



Part I

Why STEM?

Here's to the crazy ones. The misfits. The rebels. The troublemakers. The round pegs in the square holes. The ones who see things differently. They're not fond of rules. And they have no respect for the status quo. You can quote them, disagree with them, glorify or vilify them. About the only thing you can't do is ignore them. Because they change things. They push the human race forward. And while some may see them as the crazy ones, we see genius. Because the people who are crazy enough to think they can change the world, are the ones who do.

—Steve Jobs (Apple Inc.)

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The Tipping Point

The tipping point is that magic moment when an idea, trend, or social behavior crosses a threshold, tips, and spreads like wildfire.

—Malcolm Gladwell

The past decades have presented multiple attempts at education reform. Still, the demands on the system for change endure. Those demands come from multiple sources and are multifaceted. They arrive with unrelenting speed. Think time has vanished to the point where it seems a luxury for leaders. As a result, wise, committed, innovative educational leaders have become master tinkerers. Neither the demands nor our responses have resulted in a reconceptualization of public education.

Past reform efforts led to relatively minor increases in performance. It is not surprising that the role of the federal government in education became more heavy-handed as the 20th century turned a corner. United States students were slipping in performance when compared to students from the Far East and Finland. Bipartisan support led to the passage of the No Child Left Behind (NCLB) act in 2001. The shortcomings of public education, the need for increased accountability, and a zoom lens on teachers became rallying calls for reform mandates and political agendas nationally.

The debates, like many others currently ongoing in our country, polarized the stakeholders. Common Core Standards, related assessments and teacher and principal performance evaluations, global competition, charter school competition, and declining resources made for a perfect storm.

● DATA AND LEGISLATION

Educators knew there was a soft underbelly about which they did not speak. The achievement gap appeared on center stage as agencies began reporting the data by subgroup population performance. The focus on high school graduation rates and college entry now was accompanied by a conscience factor. Children in poverty were receiving a second-class education. According to the 2013 Kids Count data, that population comprises 40 percent of Black and African American children, 37 percent of American Indian children and 34 percent of Hispanic and Latino children and compared to 14 percent of non-Hispanic white children (see Kids Count). The school-age population is increasingly bilingual as well. Immigration and birth rates combine to accelerate the nation's schools to the shifting point where there will no longer be a non-Hispanic white majority. It is these very children with whom schools have been least successful. Alarms went off. The goal of No Child Left Behind was to eliminate the achievement gap associated with race and social class (Rothstein, 2004). NCLB set a goal that proficiency for all was to be reached by 2013–2014. That date has come and gone. The achievement gap remains.

The U.S. Census Bureau's report, *Educational Attainment in the United States: 2009*, indicates that only 60.9 percent of Hispanic students complete high school or more, for example, compared to 90.4 percent of non-Hispanic whites and 81.4 percent of African Americans (see Ryan & Siebens, 2012). The most difficult and legitimate complaint against our system emerged from this kind of data.

Fiscal policy exacerbates the problem. State funding does not flow based on the needs of the children served. The Great Recession of 2008 resulted in cuts to state funding for education across the country. Tax caps were passed to alleviate tax burdens, as school funding and public employee benefits became hot spots in the political arena.

Race to the Top was passed in 2009. Its purposes were to increase all student achievement, eliminate existing achievement gaps, increase the graduation rates, and produce graduates who were college and career ready to compete in the global economy. States desiring access to the funding associated with the law adopted the Common Core Standards, created new testing and tracking systems, and incorporated student results into personnel evaluation systems.

That final provision is most revealing. It touched the heart of every school with teacher and principal evaluation. Now, the federal government was not just lifting up expectations for students; it was also threatening the

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work security of those who were not making enough contribution to that effort. Funds were included to entice states and districts to “choose” compliance. In desperate fiscal conditions, due to the loss of state revenues and the repercussions at the local level, most did.

Educators, parents, and policymakers alike knew for years that not all children were receiving equal educations. But it was politically expedient and purposefully essential to maintain public support. America’s schools are, at least most of them, publicly funded and responsible to children, parents, and taxpayers. Therefore, educational leaders became masters at discussing and publishing those data that were positive.

The percentage of graduates going on to higher education was one of those. The open enrollment admission policies of many colleges bolstered the numbers. Then, those very same institutions began complaining about the preparation of their freshmen. All the positive data was true, but it was also incomplete. As others began to reveal more negative data, efforts to retain public support made educators look as if they were purposely hiding something. All were hampered by the complexity of the issue and the dimensions of the problem. Even with no personal gain or systemic benefit at stake, trust for the system and its leaders eroded.

