Chapter 4
K-12 Engineering – the Missing Core Discipline

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The Missing Core Discipline

We live in a human-made world. From the moment we wake up until we lie down to sleep, we are immersed in technologies. The faucet we use to wash our face, the toothbrush we use to clean our teeth, the clothes we wear, the car we drive, our office or school, our home, and even the mattress we sleep on are all the results of engineering processes. The water we drink has undergone an engineered purification process. The food we eat is the result of countless engineering technologies. If you are reading this inside a building, take a moment to look around. Imagine how your environment would look without any human-made things. Almost nothing you see or experience would be present – no electricity, no chair, no walls, no book, and maybe no YOU. Without human-made pharmaceuticals and sanitation processes, the life expectancy would be 27 years.

We live in an engineered world. Engineering design creates the technologies that support our health, convenience, communication, transportation, living environments, and entertainment – our entire day-to-day life. We school our children so they can live a healthy, productive, and happy life. Our curriculum includes disciplines that prepare students to understand the physical and social world around them so they can be informed users, producers, and citizens. Social studies prepare students to understand human relations and dynamics. Mathematics prepares them to think in quantitative manners to model processes and to calculate. Language arts prepare them to communicate effectively and provide them with tools to learn other disciplines. Science prepares them to analyze and understand the physical world around them. Beginning in preschool, students learn about rocks, bugs, the water cycle, dinosaurs, rain forests, the human body, animals, stars and planets, chemical reactions, and physics principles. These are all important topics, but they only address a minute part of our everyday life.

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The science curriculum focuses exclusively on the natural world, which arguably, occupies less than 5% of our day-to-day activities. The classical K-12 curriculum essentially ignores the other 95%, the human made world. Technology is not part of the mainstream curriculum. In most academic environments the term technology is used to describe electronic devices. Most people do not understand that everything human made, other than some forms of art, are technologies. Although students spend years in school learning about the scientific inquiry process, the process scientists use to discover the natural world, they never learn the engineering design process, which is responsible for most of the things that support their day-to-day lives.

When I first realized this blatant omission, I was shocked. There are so many brilliant people working in K-12 education fields, so many higher education institutions that prepare educators and curricula, and many committed government leaders that care about education. How, then, have we reached the ridiculous point where one may be considered illiterate if she does not know how many legs a grasshopper has, yet is considered perfectly fine in not understanding how the water comes out of a faucet? Students in middle school can spend weeks learning how a volcano works, and no time understanding how a car works. How often will they find themselves in a volcano?

Understanding the natural world around us is essential, but ignoring the other 95% is simply wrong. I was curious to learn the reason that the human-made world is not part of the curriculum. I discovered that one of the most significant moments in American education was the publication of the report of the "Committee of Ten" in 1893. Charles Elliott, the president of Harvard University at the time, led this impressive group of education leaders. They used a quite rational approach to determine which disciplines students should be taught in K-12 schools in order to be prepared for productive work or college entrance. First, they decided what students need to know by high school graduation, then they looked at the things that typical students learn at home, and by subtraction, they decided what should be taught in schools to cover the difference. Fields such as biology, chemistry, physics, and earth science are typically not covered at home and they made the list. Yet technology was left out. Think of the state of technology in 1893. Not only was it quite basic and simple, but most of it focused on farming. And since the majority of school children were living in agrarian areas, they were learning "technology" at home. So the committee determined that it was not necessary to include technology in the regular curriculum. In addition, the committee was likely influenced by the bias of its leader. President Elliott was not a friend of "applied knowledge." He closed Harvard's Engineering school because he deemed Engineering to be too mundane for Harvard. The "Committee of Ten" report was used as a template to create textbooks and curricula and thus technology and engineering were omitted. As technology advanced to become a major influence on our lives, the core curricula and textbooks never caught up.

There was a parallel, yet not as successful movement to create "manual schools," led by the C.M. Woodward, the Dean of Engineering at the Washington University in St. Louis. This movement focused more on vocational education versus basic technological literacy for all. Industrial arts emerged as an elective discipline in some schools in the early 1900s, but also focused on the vocational side of technology. Industrial arts' aim was to train students to become technicians, such as builders and plumbers. Industrial arts gradually evolved to technology education (Tech Ed) which leans closer to engineering, but in most cases it was still viewed as "shop." Tech Ed teachers are not high in the prestige hierarchy in the K-12 academic world. Although in the beginning of the 1900s, Tech Ed programs were developed by engineering schools, schools of education gradually took over the discipline. Many Tech Ed programs are now in colleges and universities which have no engineering programs. This trend inhibited growth in the field that would parallel the explosion of engineering and technology, with a resulting focus on the vocational, rather than the academic. At present, technology education is either a small part of the student's education or simply an elective. In tough economic times, these are the first areas to be cut from the budget. As a result only a small number of students are afforded an opportunity to learn even that limited part of the human made world.

