noted, for successful implementation, the integrative approaches require close collaboration among STEM teachers, STEM teachers' commitment to the integrative approach, and administrative support.

It is essential to highlight all gains, whether large or small. Student engagement and achievements can be posted on the website, in newsletters and throughout the halls of the school. Inviting the community in to STEM fairs will also celebrate student work.Specific priorities for the short-term goals in school districts throughout Maine came out of strategic planning retreats that implemented additional programs to meet objectives to Foster STEM learning approaches and skills development. Efforts were highlighted that promoted educator professional and leadership development in STEM. These short term winsthat were generatedhelped build, integrate, and coordinate STEM efforts in Maine, promote STEM careers and their pathways and engage in awareness and advocacy STEM linked to Maine's economic vitality. By promoting STEM measurement and evaluation activities and by catalyzing greater financial support for STEM education efforts in Maine the changes were able to continue forward momentum.

Schools must reflect on the goals, mission and vision of implementing STEM principles constantly throughout the school year to ensure the changes are occurring and in the direction that was intended. The school must, "never let up allowing momentum to be lost and regression to follow (Kotter, 2008, p.139 as cited in Borrego & Henderson).

It is important to let the new practices take root and it becomes clear that they work. Teachers, students, staff and parents must talk about the changes and constantly discuss the validity of the new approaches (Kotter, 2009, p.166 as cited in Satchwell&Loepp). With on-going celebration of the short term wins, identification of what works and what needs improvement and collaborative efforts of all stakeholders, the improved school culture will anchor and develop naturally. In order to consolidate gains and promote more change, Educational leaders throughout Maine provide their schools with ongoing support for STEM that is provided through a variety of programs. These programs include the Learning Technology Initiative, Title IIB Mathematics and Science Partnership Grants, and support for numerous awards programs and competitions including the Presidential Awards for Excellence in Mathematics and Science Teaching and the National Science Youth Camp. Recently, DOE funded the Math-in-CTE Program and the Third Cohort of the Governor's Academy for Leadership in Science and Mathematics. DOE is currently finding Maine's statewide strategic plan for STEM learning, and is drafting an Environmental Literacy Plan (ELP) for Maine's students. The development of the ELP is a partnership among the Maine Department of Education, the Maine Environmental Education Association, the Maine Department of Conservation and Maine Audubon. In order to anchor the new approaches in the culture educational systems in the state continue to monitor and study changes in the workforce to drive instruction that will allow student to compete in the global economy. The Center for Workforce Research and Information (CWRI) looks at STEM analysis in two unique ways. The first is through our Quarterly Census of Employment and Wage program (QCEW) which collects employment and wage information for workers covered by unemployment insurance. This data includes wage, employment, and industry information for individual establishments and is used to evaluate labor trends, industry developments, and comparisons in a time series analysis. The second is the Occupational Employment Survey (OES) which gathers information from employers about the number of workers, their duties and skills, and the wage distribution for those workers. It is through this program that we begin to see the dramatic differences in wage and skill sets between STEM occupations and all other occupations. Pairing this information with data from the University of Maine Systems and employment forecasts gives school systems a better glimpse into the future. The outlook for STEM occupations is promising and schools must now ensure that they educate, train, and prepare the workforce with advanced knowledge, skills, and abilities to meet future demand.

6. Conclusion and Future Study

In education and political circles STEM education has been gathering enormous support in the last decade. Not only has President Obama announced a $250 million public-private initiative to recruit and train more STEM teachers, but also the U.S. Department of Education's Race to the Top grants competition is giving bonus points for applications that stress STEM instruction (Piro, 2011). This funding is on top of the nearly $700 million the federal government already spends on science and math education programs within NASA, NSF, and other agencies (Piro, 2011). This financial support is largely being perpetuated on the belief that the U.S. is becoming less competitive and secure and that we are losing our national status in STEM fields. Yet, in the midst of all the interest in STEM education, educational and political leaders may want to also invest in programs that promote innovation and creativity, as well as STEM. School systems have joined the guiding coalition to create change in their schools to meet the highly publicized need for a focus on STEM education. It would be of interest to investigate another implication, cited by Humphreys (1981), which revolves around assessment of student learning. Additional research and data are needed on organizational and instructional practices to complement the growing body of longitudinal data on student outcomes, as well as additional research that measures outcomes other than test scores. In addition, more research on the effects of integrative approaches by grade levels should be conducted to design effective instruction of STEM education with careful consideration of students' ages.