● SOCIAL AND ECONOMIC FACTORS

In addition to the purely educational issues, there are social and economic issues driving the agenda. The nation’s population is aging rapidly. The United Nations Population Division coined the phrase *gray tsunami* to describe the growing percentage of the population that is over sixty years of age and living well into their eighties. These Americans will be dependent on the growing immigrant population in the United States, as they become the workforce on which our economy, and our democracy, will rely. Of course, minority students’ lower achievement in science and math presents a jeopardized feeder system for professions in those fields.

The Federal Reserve Bank of Dallas (2013) reports the immigrant population had increased from twenty-five million in 1996 to forty million by 2011. So it is not surprising that the Pew Research Center notes that an astounding 93 percent of the workforce expansion over the next thirty-six years will be made up of new immigrants and their second-generation offspring. As immigrant population numbers increase, the United States school population reflects that changing landscape. According to the Center for Public Education (2012),

The U.S. Census Bureau predicts that “minorities” will make up the majority of U.S. schoolchildren by 2023, the majority of working-age Americans by 2039, and the majority of all Americans by 2042 . . . American students can expect to live and work in communities that will be much more diverse.

Within a few decades, the school-age population will be primarily black, Hispanic, and Asian; the elder population will be primarily non-Hispanic white. The profile of race in America will be profoundly evident when the age factor is considered.

● WORKPLACE AND TECHNOLOGY

The need for a highly skilled workforce and the lack of success with the very populations that will constitute the workforce of the future captured the attention and heightened the concerns of business leaders. They are already seeking foreign workers in STEM professions at increasing rates. H-1B visas allow companies to employ foreign workers in occupations that require highly specialized knowledge in fields such as science, engineering, computer programming, medicine, health, and economics, among others. Those workers can be employed in the United States for full-time jobs for up to six years. Companies like Microsoft, Facebook, and Google have advocated increasing the number of those visas allowed each year, indicating they cannot find American workers for these jobs. In fact, Facebook is called a “**visa dependent**” company with 15 percent of its workers from other countries. But they are not alone.

Forbes reports that IBM hired 6,190 highly skilled immigrant workers in 2012 and paid them an average annual salary of \$82,630 (see Forbes). In the same year, Microsoft employed over 4,000 foreign workers. They received an average annual salary of over \$109,000. From big to small, businesses are clamoring for a more highly skilled workforce prepared to enter STEM professions. A 2012 report from Information Technology Industry Council, Partnership for a New American Economy, and the U.S. Chamber of Commerce suggests that “by 2018 there will be more than 23,000 advanced degree STEM jobs that will not be filled even if every new American STEM grad finds a job” (p. 1). In addition, this report discloses that currently there is full employment for U.S. workers with advanced STEM degrees and that STEM fields hire a higher proportion of foreign workers than non-STEM fields.

Simultaneously, the cost of a computer has decreased as computer capacity has increased. More people own laptops, and mobility has

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become an asset. More businesses offer wireless service to their customers. *Wi-Fi* has become a word. The proliferation of programs has extended down to the youngest of users and has broadened the scope of possibilities for all.

Social media continues to be adopted by the mainstream. Businesses and professionals, alike, use LinkedIn, Facebook, and Twitter as means of meeting the public and sharing information. Apps for newspapers and magazines are downloaded and are being used more exclusively in growing numbers. Storage is in clouds, and collaboration is available over multiple platforms.

Resistant or resilient, education has survived for decades by growing and adding but fundamentally remaining structurally recognizable. That day has passed. Classrooms with desks and blackboards and teachers lecturing will soon take a place in a historical photo album next to a one-room schoolhouse and a Conestoga wagon. Schools cannot be the bastions of the past. They must be the conveyors of the values and lessons of the past, but their role is to ready children for the future. And the future is not a patient partner.

