Problems and Prospects for Recent Time in ScienceEducation

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Introduction

Coming to an American college campus, one finds undergraduate students from all over the country, as well as the world. They include recent high school graduates, war veterans and students from the emerging middle classes of China, Taiwan, South Korea, Brazil and India. There are multiple issues facing modern science education in the USA; consequently new priorities must be examined and emerging issues need to be addressed. As shown by a recent study there is an economic value to science education, leading to degrees in engineering, mathematics, and science, (1).

The United States with a $15 trillion economy is a leading global player. In terms of military power, the U.S. is the only remaining superpower. It is still true today that one American farmer feeds six people and one American worker is six times more productive per capita than a Chinese worker. Still, a closer look is appropriate due to the looming challenges from emerging economies, in particular China and the limitations of economic growth and dwindling potential future resources.

The President's "American Recovery and Reinvestment Plan" was supposed to jump start job creation and long-term growth. It included "equipping tens of thousands of schools, community colleges, and public universities with 21st century classrooms, labs, and libraries" and "investing in the science, research, and technology for new medical breakthroughs, new discoveries, and entire new industries". These are significant and valuable investments for the future of our country. (2) Still, we cannot take developing future leadership in scientific technology for granted.

Crisis and Challenges

To tackle a big, simmering national problem in science and math education, one must consider all the facts. When you look at the numbers of science ranking, the emerging picture for USA is not pretty. In a math and science exam given to students all over the world in 2009, U.S. kids placed 25th in math and 17th in science. That should be a matter of concern at the highest levels and should be unacceptable.

As Benjamin Franklin stated, "Tell me and I forget. Teach me and I remember. Involve me and I learn." America's scientific community must foster a national sentiment to rejuvenate science curriculums. Scientists must help education and the creation of a potential pool of innovators for the future. In 1958, science curriculums received an infusion of over a billion dollars after the Sputnik shock as part of the National Defense Education Act. It impacted science curriculum across the country. This infusion helped the baby boom generation through enhancement of resources in labs. In the science classroom, overhead projectors and educational films were made available. More recent legislation, the "No Child Left Behind Act" (NCLB) has focused on reading and basic math skills, leaving the funding of science aside. Due to the lack of emphasis, the U.S. is again losing its science lead to countries like Korea and China, where more advanced degrees are awarded and more patents are registered. The number of inquires sent by Ph.D. holders, from India and China, for further research opportunities in U.S. universities is increasing every day. The time has come for a new generation of Americans, well versed in math and science, to be trained and recruited. Despite the global recession, the United States continues to face a workforce shortage in science, technology, engineering and math (STEM) fields. The development and search for talented citizens, particularly from underrepresented groups such as women, African-Americans, Hispanics and American Indians, in STEM fields should be undertaken. Our global competitiveness depends on many factors and our ability to attract and retain bright students among future generations is crucial.

Experiments also allow students to practice resolving the gap between their predictions and the underlying scientific principles of an experiment. The importance of this shift is reflected in a study done at Ohio State University in which students in China and the U.S. were tested on science "facts." The Chinese students outperformed the U.S. students. (3) The trends in science study showed U.S. student performance is weaker at higher grade levels in the pre-college system. Seventeen-year-olds scored below the international average on the most recent assessment for that age group. On advanced mathematics and science assessments, U.S. students performed poorly compared to their counterparts in other countries. The Boston Consulting Group and the Information Technology & Innovation Foundation (ITIF) surveys find that the U.S. does not rank in top five. In fact, the ITIF rankings for government funding for basic research, education for the 40 countries analyzed, the U.S. came last. They use hard measures such as spending on research, patents and venture funding as the measuring factors. (4)

Skills in science are learnable, but not easily teachable. This is evident from the present intractable issues facing science education in our country; a country with the highest number of science Noble Prize winners in the world. It is impossible to deny that students' social background, environment, limited opportunities, lack of vigorous science curriculum, lower expectation and lack of role models play important roles in their reasons to pursue scientific careers. A new normal in science education is needed due to the changing economy and an aging workforce. Our economy's fasting-growing sectors include high-tech manufacturing, health care and new energy. Yet, many in the skilled trades either lack these skills, or are retiring without a younger generation trained to fill open slots. As a result, too many Americans remain out of work and too many U.S. industries are on the brink of a skills crisis.