An integrated approach to instruction may impact performance on standardized tests but currently requires alternative methods of assessing student understanding of essential concepts. In addition, Teachers who are not provided with adequatein-service or time to thoughtfully develop an integrated curriculum may go to an unstructured, "a little of everything" approach (Jacobs 1989, as cited in Lake, 1995), rather than a truly integrated approach to learning. This does not facilitate the kinds of understanding and achievement that integrated programs discussed in this report have documented. Best practices for initial and ongoing in-service training need to be explored more fully. A related issue is the extent to which pre-service teachers are prepared to teach in settings that are committed to curriculum integration (Lake, 1994) in the STEM domains.

STEM education research has a wide range of methods, outcomes, subjects, and faculty working to discover more about students and teachers in STEM classrooms. There is a research base, but more research is also needed in both descriptive classroom applications for practicing teachers and in rigorous qualitative/quantitative research projects. Johnson and Daugherty (2008), and others prior (Zuga, 1994, Patrina, 1998), have also suggested that technology education research could be improved by using more rigorous methods. Johnson and Daugherty's (2008) argument could also possibly be made about STEM education research in the past 4 years, especially in relation to the lack of large scale STEM classroom research studies being conducted in K-12 classrooms. When looking at research from the past 4 years in STEM education, the data in this paper suggests an even balance between academic research and action research for practitioners. There are practicing teachers interested in STEM education as a method of classroom instruction, which is evident by the numerous "small" research activities developed by teachers. The data suggests there is interest and opportunities to study STEM education at research institutions as well as more teaching focused universities. Collaboration between faculty in STEM disciplines, along with classroom teachers is evident in the participants data in the research studies, but may need to increase to gain access and perspective to the way STEM content is understood and taught in K-12 settings (Brown, 2013).

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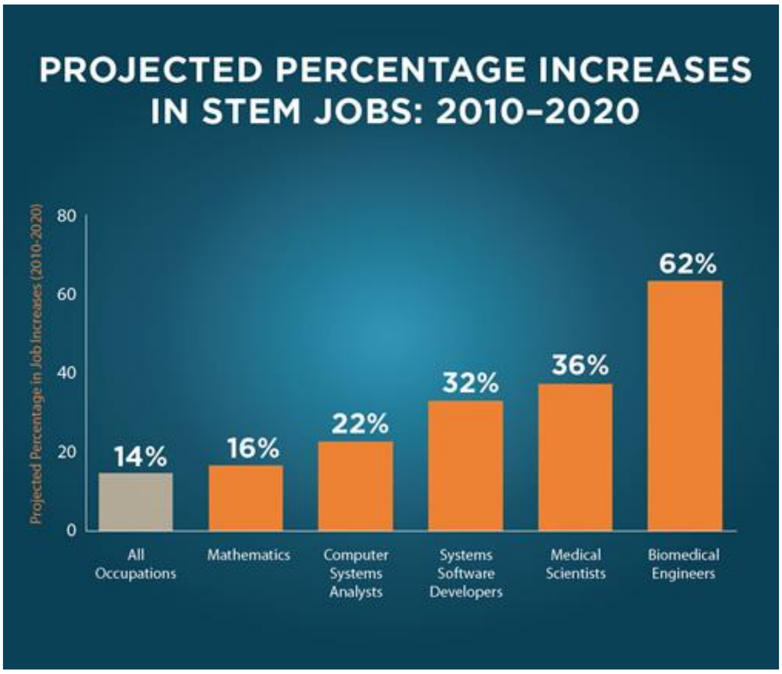
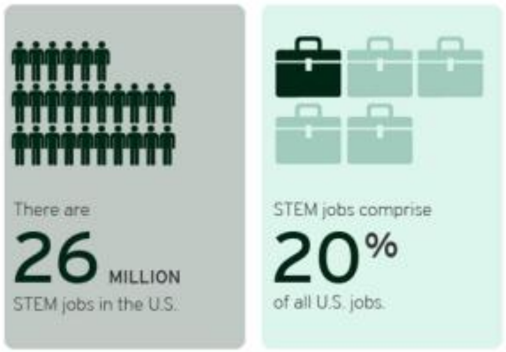
Appendix A

