Thoughts and Ideas for Action on After School Science Programs and Advanced Science Course Taking

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I. Introduction

Public science issues and challenges such as stem cells, cloning, gene therapy, climate change, conservation, genetically modified organisms, natural disasters, and sustainable development mean that all high school students need to successfully complete advanced science courses. Also, given the advances in communications and technology in schools, homes, the workplace, the military, and the community, all high school students need to develop technical competence, particularly as related to modeling and visualizing complex science and engineering concepts (http://www.nsf.gov/pubs/2007/nsf0728/index.jsp).

In addition to an informed citizenry, to maintain the U.S. leadership in science and innovation, we need to interest more U.S. students in pursuing higher education degrees in the sciences, technology, engineering and mathematics (STEM). Science and engineering discoveries and innovations drive our economy, as well as help us to meet societal challenges. Shirley Ann Jackson, President of Rensselaer Polytechnic Institute, coined the term the "quiet crisis" to describe the long term threat to the U.S. leadership in science and engineering innovation. In her words:

> *It is "quiet" because it takes decades to educate a physicist or a nuclear engineer, so the true impact unfolds only gradually, over time.*
> *(http://www.rpi.edu/president/speeches/ps041607-edisanjuan.html)*

It is a crisis because trends such as the aging of the U.S. scientific workforce, the declining number of U.S. citizens earning STEM doctorates, and the poor quality of U.S. elementary and secondary school mathematics and science education could be early indicators of a weakening in the U.S. scientific and engineering workforce infrastructure. Given these trends, it is particularly important to examine how after school science programs can provide the extra support that K-12 students need to be successful in advanced science courses and to persist in STEM careers.

Towards this objective, this position paper:

- Summarizes what we know from the research synthesis about high school advanced science course taking commissioned by the Coalition for Science After School.

- Explores some areas not covered or elaborated on in the commissioned research synthesis.

- Recommends some program approaches and directions for after school science programs as related to advanced science course taking.

II. What We Know from the Research Synthesis

The research synthesis commissioned by the Coalition for Science After School makes the case that after school efforts can play a key role in providing the skills and support that K-12 students need to be successful in advanced science and mathematics course work and to persist in the STEM educational track. In general this research identifies:

- Factors that contribute to students' completion of advanced science and mathematics courses and persistence in the STEM education track.

- Key program characteristics and challenges related to strengthening and scaling up after school programs that help students to complete advanced science and mathematics courses and pursue a college STEM major.

- Gaps in the current research and new research directions to explore in this area.

- Resources, standards, and practices than can be adapted to strengthen implementation of after school science programs.

Further, the research synthesis indicates that teachers and staff in effective after school science programs should:

- Recognize that self-efficacy is an essential factor for students' engagement and persistence in advance science courses and the STEM track.

- Expect that all students can succeed in advanced science and mathematics courses and pursue a STEM major, regardless of racial/ethnic background, gender, disability, English language ability, or socioeconomic status.

- Recognize that after school programs can counteract socio-cultural and institutional factors that limit students' participation and completion of advanced science and mathematics courses and persistence in a STEM track.

- Inform students and parents about STEM course and career planning, including career paths, course sequences, and college planning.

- Use student data and ongoing program evaluation to guide instruction and strengthen the program.

Teachers in after school science programs should build their capacity in advanced science and mathematics courses and should be able to:

- Provide supplementary instruction, as well as enrichment activities that complement the science and mathematics learning that takes place in school.

- Utilize authentic instructional work and a variety of effective teaching strategies that engage all students, including inquiry-based and minds-on learning.

- Create a learning environment that recognizes student diversity and emphasizes the seven principles of learning and that is learner or student centered, knowledge-centered, assessment-centered, and community centered.

- Provide students with the opportunity to communicate about science, including written and oral communications.