Nationally between 17 percent and 28 percent of public high school science teachers, depending on field, and 20 percent of mathematics teachers lacked full certification in their teaching field; the problem was proportionally higher for middle grades.(5) Although most mathematics and science teachers hold a bachelor's degree, many are teaching subjects for which they have had little or no training; this "out-of-field" teaching is most prevalent in rural and urban districts and high poverty areas.(6) Many of these districts reported difficulty acquiring and retaining well-qualified mathematics and science teachers. (7)

Opportunities and Scope

Science educators have to address multiple issues. The need to be selective despite many priorities is important to a good educator in any field of science. For example, how much time should be devoted to the multiple teaching methodologies of science education is a question rarely addressed. Is the traditional lecture and laboratory teaching good enough to keep a student interested in learning and pursuing a career in the field of science? Should other aspects of science education be included, such as co-operative groups or learning communities, journal writing, portfolios and term papers?

The breadth of teaching strategies can overwhelm college students who may not be equipped with a sufficient and strong background. The excessive self-focus of science educators may need to be re-directed into resurrecting meaningful teaching skills that have been proven as strengths of U.S. higher education in the past. Laboratory work using an inductive approach, rather than content coverage, may improve problem-solving abilities. Sometimes a better than average, common sense driven education may contribute to the long term good rather than chasing the latest bells and whistles with state of art equipments hoping for top quality. To provide good value to a college science student and to mitigate rising tuition and fees, we must find better ways. As educators of science, in a college, do we focus on short term technician focused education or transfer comprehensive education? How do we use limited resources and still be effective? The overall aim of science education should be directed towards fostering students with scientific skills and fluency in scientific terminology. After successfully completing any basic college science class, it is expected that each student's ability to distinguish among opinions, facts, and theories should be improved. Teaching science effectively changes the lives of many students helping them become productive and informed citizens. The aim of a meaningful science education is to allow a student to think like a budding scientist, open his mind to a brighter vision of his fascinating natural world. The need to develop scientific curiosity and critical thinking as a learning experience is particularly important for any science major. In order to improve verbal and quantitative reasoning, science journal assignments to read and write summary with scientific terminology should be required. This in turn may help in systematic building of general vocabulary and understanding complex technical terms.

To recruit students for science and related disciplines, the University of Texas system has hosted summer research since 1999. While continuing the undergraduate emphasis on recruiting, training, and graduating top students, the alliance now includes a Bridge to the Doctorate (BTD) program. Housed at the University of Houston, the lead institution, the UH Bridge to the Doctorate is an outstanding, value-added component program. The City University of New York offers research assistantships and special courses in chemistry, math and physics. The California State University system's program "Bridge to the Doctorate" supports biological and related life sciences providing stipends, an allowance for education costs and mentoring to underrepresented students. (8) These programs have been created to fit the changing landscape of science education.

In the U.S.A., most productive scientific institutions are liberal colleges that target science across the curriculum to produce science literate graduates. A new initiative between nine Michigan community colleges and four public universities aims to use "pre-first year" programs, paid research experiences and other strategies (9) to develop students. This program will expand the number of minority students in STEM majors from community colleges, and more students are considering community college for economic reasons. Chemistry, engineering, biological sciences, mathematics and computer sciences will be given priority in terms of funding and future job creations. In the areas of math and science, talented and knowledgeable teachers seem to be in short supply. This deficit has become so severe that some districts are importing qualified teachers from other nations. Additionally, in classes where science is being taught, too many sessions seem limited to lectures and videos. Doing actual experiments with hands-on activities demonstrates the inevitable variations in experimental results. In Michigan, the alliance is led by the University of Michigan chemical engineering professor, Dr. Levi Thompson and includes the University of Michigan, Michigan State University, Wayne State University and Western Michigan University. Between 2005 and 2010, those universities increased the number of STEM bachelor's degrees awarded to underrepresented minority students by almost 50 percent. At Western Michigan University, the collaborative efforts include a summer "pre-college" program to prepare incoming students with their problem-solving and other skills, according to Dr. Edmund Tsang, associate dean of the College of Engineering and Applied Sciences of Western Michigan University. (10)

When one inquires about the present status and future prospect of science education, many views are evident. Science education must encompass knowledge rather than belief, opinion, and impressions. The knowledge must be derived from real life experience of education. Systemic instruction may cover the finer aspects of classical, technical or commercial information, but must also provide the wisdom and skills of unanticipated problem solving utilizing available resources. In science, it is imperative to use teaching tools that not only foster, but also encourage lifelong learning. It is not easy to teach the thought processes involved in a Noble Laureate's mind when going over a simple science problem in a college science class. But the basic methodology of thinking processes can be conceptualized, including comprehending the main idea, classifying it, and organizing to simpler level. This can lead to precise interpretations, verbal expression of the problem and putting it into familiar words for solving by scientific methodology. Science problems must be written to define terms within the context. Scientific ideas can be understood in terms of concept based knowledge which is then applied to develop an explanation.