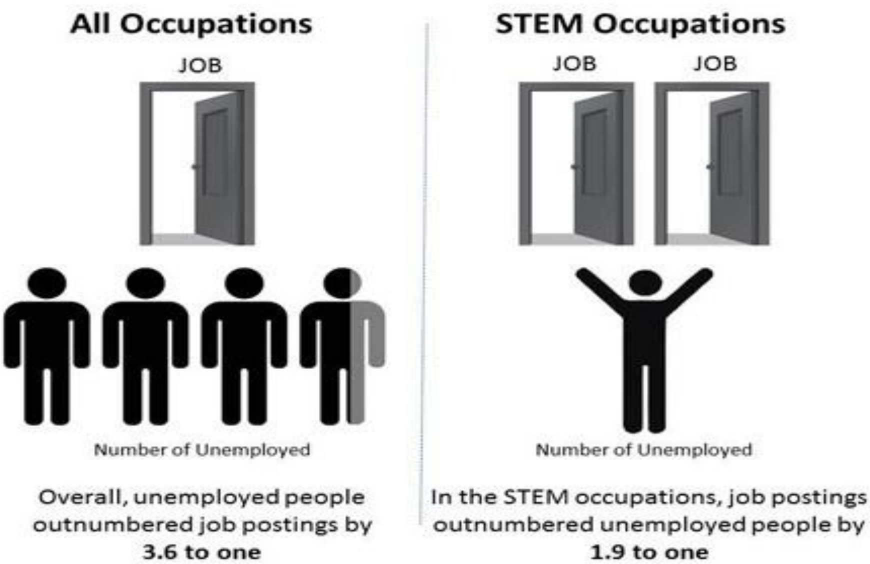
Table 1. STEM Education Coalition Fact Sheets and Messaging on STEM Education Issues





U.S. Department of Education (2007). Retrieved from http://www.ed.gov/stem.

Table 2. Future Jobs for the 21st Century Learne



U.S. Department of Education (2007). Retrieved from http://www.ed.gov/stem

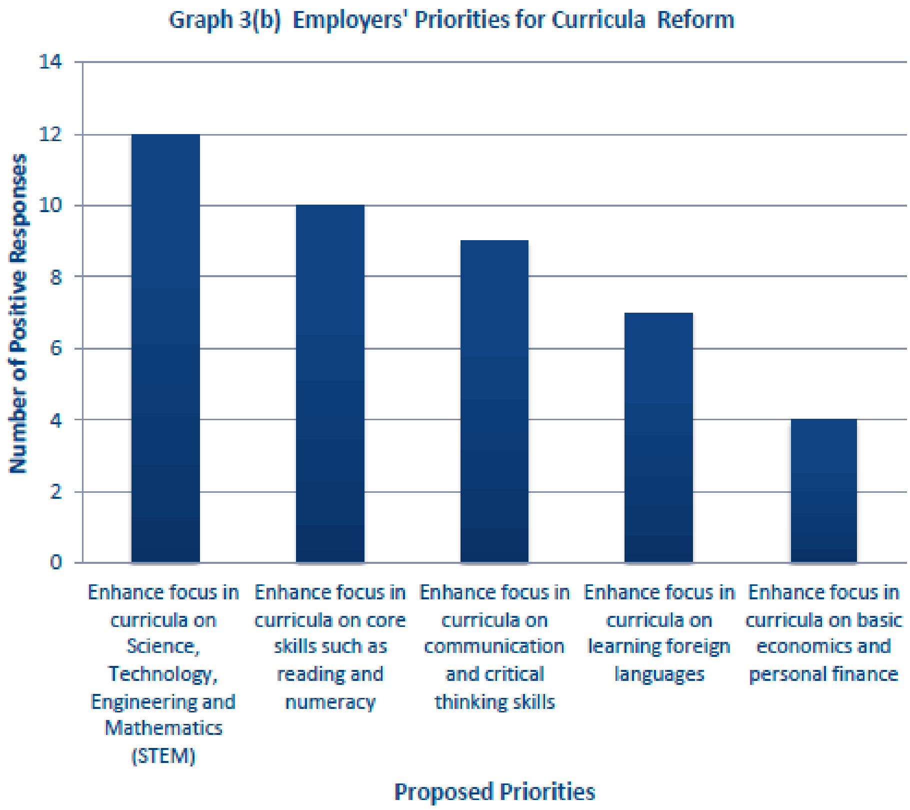
STEM	9.2 million
Architecture/Engineering	2.8 million
Computing	4.6 million
Mathematics	0.1 million
Life Sciences	0.6 million
Physical Sciences	0.4 million
Social Sciences	0.6 million

Source: Jobs data are calculated from the Bureau of Labor Statistics (BLS), Employment Projections 2010-2020, available at http://www.bls.gov/emp/.