Why Should Engineering Be Part of the Core Curriculum?

Technological Literacy is Basic Literacy

How can one claim to be literate if she does not understand how 95% of her environment works, or how it was made? Technological literacy is simply *basic* literacy. It is no less important than understanding US history or trigonometry. Understanding how an engineer designs is just as important as understanding how a scientist thinks.

Engineering Promotes Problem Solving and Project-Based Learning

The engineering design process starts by identifying a need or a problem. It follows an organized path to arrive at one or more solutions that satisfy the need or solve the problem. Problem solving skills are far more valuable than many of the other skills that are the focus of our K-12 educational systems. I use my engineering training constantly to solve problems far removed from engineering, such as dealing with personnel issues or fundraising. Engineering provides a life skill that can be used in everyday life and in any occupation.

Engineering pulls other disciplines together, enabling students to work as a team to solve a problem they are passionate about. Imagine a second-grade engineering team trying to solve the problem of how to keep their classroom pet bunny rabbit at the school, even though one of their classmates is allergic to it. This problem presents a welcome opportunity for the students to apply the skills they have gained from other disciplines to solve a problem they personally care about. In order to build an outdoor habitat for their rabbit, students have to use their math to figure out the measurements of the hutch so the bunny can comfortably live in it and enter and exit, while not allowing the neighborhood raccoon to move in. They have to use their science knowledge, including the fact that heat flows from hot to cold, while insulating the habitat so the bunny can be comfortable during the cold winter months. They even have to use their art skills to make the habitat appealing. While doing this, they sharpen their team and collaborative learning abilities.

Engineering Makes Math and Science Relevant

Why do students lose interest in math and science in the middle school years? Some blame teacher quality and preparation. That may be a factor; however, I believe it is primarily because curriculum content is disconnected from the content of the students' daily lives and interests. In elementary school years, students love science because they learn about rocks, bugs, dinosaurs, and rain forests. These topics are exciting in elementary school, but quickly lose their appeal as the students reach puberty. In middle school, science begins to become more abstract, rocks become earth science, bugs become life science, and physical science deals with forces, energy, and other things that are "invisible" to students. These "natural world" topics are not so natural for children that live in inner-city, urban environments with few opportunities to travel and enjoy the natural world.

The "lack of relevance syndrome" continues at the college level. About half of the students that enter engineering school quit or transfer to liberal arts. Granted, some of these students are not adequately prepared in math and science and are challenged to the point where exit is the only solution, but many of them do quite well in math and science, yet they decide to switch. All colleges and universities, even the elite ones, lose a large portion of their first-year engineering class to liberal arts. When I became Dean of the School of Engineering at Tufts University in 1994, I learned that 22% of the first-year engineering students transferred to liberal arts. What I found even more disturbing than the shear number of transfers was the grade point average of these students was a B+, with average math plus verbal SAT scores was close to 1400! Lack of preparation was not the reason.

Why, then, were students switching at such great rates? I held a number of focus groups in order to understand the reasons. The number one response was "I did not find Engineering interesting." What I found interesting was that they had not yet taken any engineering. The first-year curriculum was filled with math and science, along with some computer programming and perhaps a basic design course. The magic and excitement of engineering was just not part of their experience. As a result, we changed the curriculum to not only include engineering earlier, but also to include it in an engaging way. We introduced engineering courses for first-year students that stemmed out of faculty's personal hobbies and interests and we opened the courses to liberal arts students as well. There were courses in Acoustics and Chemical Engineering under the titles "Design and Performance of Musical Instruments" and "Microbrewery Engineering." I developed two courses stemming out of my fishing and cooking hobbies. My fishing-related course was called "Life in Moving Fluids." It was an introductory fluid mechanics course, but from the point of view of a fish or a tree. The laboratory looked more like a biology lab than an engineering lab with live fish, sea anemones, and plants, along side liquid and air tunnels. The other course was called "Gourmet Engineering" where transient heat conduction-related differential equations would come alive in a state-of-the-art kitchen laboratory. Finite cylinders took the form of meat roasts, instrumented with thermocouples that would monitor the temperature to show if the math really worked. All these courses were designed in a way that made math and science relevant. The experiment worked. Within a year, Tufts became, and still is, the only school in the country where in some years more students transfer from liberal arts into engineering versus engineering to liberal arts.