For a comprehensive picture, a science student needs to see the given problem in context, which is only possible by analysis and structural classification after recognizing patterns presented. The problem solving pattern can be applied in science after this rudimentary understanding of basic question, interpretation, expression, classification and organization leading to final synthesis of understanding. Hypothesis, theory and natural laws are the end results of this process. If we do not make the questions overly complex, it avoids the desperate feeling commonly observed among less talented students. Opinion questions including homework assignments and then discussing their opinion in the form of anonymous feedback, is a great way to generate curiosity and interest in science. This is one easy strategy to implement and to guide discussions makes teaching as well as learning fun. Science is concerned with matter, its composition, the investigation of properties and changes to form new substances to improve quality of human life, and when it is shown in a quantitative manner, including tables and charts, as well as with case study examples, it becomes appealing even to those who may not opt to be scientists. It can help the students learn science content and become the innovators of tomorrow. The hope is, they go become an engineer or a game changer scientist.

As educators in science and related disciplines, we face the limitations. These become evident when we attempt to be all-inclusive, for example, writing lab reports for in-class laboratory experiments, term papers for researched subject, supplemental instruction, pre-lab quizzes, and many activities, inquiry-based lab instruction, mini research projects, seminar, preparing and analyzing expected student outcomes, molecular modeling and visualization, computerized assessment, field trips and seminars. (11) We must remember that a typical curriculum can include only certain significant concepts, a laboratory based science class may not cover all twenty-six chapters of a typically required textbook. Helpfully, many virtual laboratory software programs (12) are being made available, but such resources do not provide all the answers. They must be considered complimentary and additional tool of the trade. We must remember that not all students learn from virtual environment doing simulation experiments. A typical experiment in a real laboratory set-up provides real life experience and builds enough confidence in a student who may initially be afraid of chemicals, pathogens, blood, fire, accident and related issues.(13) Students need to be taught and encouraged to apply scientific principles in and out of the classrooms. Only after hands-on lab instruction, students understand theoretical concepts more thoroughly. They may be presented with a problem or a demonstration to explain why a particular experiment is being carried out e.g. what is the protocol and a "show & tell" about new skills, for enhanced understanding. Students have been shown to improve in their ability to write procedures for inquiry based experiments followed by evidence-based conclusions. The process of transforming the curriculum to confine instruction to a standards-based education must include an inquiry-based approach to enhance student understanding, interest, and experience. But if this is done in addition to the traditional teaching, the results are found to be less than satisfactory. (14) Learners must get a chance to see what is inside of these modern items, to learn how they work.

In any given science classroom, there will be a few gifted and talent students. Should we take student heterogeneity into consideration? Doing so increases the complexities and challenges for a science educator. Should we apply inquiry-based teaching for gifted and talented students? Should we emphasize conceptual and traditional understanding for others? Do cooperative learning experiences benefit all or do talented students feel cheated? How much real world experience, such as case studies and field trips, should be part of science curriculum? Just including case study for the sake of providing examples do not serve the teaching purpose; it must be incorporated within conceptual description of the text. Do standardized computer assessment strategies work for all the students? How much importance should be given to student seminar assignment? Should the science faculty move away from lecture-based courses and if yes, what should replace it? Such critical examination of teaching practices or theories for improvement of science education is needed presently. (11)

Many science educators utilize diverse assessment strategies for assigning the final grades. How much should we rely on computerized multiple choice tests and how much should we rely on student journals and written or oral quizzes to assess students' progress? Are students capable of analyzing critically their own or fellow students' performance? The formal as well as effective assessment strategies may include graphic representations, short seminars with question answers and follow up interviews or written report, as part of total evaluation (15).

A science educator should relish the opportunity to explore different avenues to foster science students' curiosity and interest, which can help create a richer learning experience. Teaching can extend the frontiers of any scientific field when questioning of the most fundamental assumptions becomes a way of teaching and may provide paradigm shift in the scientific research. When students explore scientific principles in the lab, they go one step further and use their knowledge by applying it. Science education success depends on learner's awareness and sensitivity to knowledge. This can be enhanced and promoted by educator's caring approach to teaching fundamental and sometimes abstract scientific principles.

The art of teaching involves multiple strategies in addition to caring e.g. positive attitude, encouragement, accommodation and openness to change and innovation. Scientific mastery and competence do not come only from understanding abstract knowledge and memorizing mathematical relationships, but from the blend of a deeper understanding of meaning and prudent application of the knowledge. As educators, we must remember that most of scientists have honed their skills using assets, which are available to all, including use of time, free will of thinking and choice of reading. Problem-solving questions should allow students to progress through the questions from simple to complex. Science class assessment should include strategies where students have to do more than plug in an answer. If the learners have to think, figure something out, even it may be approximate solution can stimulate new thoughts. To see how students can learn doing and building things is exciting component of education. Learning should be a progression, like marathon and not sprint run. We must remember young minds want to do more interesting things and acquire more skills, more knowledge and we should act as mentors. Science education doesn't begin or end at the classroom. A lot can be learned working with peers and in a garage.