Challenges to implementing high quality after school science programs that increase the number and percentage of students who successfully complete rigorous advanced science and mathematics courses appear to be related to institutional factors, including:

- Some schools not offering advanced science and mathematics courses.

- Types of science and mathematics courses states require for high school graduation.

- The shortage of teachers with adequate content and pedagogical preparation to teach advanced science and mathematics courses.

- The need for after school professional development standards.

- Limited access to resources and tools for advanced science courses, including computers and related technologies, Internet access, and laboratory tools.

- The lack of challenging homework assignments and after school projects that augment the in-school science curriculum.

- Ambiguous messages to children from parents or guardians about taking advanced science and mathematics courses.

- Ineffective parental communications to schools and teachers about the urgent need for all children to participate in advanced science and mathematics courses that help students to succeed in college and in the workforce.

The commissioned synthesis report recognizes that many print and online resources and tools identify what science and mathematics topics students should know and learn by grade level bands, including topics identified by the AAAS Project 2061 Benchmarks, the National Research Council (NRC), the National Council of Teachers of Mathematics (NCTM), and the College Board. In addition, the NRC and the NCTM provide some guidance about standards for teaching, professional development, and assessment. The

NRC document includes science education program and system standards. Many school officials in state education agencies and school districts use these resources to guide and refine science and mathematics standards, curriculum, assessment, and teacher professional development.

However, it should be noted that many of these standards resources were developed well over a decade ago. Since then, groups such as the International Society for Technology Education (ISTE) have developed teaching and learning resources related to technology. Also, the Boston Science Museum has developed a National Center for Technological Literacy and is developing resources, including standards and textbooks, for teaching elementary and secondary engineering and technology (http://www.mos.org/nctl/nctl_overview.html).

Further, the research synthesis indicates that there are a variety of after school science programs, including programs in schools, museums, community organizations, and colleges and universities. However, many of these programs are not rigorously evaluated, as defined by the use of randomized control trials or comparison group studies (www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf).

Programs that have been designed to get underrepresented minority students and girls to pursue a science college major and career have been shown to increase college and university enrollment in STEM majors. However, to better understand the academic and employment outcomes of these and other types of after school science programs a methodologically rigorous longitudinal study that follows representative cohorts of students who participated in well-designed and carefully implemented programs from the early grades to college completion is needed.

III. Other Research, Resources, and Strategies

Other areas that the commissioned research synthesis briefly covers but does not elaborate on are:

A. Course rigor and grades.
B. Technology teaching and learning.
C. Assistive technology for students with physical and learning disabilities.
D. Learning styles and strategies.
E. Knowledge about the science and engineering workforce skills and mentoring.

What research tells us about these areas can inform recommendations for actions in after school science programs.

A. Course Rigor and Grades

Rigor at Risk: Reaffirming Quality in the High School Core Curriculum, an ACT report on core high school courses and college readiness indicates that of the ACT-tested 2006 high school graduates who took more than a core curriculum, *only 62% are ready for college level mathematics coursework, while just 38% are ready for college level science coursework after taking an additional year of science* (http://www.act.org/path/policy/reports/rigor.html).

Both the ACT report and the *Toolbox Revisited: Paths to Degree Completion from High School through College* identify the key determinant of success in college coursework as the academic quality and intensity of the core high school courses. *Toolbox Revisited* indicates that:

- *The combination of getting beyond Algebra 2 in math and taking three Carnegie Units in core laboratory science (biology, chemistry, physics) is more critical than taking three units in foreign language or Advanced Placement classes, even though Advanced Placement courses contribute to the highest level of academic intensity in a high school curriculum.*

- *It is not enough to count Carnegie Units in broad subject areas; it is necessary to know what is actually taught in particular courses and whether it matches the demands for entry-level courses in two- and four-year colleges (http://www.ed.gov/rschstat/research/pubs/toolboxrevisit/index.html).*

The ACT report identifies several factors that limit students' college readiness for science and mathematics course work, including state diploma requirements, state learning standards, high school readiness, high school grades, and teacher quality. In regards to high school grades, the report indicates that:

- *Whether because of grade inflation, lack of challenging content, or both, high grades in high school courses do not translate to college readiness for around half or more of ACT tested students taking Algebra II and physics*.