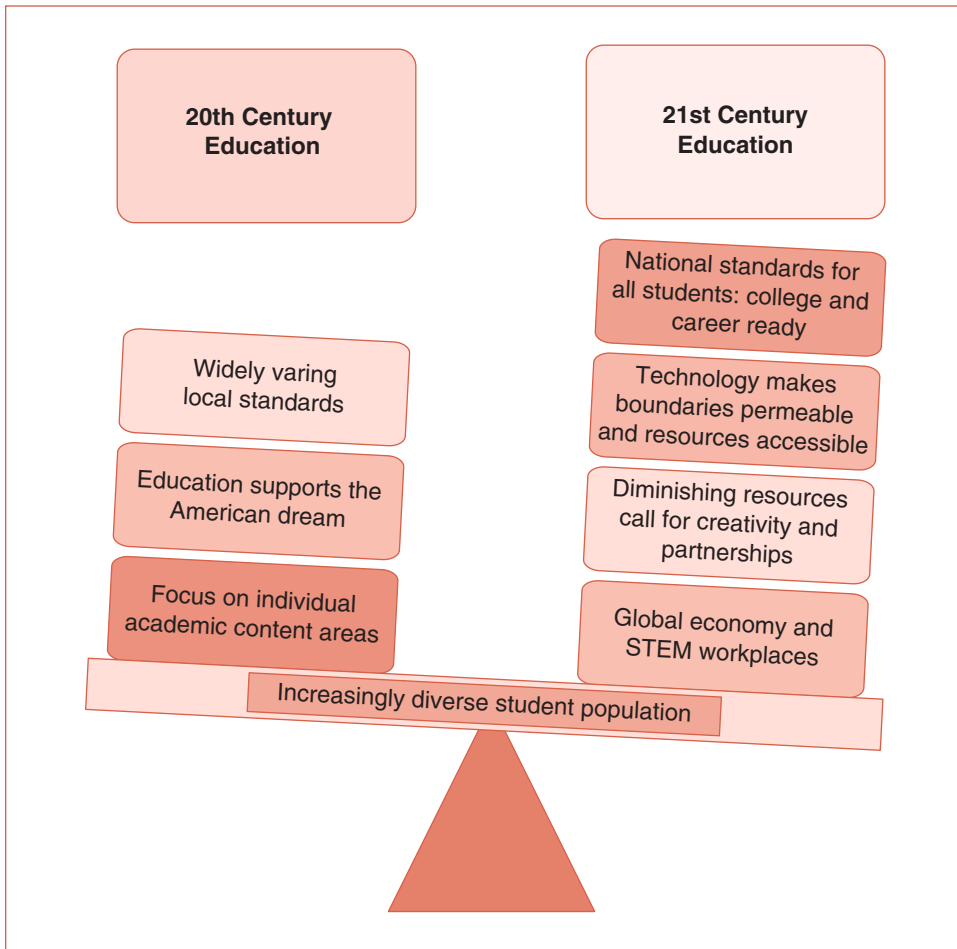
● PUNCTUATED EQUILIBRIUM FOR EDUCATION

STEM possesses the first really promising potential to reenvision the educational orientation from the bottom up. From that small turn, systemic change can follow. The cause for hope comes from the sciences. About forty years ago, paleontologists Stephen Jay Gould and Niles Eldredge introduced the concept of “punctuated equilibrium” (see Gould & Eldredge, 2013) to explain the phenomenon of sudden change within a species. This model suggests that organisms can exist with very minor changes for long periods of time. Then, usually as the result of a change in an environmental or external factor, the organism reinvents itself in a very short period of time. Those who don’t make the change find their survival threatened. We suggest this is where education finds itself at this moment in time.

It is already the second decade of the 21st century. Yet schools hold to ten-month school years, minutes of content instruction, bells, separate subject areas, and massive transportation systems. Too often, educational leaders wait for money to incentivize our decisions about how and what to change. Or the next policy change comes along, and educators respond. Major differences between the 20th and the 21st centuries lie in the push to

national standards, the explosion of technology, the fact that resources are diminishing while a call for creativity and innovation is heightened, the global economy and the increase in STEM workplaces are all undergirded by an increasingly diverse student population with increasingly diverse needs (see Figure 1.1).

Figure 1.1 The Tipping Point



● STEM CREATES A RADICAL OPENING

The process associated with STEM requires a transition in what educators do and how they do it. It provides a vehicle to free educators from 19th and 20th century thinking, morphing how we have structured schools, teaching, and learning. STEM provides the curricular foundation for an

environment that allows creativity to reenergize education and educators. That environment empowers students to be active, engaged, innovative, creative learners.