Table 3. U.S. elementary schools devote and average of 2.3 hours per week to science, a decline of 43 minutes since 1994

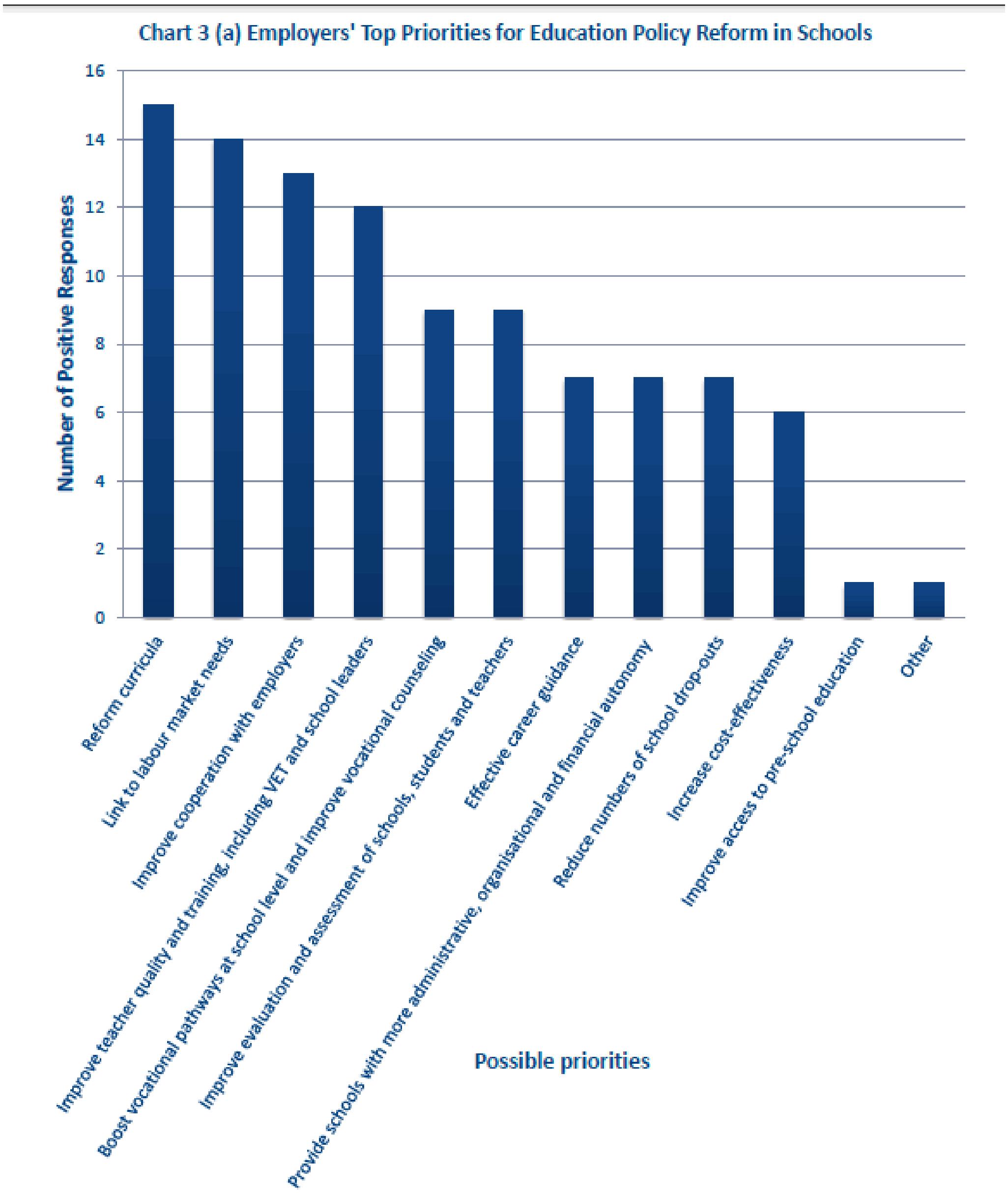
Source: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public Teacher Data File," 1987-88, 1990-91, 1993-94, 1999-2000, 2003-04, and 2007-08; "Public School Data File," 1987-88, 1990-91, 1993-94, 1999-2000, 2003-04, and 2007-08; "Charter Teacher Data File," 1999-2000; and "Charter School Data File," 1999-2000. Retrieved from http://nces.ed.gov/surveys/sass/tables/sass0708_005_t1n.asp

Table 4. Business and Industry Advisory Committee (BIAC) survey



Retrieved from http://curriculumredesign.org/wp-content/uploads/130605_BIAC_Education_Survey_PREMIUM.pdf.