Engineering makes math and science relevant which is critical in the middle school and high school years. Relevance is particularly important for retention of girls in science fields. Girls gravitate toward science disciplines that have an evident benefit to society. Half of the medical school students are women, and women comprise the majority of students in the life sciences. In some highly competitive veterinary schools, more than 80% of the students are female. Ability is clearly not the limiting factor. Engineering in K-12 can make science relevant and improve student interest, especially among girls.

Engineering as a Career

There has been considerable discussion and expressed panic for the prospective lack of engineers in the United States. Some skeptics argue that the gap between demand and supply of domestic engineers could be covered by outsourcing work to foreign engineers for less money and, in some cases, better work quality. While there are some engineering jobs that could, and probably should be outsourced, there are others that must remain domestic. If these jobs were outsourced, the security and culture in the United States would suffer.

Engineering jobs related to local infrastructure are prime examples. The design, construction, and maintenance of buildings, roads, power plants, airports, electric grid systems, etc., are best accomplished by engineers who are familiar with local conditions. Engineering jobs related to our national defense systems also cannot be outsourced. Would you be comfortable being protected by weapon systems imported from another country?

The United States has always been the center of innovation. Innovation, driven by US engineers, has made this country special and has attracted some of the best minds to immigrate here. This innovation has created the products, services, and wealth that still make living in the United States better than most countries. If this innovation culture gets eroded or outsourced, the entire character and culture of our nation will be affected dramatically.

In order to preserve the innovation culture in the United States, numerous committees have issued reports calling for an increase in support of K-12 mathematics and science education. What these reports have missed is that the connector between math, science, and innovation is engineering. Unless this connection is made in school, the number of future engineers will continue to fall short of the current and future demands.

The United States would have a lot more engineers if young people knew what engineers do. Approximately seven out of ten engineers in this country have had a relative that was an engineer. There are few other non-trade professions that are connected like this to family. Unfortunately, school career guidance counselors are typically uninformed about engineering. The general public is similarly uninformed and confused about what engineering is and what engineers do. In China, Europe, and India the engineering profession is better understood, and Engineering is considered a very prestigious career choice. Some of the most competitive admissions to European universities are for engineering majors. Almost half of the members of China's politburo have an engineering background.

As the demographics of our country change, and the percentage of Caucasians decreases, so, too, will the number of engineers. In African-American communities, most young adults that attend college focus on education, medicine, and law, largely because these were culturally considered respectable professions. These are the professions that their community has encouraged them to enter and thrive in – since African-Americans have historically been shut out of many professions including engineering. Given that the engineering profession is overwhelmingly comprised of Caucasians, and given the strong link between the engineering career choice and relatives in the profession, the numbers are bound to decrease.

Here in the United States there is confusion about the term "engineer." We call train drivers, radio station sound technicians, and janitors engineers, along with the traditional college educated engineers. It is not uncommon to see the doors of high school janitor closets lettered with signs saying "ENGINEERING." Even the janitor's closet at the National Academy of Engineering's old building had a sign saying "ENGINEERING." If you have a problem with your toilet in a hotel and you call the front desk for help, they may tell you "we are sending the *engineer* up right away."

The role of engineers could be better understood if public media represented the profession more prominently and accurately. Engineers are largely absent from mass-market television, where both kids and adults get their information. News programs could be encouraged to solicit input from engineers on topics such as cutting-edge technologies, port designs, earthquake prevention, and heart stents. Newspapers could include more statements from engineers when new designs succeed (vs. during failures). The nation has missed great opportunities to celebrate engineering achievements and to excite young people to pursue engineering careers. When NASA's Rover made it to Mars, the press called it a "science miracle." When something went wrong with it, the press called the event an "engineering error." There are no prime time TV shows with engineering heroes or main characters.

Unless the United States makes an effort to teach students about engineering early and to present the engineering profession in a realistic light, there is little chance of improving the career-choice statistics.

Navigating in a Three-Dimensional World

We live in a three-dimensional world and we should be able to conceptualize it as such. At times we all have to imagine and sometimes sketch things in three dimensions for considering optimal designs, for example when we redesign a kitchen or set up a warehouse.