As educators, most often, we apply the same techniques that have worked in the past. But we must remember that present learners may be radically different. To help students from diverse backgrounds and a lack of resources, thread through the maze of higher education, a caring educator must take into account multiple strategies with additional tools to cope. As a foreign student advisor, one of us recruited twenty-nine students in a small rural college in the state of Colorado (16). Initially, none of them were able to speak a correct sentence in English effortlessly, but most of them were able to earn their associate degree within two to three years. This is only possible due to understanding interaction among many variables needing background study, individual intellectual initiative, resourcefulness and caring approach to understand each student's ability and limitations. These foreign students during the course of their education realized that innovation is American national character derived from freedom, and flexibility to question conventional assumption and defy authority for the sake of truth. The higher education equipped with the scientific method informs the learner and appeals the intellect without trivializing the investigative aspect.

Emerging Issues and Priorities

In a science curriculum an emerging technology that should be developed include the skills and applications of computational procedures commonly used to generate three-dimensional structures. This can be possible due to the recent development of software and hardware tools for image acquisition and analysis that are made available at reasonable prices by commercial vendors.(17) Optimization of conditions for the development and validation of novel methods which can advance comprehensive evaluation of the technology environment within regulatory situation should be welcomed. The opportunity to address a specific opportunity or solve a problem is an integrated scientific task. The perspective gained should be comprehensively analyzed to recommend a plan to solve similar scientific problems. These strategies lead to mastering decision-making, project management, and technology exploration by hands-on training.

Educators understand how countries are changing, but they need resources to address changing requirements. Schools and colleges understand how to provide students with the skills and credentials that employers need. But corporations need to help our science education curriculum, so we provide training that makes it easier to provide skilled workers. To improve America's economic competitiveness and put the American Dream within reach for more people, diversity must be a focus of higher education policy, law, and scholarship for decades, continually expanding to include not only race, ethnicity and gender, but also socioeconomic status, sexual and political orientation, and more. The world is a big place, and as companies spread across it at a steady pace, the definition of diversity is changing. Diversity is most often discussed in terms of differences in race and gender, next in terms of different backgrounds and perspectives within a given population, but when approaching workforce management on a global level, educators must take geographic and cultural diversity into account as well.

A child who has teachers with the knowledge and skills needed to teach mathematics and science effectively in pre-college grades is more likely to be able to close the achievement gaps that he or she encounters. The number of certified science and math teachers at the middle and high school levels is down, science education for pre-service teachers at our Nation's education schools appears to be less rigorous compared to other subjects, and many teachers do not feel qualified teaching science. College graduates entering the teaching profession tended to have somewhat lower than average academic skills as evidenced by their lower rates of participation in rigorous academic courses in high school, lower achievement tests and lower entrance exams scores than students in other majors. (18)

To evaluate and analyze the present state of science education and for solutions to evolve, professional scientists, science educators and key policy makers at the local, state and national level must deal comprehensively with the wide variety of issues. This must be done keeping long-term benefits for all the citizens in mind. One necessity is to upgrade content and methodology of the curriculum. It should include hands-on, inquiry-based, experiential and related to real-world applications. Such modifications encourage critical thinking, problem solving and team working beyond minimum competencies and standards. Many science teachers do not have access to and time allotted for professional development that hones their science knowledge. This should be changed, too.

Conclusion

The idea of critical examination of science instruction for conceptual change, with reference to crisis and opportunities, issues and priorities is critically needed. To change is not simple, as all learning is a process of personal construction and students, given an opportunity, will construct a scientifically conception of physical phenomena if they see, feel and do the science experiment. It is well established that scientific conception derived from accurate and precise methods is superior to pre-instruction conceptions (19). Researchers have proven that in making sense of the world in explaining and predicting phenomena is to go through the process of experience (20). At present, the future generations of Americans require that more intelligible, plausible, and fruitful methodology to encourage science education must be explored. Like any issue in higher education, science education and teaching priorities have challenges and opportunities. Benefits may compensate challenges and limitations, if proper and careful choices are made. Any learning focused approach must be re-evaluated and examined critically before large scale application. There are no easy answers with definite, clear-cut simple solutions. Always, there remains additional ways to approach the issue and research may provide some of the first rigorous evidence that a range of strategic applications of new resources can indeed, improve educational outcomes for our students in science and related subjects. The findings can lead to additional ways and means to test some of the most promising strategies. However more work must be done by all those who care.

Science education is too important for maintaining the leadership role. In a predictable world, to solve problems citizens must be able to understand and appreciate the marvel of ever changing science based technology.

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