Table 5. Business and Industry Advisory Committee (BIAC) survey



Retrieved from http://curriculumredesign.org/wp-content/uploads/130605_BIAC_Education_Survey_PREMIUM.pdf.

Table 6. Average Scores for Countries Ranking Above the United States in Reading, Mathematics, and Science on the 2009 PISA

Reading		Mathematics		Science	
Country/Region	Score	Country/Region	Score	Country/Region	Score
Shanghai, China	556	Shanghai, China	600	Shanghai, China	575
Korea	539	Singapore	562	Finland	554
Finland	536	Hong Kong, China	555	Hong Kong, China	549
Hong Kong, China	533	Korea	546	Singapore	542
Singapore	526	Chinese Taipei	543	Japan	539
Canada	524	Finland	541	Korea	538
New Zealand	521	Liechtenstein	536	New Zealand	532
Japan	520	Switzerland	534	Canada	529
Australia	515	Japan	529	Estonia	528
Netherlands	508	Canada	527	Australia	527

Belgium	506	Netherlands	526	Netherlands	522
Norway	503	Macao, China	525	Chinese Taipei	520
Estonia	501	New Zealand	519	Germany	520
Switzerland	501	Belgium	515	Liechtenstein	520
Poland	500	Australia	514	Switzerland	517
Iceland	500	Germany	513	United Kingdom	514
United States	500	Estonia	512	Slovenia	512
		Iceland	507	Macao, China	511
		Denmark	503	Poland	508
		Slovenia	501	Ireland	508
		Norway	498	Belgium	507
		France	497	Hungary	503
		Slovak Republic	497	United States	502
		Czech Republic	493		
		United Kingdom	492		
		Hungary	490		
		Luxembourg	489		
		United States	487		

Source: Comparing countries' performance in reading, mathematics, and science (Figures 2.16, 2.17, and 2.18). OECD (2011b), *Lessons from PISA for the United States: Strong Performers and Successful Reformers in Education*. Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264096660-en.