Most engineering schools have a course on engineering design which is required for all first-year students. A significant component of this course focuses on 3D visualization skills. A surprising phenomenon that schools throughout the country once noted was that young men entering the engineering school were more capable tackling 3D challenges than their female counterparts. Both men and women had comparable college entrance test scores, high school grades, and in some cases, were from the same family. The phenomenon could not be attributed to some genetic factor, since after the design course, the 3D gap would close and both men and women could tackle these challenges with similar abilities and skills.

Researchers in Michigan studied the phenomenon and came to the conclusion that the reason for the differential performance between young men and women in 3D skills was attributed to the toys that they played with during their growing years. I was fascinated by the study and wanted to take a personal look at the different toy availability for boys and girls. I went to a large chain toy store and spent a few hours with the gender bias in mind. I was fascinated! There was an abundance of toys for boys that sharpened 3D visualization skills such as LEGOs, Lincoln Logs, construction sets, and lathes. The availability of such toys for girls was a different story. Most girl toys focused on nurturing and fantasy. Barbie's aisle was loaded with toys such as "Teen Talk Barbie" which once said "Will I ever have enough clothes?" and "Math class is Tough!" "My Little Pony" was another top seller which featured a plastic little horse with a fuzzy tail and a plastic comb. I quickly understood the validity of the Michigan study and realized that toys stemmed this inequity.

Currently, I am more worried that what used to be a boy versus girl issue has become a boy *and* girl issue. Children now spend most of their discretionary time in front of 2D screens, televisions, video games, laptops, MP3 players, and mobile phones. Building, tinkering, and other activities that primarily engage boys are no longer the preferred pastime. We have started creating generations of people that will not be able to visualize and design in three dimensions. This will not only affect the abilities of future engineers, designers, and architects, but also deprive people from a basic life skill. By introducing engineering in K-12 schools we will remediate this issue for both boys and girls.

These are the five driving issues that created the "call for action" to introduce engineering as a new discipline in the K-12 curriculum. This discipline should be parallel and equal to language arts, mathematics, science, and social studies. I recall someone once saying, "Introducing a new discipline in K-12 education is as challenging as moving a graveyard." I am beginning to see the truth in that statement.

The Transformational Moment

A small number of K-12 engineering curricula were developed in the early to mid-1990s; however, their purpose was to motivate students to pursue careers in engineering. Most focused on a specific engineering area such as electronics or automotive engineering. "Project Lead the Way" offered the first sequence of high school engineering courses aimed toward students that planned to attend engineering schools. Many engineering colleges also started K-12 education outreach programs. Recruiting and community service were the main motivators. The first effort to introduce engineering to all children, starting in kindergarten, was undertaken by the School of Engineering at Tufts University in 1994. The Center for Engineering Education Outreach was established and it created curricula and professional development programs for educators spanning all grade levels. The center also partnered with LEGO and created Robolab, the software that enabled the LEGO Mindstorm robotic kit to be used in classrooms.

While these breakthrough programs were very good, they only reached a small number of schools and students. There was clearly a need for a systemic change in order for the K-12 engineering movement to gain momentum. The opportunity was created in 1998, when the Board of Education in Massachusetts appointed a committee to re-write the Massachusetts curriculum framework and learning standards. I was appointed to the committee that would re-write the technology education component of the science standards. I worked with a team of K-12 educators, primarily K-12 Technology Education teachers and introduced the first engineering curriculum frameworks and standards in the United States. The senior staff in the Massachusetts Department of Education did not have much appreciation for Technology Education standards at the time and they saw the transformation of Technology Education standards to Technology/Engineering standards as a move in the right direction. The Technology Education teachers in the group also saw it as yet another evolution of their field and an opportunity for their professional position in the K-12 educator hierarchy to be upgraded and become more secure. On December 20, 2000 the Massachusetts Board of Education voted unanimously to adopt the new technology/engineering standards and to make them part of the state's assessment. Assessments at the elementary and middle school levels were revised so that science and technology/engineering comprised 20%. At the high school level, technology/engineering became one of the four end-of-course assessment options for graduation, the other three being biology, chemistry, and physics.

At the elementary level, the engineering standards focused on distinguishing between the natural and human made world, such as comparing tools with animal body parts, e.g., scissors vs. lobster claws and dog paws vs. rakes. Material properties and the basics of the engineering design process were also included. They are intended to be covered by the mainstream classroom teacher, who also covers all other core subjects. At the middle school level, the standards focus again on the engineering design process and also on five technology areas: construction, manufacturing, communication, transportation, and bio-related technologies.