STEM is not a program that simply amplifies and accelerates the integration or focus on science, technology, engineering, and math in secondary schools. A STEM shift encourages reimagining schools, from kindergarten through the 12th grade, including the way curriculum is designed, organized, and delivered. This book is intended to open minds to an approach that has the potential to disrupt long-held traditions. Like the ox cart man in Donald Hall's famous children's story, this book invites educators to kiss those traditions on the nose and let them go. **Then, we make room for new life, a new way of working together, a new way to engage students, and local answers created by local leaders.**

Some may wonder why these four disciplines—science, technology, engineering, and mathematics—have become the fulcrum for an educational system shift. STEM is the first vehicle to enjoy the combined support of business leaders, government leaders, philanthropists, and communities at large. It holds exciting potential for teachers to reignite creativity in their work and to share with their colleagues, bringing reinvigorated energy back to school. It is a large enough umbrella to embrace comprehensive change. It encompasses how we learn and changes how we teach. It calls for access to technology as an unlimited and unlimiting resource. It addresses the development of 21st century skills such as critical thinking, problem solving, collaboration, agility, initiative, effective communication, social-emotional behaviors, morals, and accessing and analyzing information. It modifies how time is seen and used. It utilizes real-world problems and opportunities for authentic problem solving.

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The STEM shift is not a call for the elevation and focus on the subject areas of science, technology, engineering, and math, but an entire systemic shift in how learning happens. It is not about the subject but about the learning process of inquiry, imagination, questioning, problem solving, creativity, invention, and collaboration. Science is the most viable subject for inquiry. Science, technology, and engineering do not exist without mathematics. None exist without the capacity for reading and writing. Creativity is required with all inquiry and invention, so the arts are no longer for the artists but for all. **STEM is an organizing principle upon which to build the interconnectedness of subjects.**

Engagement and motivation connected with a topic of interest can bring a learner to a point. Application in real-world settings takes that

learning into relevance and related achievement. Opportunities to apply learned information and concepts are key facets of a true STEM shift. Application of knowledge is a planned part of the curriculum and includes ever-increasing levels of difficulty and a variety of projects and problems to be investigated alone and with others.

As educators, we recognize that debate often triumphs over purpose. Here, the language and the name of the shift are caught by this propensity. Is the shift arising from STEM, STEAM, or something else? Dr. Vicki Metzgar, director of the Middle Tennessee STEM Innovation Hub, prefers the term *TEAMS*, reordering the letters to represent an underlying principle of the shift. Dr. Eli Eisenberg, senior executive director general of ORT Israel, prefers the term *iTEAMS*, identifying innovation as an essential component of the shift. Both agree a more realistic representation of the goal to integrate subjects to be active, engaged, problem solving, project based, collaborative, dynamic learning centers must include the arts. It remains to be revealed, as implementations unfold, whether the term *STEM* endures or morphs to be more inclusive.

In their book, *The Art of Possibility*, Zander and Zander (2000) remind us, “Art, after all, is about **rearranging us**, creating surprising juxtapositions, emotional openings, startling presences, flight paths to the eternal” (p. 3). They suggest a tightly coupled connection between scientists and artists. Inventors and entrepreneurs cannot do their work without imagination, play, and career-specific skills. The arts support imagination.

Throughout this book, we use the label *STEM*, albeit a currently debated term. *STEM* is an already recognizable name, with support from multiple stakeholder communities. We use it for that value, not to exclude the arts or innovation but simply to seek foundation agreement on a beginning term. This book hopes to ignite a dialogue among leaders and teachers and policymakers, and we hope to encourage some among them to unleash the potential of this giant opportunity with an entrepreneurial spirit.

In order for change to occur in the educational system that permeates practice and affects every student, a radical opening must take place. Current government policies are destroying morale, exhausting the system, and doing little to improve practice and results with too many students. The migration of schools into STEM schools and STEM districts is possible at the local level, and it can be accomplished now. Examples throughout the book support that contention.

STEM shifts practice, process, and methodology. It can release education from the constraints of time, focus training, and generate prolific partnerships. This book offers suggestions for how to make the STEM shift to a school for the 21st century. Dozens of interviews and many years of

research contain examples and suggestions for the leadership steps to be taken in order to plant and grow this major change within schools and districts. It draws on the experience of STEM pioneers to reveal guideposts and land mines.

This effort is not for the faint of heart, as it will take time, energy, training, and courage at the very least. Education is a field filled with those who care deeply about their work and who are tired of responding to mandates and following old routines. They want to think again and are standing at the ready to make the change that seems elusive.