Appendix B

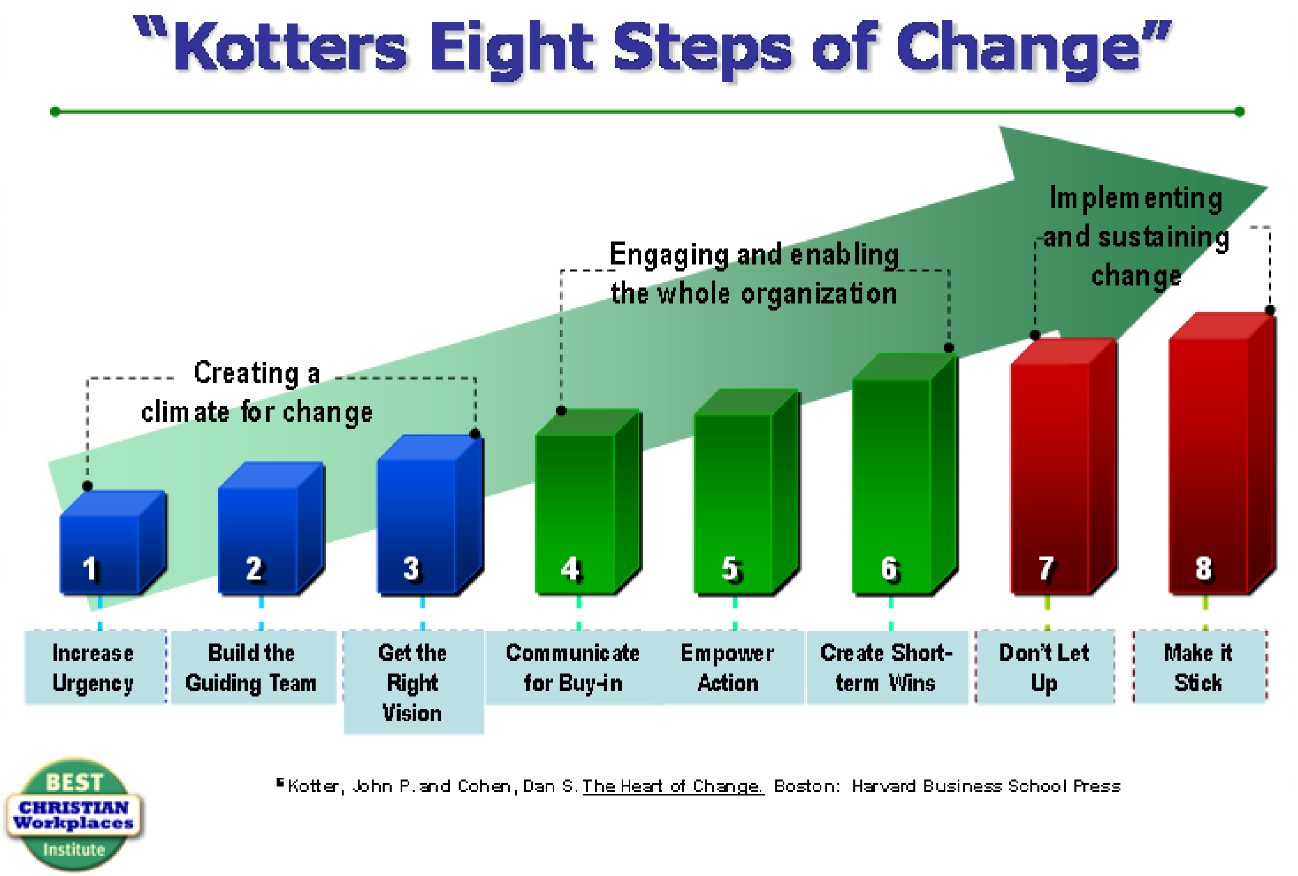
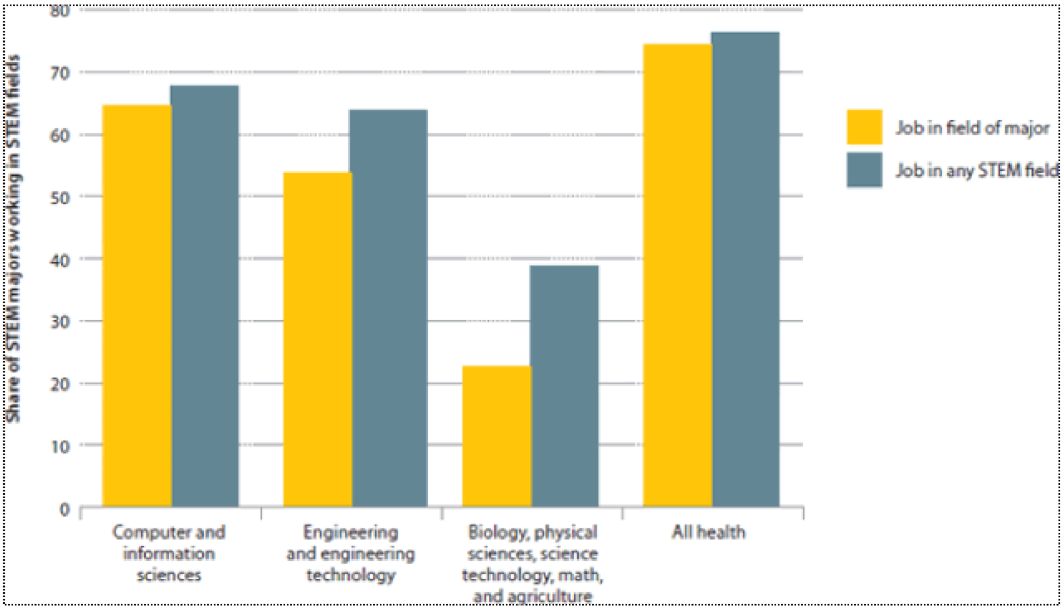