The middle school curriculum is intended to be covered primarily by technology education teachers and science teachers, if technology education teachers are not on staff. At the high school level the standards include more advanced content, including topics such as fluid mechanics and heat transfer.

Although the vote of the board was unanimous, the new standards were not received enthusiastically by all members of the academic community. Many superintendents were against them because their districts did not have the necessary resources to implement them, and many technology education teachers were ambivalent because they saw the inclusion of engineering as a challenge to the traditional instruction. Fortunately, the commissioner of education was strongly behind the new standards and they survived. As a result, Massachusetts became the first state to have engineering standards and assess them at all levels.

Expanding to the National Level

Massachusetts' bold move attracted the attention of the National Science Foundation and it began to fund K-12 engineering education curriculum development and programs. The relevant activities in Massachusetts schools increased in scope and in number; however, no other state followed suit. It became clear that if the initiative were to spread nationally, it would need a focused champion organization. Such an organization could not be in competition with the partners needed to expand it to the national level. Universities tend to be very competitive and so they would not be an ideal home for the lead organization.

In 2004, a year after I joined the Museum of Science in Boston, it became home to the new National Center for Technological Literacy (NCTL). NCTL's mission is to introduce engineering in both schools and museums. Its philosophy is that in order to accomplish a fundamental change in attitude toward engineering, school curriculum must change, in conjunction with the attitudes and understanding of those responsible to implement the change. In order for any program to succeed with this philosophy, it must focus on three areas: advocacy, curriculum development, and professional development. NCTL chose to take on those areas in the following ways.

Advocacy and Support

Although learning standards are centrally controlled in the vast majority of countries around the world, in the United States, they are controlled at the state level. State standards are influenced by standards developed by national groups, such as the National Research Council and the International Technology Education Association. NCTL advocates for the inclusion of engineering in these national standards, in state standards nation wide and in all relevant federal legislation and assessments. It also provides support for states that decide to include engineering standards in their curriculum frameworks such as standards and assessment tool development.

Curriculum Development

Because engineering in K-12 is a new concept, there is a lack of relevant curriculum at all levels. NCTL develops K-12 engineering curriculum at all educational levels where it has identified gaps in existing curricula.

Professional Development

NCTL provides professional development programs for in-service teachers and administrators. Using a “train the trainer” model, NCTL partners with states, so that the professional development capacity can meet the demands according to the level of need in each state. In addition, NCTL works with universities to assist them in curriculum and program development for pre-service teachers.

At the national level, significant progress has been made. The National Assessment for Educational Progress (NAEP) science assessment now includes standards in “technological design.” It is unfortunate that it is not called what it is: “engineering design,” but still there is progress. The K-12 grant program from the National Governors Association explicitly encourages applicants to include K-12 engineering in their proposals and plans. There is now explicit language in many bills about technology and engineering education. The majority of states now include engineering standards of one form or another, most of them still calling them technology standards. Thousands of schools throughout the country have adopted some form of engineering curriculum. The curriculum produced by NCTL alone is used by over 1,000,000 students in all 50 states.

Challenges

Changing curriculum on a national scale is not easy, particularly when it must be accomplished one state at a time. Over time, NCTL and other advocates have made significant progress. However, we continue to be faced with significant challenges.

Current K-12 curriculum is packed with traditional material, some of it necessary and some not. Turf issues inhibit serious revisiting of what, and to what extent, students need to learn. The turf issues extend beyond the local level. When learning standards development committees are formed at the state level, each member advocates for more standards in their specialty area. Engineering is the newcomer and threatens the each member’s “piece of the pie.” Similar turf issues occur when developing educational standards at the national level.

Fear is always a consideration when implementing change and the thought of teaching a new topic has proven to be intimidating to many teachers, especially at the elementary levels. Some educators are intimidated by science alone. If teachers have a background in a discipline, or have ready access to professional development courses in that area, they have the ability to increase their knowledge, thus reducing their fear and minimizing their resistance. Unfortunately, colleges of education do not currently prepare prospective teachers for engineering and design. In addition, state-level certification programs do not require content knowledge in engineering for elementary teachers, so few teachers have even the slightest background in engineering education.

When properly presented, most educators react positively to the idea of introducing engineering in K-12 schools. Areas of STEM (science, technology, engineering, and mathematics) education are enjoying widespread support amongst school administrators, federal department of education officials, and National Research Council appointed committee members. However, when implementation and funding opportunities arise, all the attention is focused on the S and the M part of STEM. Many reports advocate for supporting math and science in schools in order to foster innovation in our economy. What they do not realize is that the connector between math, science, and innovation is engineering. The vast majority of school administrators misunderstand the term technology and they assume that technology means computers. Computers are just a small part of technology. Some school districts feel that they offer technology to their students simply because they teach them word processing and spreadsheet skills.