STEM has been frequently understood as a secondary program or an elective program. This book acknowledges those as steps into a shift toward STEM but as not fully realizing the potential it possesses. **We hope to change minds and reveal the power of STEM as a simultaneous shift in the way educators work and in the way students learn.** We will share information about how children think and how leadership matters for the 21st century. All subjects are connected within STEM-themed school. Humanities and the arts are not diminished, even if their separate identities are melded. For some that may be a fear- and anger-arousing thought. But it is no more so than to say that plants can live without water. It is within the life of the plant as the arts and humanities are within the life of a STEM school.

● WHY THE STEM SHIFT NOW?

There are several reasons for this book at this time. Certainly, one reason is the growing need in the economy for workers who have STEM knowledge, skills, and dispositions. In order to sustain our economy, schools must graduate students who are prepared to work in and contribute to these fields. Secondly, all leaders must be conversant in the now trendy media affinity for STEM as the next right answer for education. This book will serve to expand STEM's meaning as a shift within education, a new process that brings authentic learning, inquiry, literacy, problem solving, communication in a variety of ways, reading and writing, and the capacity to abandon bias and recognize objectivity through all of the subjects, including the humanities and the arts. Understanding STEM is important not only for those who are interested in STEM careers but also for all of us to be able to make educated decisions about the scientific and technical issues affecting our lives (Matthews, 2007).

Most important, educators now find themselves at a threshold, one that relates to the purpose of education and locating it within the environment of this century. There are many voices telling educators what to do

but few places where those who meet daily with children can invent a new way of being together in a teaching and learning community. STEM offers that; it is a choice that can be locally made and created on behalf of local and global communities.

Within the goals of education lies the business of developing independent, thinking young men and women who will be prepared to face challenges, yet unknown, in the world in which they will live and lead as adults. While no one can describe that world in detail, there is agreement that the challenges will include a type of problem solving that does not spring from a school year of listening and responding, being told what is important and what is correct. The future will require comfort with questions, returning ones and unfamiliar ones. It will rely heavily on technology for living and learning and doing business. It will demand collaboration.

Twenty-five years ago, computer scientist William Wulf coined the phrase *collaboratory*. He defined it as a “center without walls, in which the nation’s researchers can perform their research without regard to physical location, interacting with colleagues, accessing instrumentation, sharing data and computational resources, [and] accessing information in digital libraries” (see Wulf, Kouzes, & Myers, 1996).

By 2003, D. L. Cogburn had refined the definition: “a collaboratory is more than an elaborate collection of information and communications technologies; it is a new networked organizational form that also includes social processes; collaboration techniques; formal and informal communication; and agreement on norms, principles, values, and rules” (2003, p. 86). Similar conceptualizations can describe the schools of the future.

The early space program offers an essential example. In 1970, *Apollo 13*, the seventh manned mission into space, met with serious and unexpected challenges. Designers, engineers, astronauts, and the flight controller were tasked with solving the problems that arose from the limited power supply, the limited time factor, and dropping temperatures in the spaceship.

The scene in the 1995 movie *Apollo 13* that tells this part of the story offers compelling evidence of the need for developing capacity at all levels and within all areas of expertise to make communication and effective collaboration possible, even in the most difficult times. It is one of the clearest demonstrations, not only of what scientists and engineers face, but also of the type of problem solving needed for and by today’s students.

In the case of *Apollo 13*, there was an assumption that those skills would emerge naturally when called forth in crisis. And in that space mission, thankfully, the assumption was correct. But we cannot leave the scene’s lesson behind. The particular skills required in 1970 of those working on that space mission represent the essence of the skills for the 21st century.

The lingering achievement gap, the traditions that have locked down flexibility, the need for our graduates to be career ready for a new world, and a global economy are present at education's doorstep. In the movie, Ed Harris played Gene Kranz, the NASA flight director; he said these famous lines, "Gentlemen, that's not acceptable. . . . We've never lost an American in space. We're sure as hell not going to lose one on my watch. Failure is not an option." Education has arrived at a tipping point and can take its lead from Gene Kranz.

Regardless of whether educators believe in the success of the work they have been doing, education has not kept pace with change and has not solved the problem of the achievement gap. Failure is not an option. Not on our watch. The STEM shift provides an option.

QUESTIONS AND REFLECTIONS

- All educational systems are currently living in the pressure point created by governmental mandates and the demands of an amorphous century. How is your current school or district responding to this pressure point moment?
- As you look around your workplace, where are there pockets of energy and creativity?

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