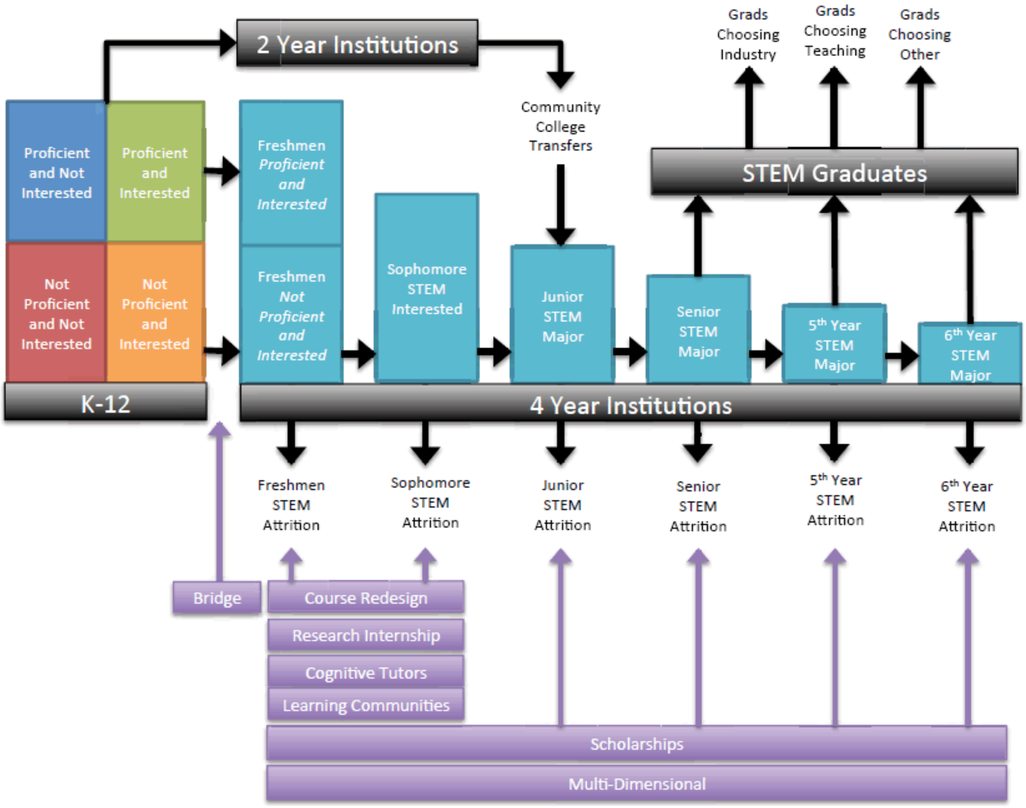
Table 7

Occupational field of STEM college majors one year after graduation, 2009



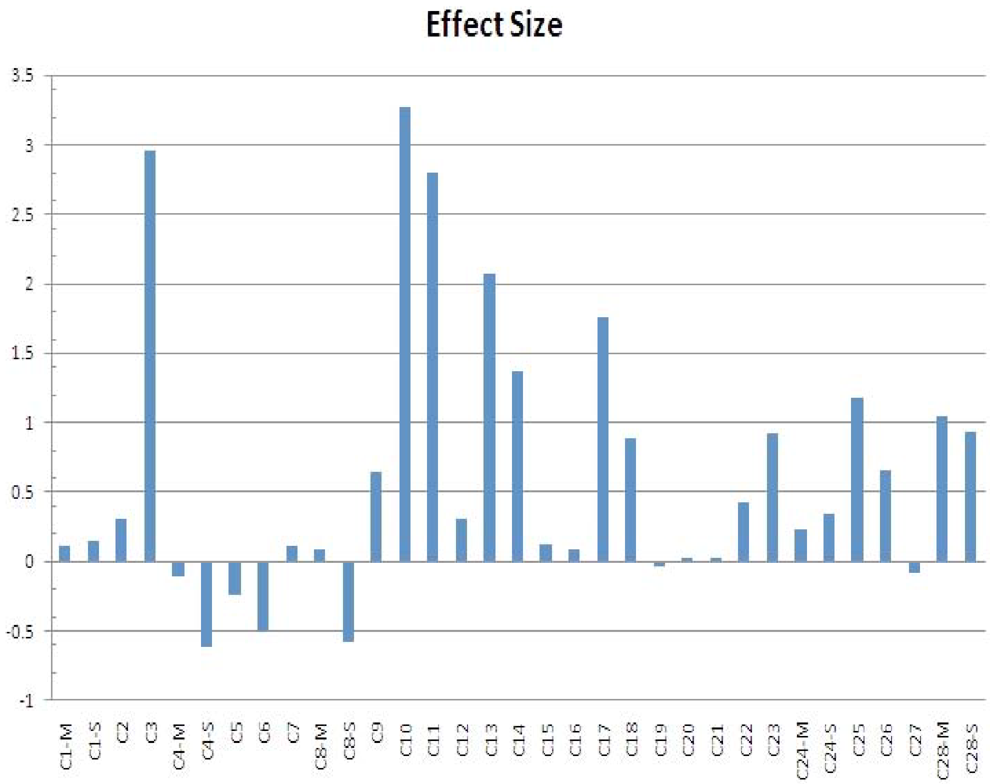
Source: National Center for Education Statistics. (2013). 2003–2004 Baccalaureate and Beyond Survey (B&B) [Restricted data file]. Washington, DC: U.S. Department of Education.; tabulations by authors.