Education is a cyclical process. Students learn, and then some grow to be teachers and teach what they know. When a new discipline is introduced, in-service teachers must learn something new during their busy, professional lives. For this reason, there are few qualified to teach engineering at the middle and high school levels. The teachers that graduate from technology education programs are qualified to teach the technology components of the curriculum, but in many cases are under-prepared in mathematics and science, which provide the basis for engineering. Engineering schools have not stepped up in encouraging their graduates to pursue teaching careers, and certification requirements have made the process of switching from engineering to teaching cumbersome.

College admission requirements have also presented a challenge to the effort of early engineering education. It is ironic that most engineering colleges do not accept a high school engineering course as equivalent to science. They typically look more favorably at an applicant who has taken an advanced placement course in a science area that may have nothing to do with engineering, than a candidate who has taken an engineering course. This discourages students from taking engineering in high school and schools from offering it.

The final hurdle for the introduction of K-12 engineering exists due to the applied nature of the discipline. Engineering education requires new facilities and equipment. When school budgets are tight, administrators are hesitant, if not unable, to open new budget line items.

Moving Forward

In order to maintain the momentum, we should focus our attention on six key areas.

Standard Development and Assessment

The most significant step toward inclusion of engineering in the curriculum is to introduce engineering learning standards at the state and federal level, along with regular assessments of student performance. Technology education teachers, engineering professional societies, and industry members should be strong advocates for the creation of such standards and assessments.

Funding

As mentioned above, funding has focused on the science and mathematics part of STEM, but employment opportunities are predominantly in engineering and technology. For instance, the ratio of engineers to scientists on the NASA payroll is 12:1. NASA's mandate is to educate and motivate young people to enter professions relevant to NASA's mission, yet most of the education funds flow toward science. It is time to directly fund the engineering and technology portions, so they can come up to speed with, and help enforce the others. Funding initiatives that encompass engineering education are not likely to succeed without the aforementioned changes to the learning standards.

Teacher Preparation

Engineering must be inserted into the education cycle, so that teachers are prepared and excited about including the engineering discipline in their curriculum. In order to accomplish this, college programs must be modified. Technology Education teacher training should include more mathematics and science, as well as the engineering design process. Additionally, engineering schools should offer a new track-major that focuses on engineering education. Graduates of such programs would have a broad understanding of engineering, as well a good hands-on project building background. The curriculum should include teaching methods courses. A partnership between the college of engineering and the college of education, at the same or neighboring schools, would facilitate this. Graduates would be prepared to teach both science and technology/engineering courses. Certification requirements should be updated to better reflect the new engineering standards, and also make the career transition from engineer to teacher easier. Elementary school teacher preparation programs should include at least one course in design and understanding the human-made world.

Facilities

The lack of facilities can be overcome if state programs that fund school renovation and construction require schools to have facilities dedicated to technology and engineering. At the elementary school level the facilities may be "take apart" tables with simple tools. Middle and high schools should have design and building facilities, including power tools for prototype development.

Textbooks

Science textbook publishers should include engineering content and activities in their new editions, connecting the traditional science to technology. Engineering is by nature "hands on." This blends well with science textbooks that focus on inquiry. It is more challenging to integrate engineering in traditional science texts. However, more and more publishers now include engineering components. The technology education textbooks should also be modified to emphasize the engineering design process and to include contemporary technologies such as bio-related technologies and nano-technologies.

Changing the Culture

Informal education channels such as museums and science centers, as well as popular media should include more programs on engineering, technology, and relevant careers. Such changes would not only create a more technologically literate population, but would also inspire children to pursue relevant studies, and motivate parents to encourage their children as well.

Conclusion

Understanding how the human made world works, and how it is developed, is an essential component of contemporary basic literacy. Although the value of this understanding was largely ignored in K-12 schools until the mid-1990s, significant progress has been made. Engineering and technology standards are being included in many state curriculum frameworks. Federal legislation and national assessments now also include technology and engineering, and thousands of schools in all 50 states are using engineering curricula. This is a long road, but at the end we will have a nation of technologically literate citizens. This vision continues to fuel the momentum to ensure that K-12 Engineering will emerge as the essential new core discipline.

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