Table 8

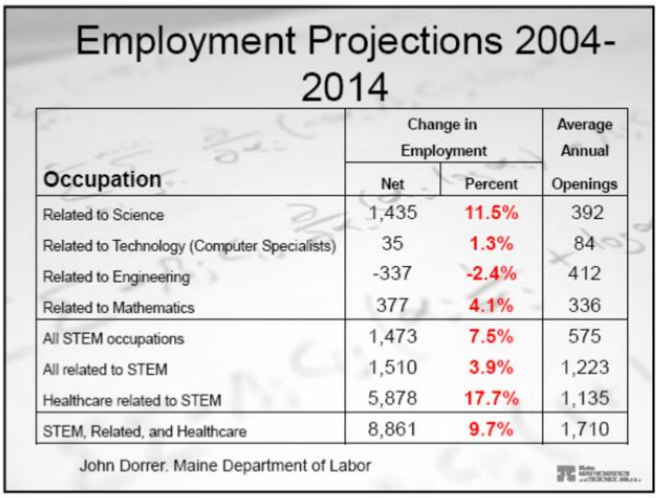


Retrieved from http://www.scoop.it/t/effective-stem-education-biotechnology-relevant-mostly/?tag=curriculum+reform.

Table 9



Becker, K. & Park, K. (2011).Journal of STEM Education, Volume 12.



Employment Projections 2004-2014

Occupation	Change in Employment: Net	Change in Employment: Percent	Average Annual Openings
Related to Science	1,435	11.5%	392
Related to Technology (Computer Specialists)	35	1.3%	84
Related to Engineering	-337	-2.4%	412
Related to Mathematics	377	4.1%	336
All STEM occupations	1,473	7.5%	575
All related to STEM	1,510	3.9%	1,223
Healthcare related to STEM	5,878	17.7%	1,135
STEM, Related, and Healthcare	8,861	9.7%	1,710

John Dorrer. Maine Department of Labor

Retrieved from http://www.umaine.edu/epscor/STEM/LRSummitReportFinal%208-13-10.pdf.

Table F.2. Superintendent Region MHSA Mathematics and Science (CM)

MHSA Mathematics and Science: CUMBERLAND (CM)	2006-2007 MHSA Mathematics		2007-2008 MHSA Mathematics		2007-2008 MHSA Science		2 Year Summary Mathematics %
	Total N	Percent ME	Total N	Percent ME	Total N	Percent ME	
Total	3192	49	3129	49	3078	50	49
Ethnicity							
African American/Black	131	6	124	2	123	6	4
American Indian or Native Alaskan	9	0	13	0	10	0	0
Asian or Pacific Islander	86	30	89	24	87	23	27
Hispanic	50	26	42	12	40	13	20
Caucasian/White	2916	51	2861	51	2818	52	51
Not Reported							
Identified Disability							
Yes	390	10	396	10	381	15	10
No	2802	55	2733	54	2697	55	54
Current LEP							
Yes	134	14	225	15	216	15	15
No	3058	51	2904	51	2862	52	51
Economically Disadvantaged							
Yes	459	20	553	19	535	24	20
No	2733	54	2576	55	2543	55	54
Migrant							
Yes	0	0	0	0	0	0	0
No	3192	49	3129	49	3078	50	49
Gender							
Female	1541	47	1556	48	1530	47	48
Male	1651	51	1573	50	1548	53	50

ME= Meets or Exceeds the standard

Retrieved from http://www.umaine.edu/epscor/STEM/ME%20STEM%20Collaoborative%20-%20REL%20K-12%20STEM%20Achievement%20Report.pdf