B. Technology and Teaching and Learning

The commissioned synthesis report indicates that instructional technology is effective in increasing students' engagement and achievement in STEM courses, but there are access issues to technology. As we seek solutions to access to technology, we cannot ignore the powerful role that technology plays in teaching and learning in science and mathematics, including:

- Basic skills tutoring and advanced skills instruction.
- Use of computer tools to model and visualize scientific and mathematical concepts or for data mining.
- Use of social networking software in teaching and research.
- Internet access to teaching resources and online professional development.

The NSF report *Cyberinfrastructure Vision for 21st Century Discovery* sees high school and colleges students as the early adopters of cyberinfratructure (http://www.nsf.gov/pubs/2007/nsf0728/index.jsp). The Internet coupled with communication, visualization, and simulation tools makes it possible for students to conduct authentic research and problem-solving activities related to local and global concerns (http://connect.educause.edu/library/abstract/AuthenticLearningfor/39343).

Social networking software is already being used for teaching, as well as online research collaborations, including writing collaboration platforms and book marking tools (http://connect.educause.edu/library/abstract/Web20ANewWaveofInnov/40615). Also, educators and science journals, such as *Science,* are periodically producing podcasts, online seminars and videos, and other types of interactive tools that can be used in teaching and learning (http://www.sciencemag.org/multimedia/).

One area not discussed in the synthesis is the use of the Internet as a tool for easy access to high quality K-12 teaching resources and online professional development. Online teaching and professional development resources that are useful for out of school science programs include the:

- National Science Digital Library (NSDL). The NSF's online library provides organized access to high quality resources and tools that support innovations in teaching and learning at all levels of STEM education. The NSDL includes Pathway portals that provide efficient resource discovery in several STEM areas including biology, chemistry, computational sciences, engineering, materials sciences, mathematics, and physics and astronomy. Other NSDL Pathway portals provide easy access to resources for middle school, community/technical colleges, and to multimedia resources (http://nsdl.org/about/?pager=pathways).

- Verizon Foundation's Thinkfinity Web site. Formally known as MarcoPolo, this portal provides standards-based resources, including lesson plans, student materials, reviews, and interactive materials in eight subject area. Thinkfinity science resources are provided by the American Association for the Advancement of Science (AAAS) (http://www.sciencenetlinks.com) and the mathematic resources are provided by the NCTM (http://illuminations.nctm.org). More information about Thinkfinity can be founded on the website (http://www.marcopolo-education.org/home.aspx).

- National Science Teachers Association (NSTA) Learning Center. This online professional development site provides users with access to more than 1,200 different types of resources including journal articles, interactive simulations, e-chapters, live web seminars, and tools for users to organize resources (http://learningcenter.nsta.org).

One Web resource that has been developed specifically for use with after school science programs is the AAAS Kinetic City After School Program for students in grades 3 to 5. This program uses standards-based science in five different ways, including (1) interactive science games; (2) hands-on demonstrations and experiments; (3) writing and language arts Internet research; (4) art projects; and (5) physical activities.

A July 2005 study conducted by the independent research company Edumetrics found that children participating in the *Kinetic City After School* program showed improvements not only in their knowledge of standards-based science content, but also in their ability to read a seventh-grade level reading assignment, and compose a letter based on the information in the passage. The complete Kinetic City After School Evaluation can be located on the Internet (http://www.kcmtv.com/evaluation.htm)

C. Assistive Technology for Physical and Learning Disabled Students

Another area not covered in the research synthesis is assistive technology for students with physical and learning disabilities. Surveys of physical and learning disabled science and engineering college students who participated in an AAAS STEM research internship program indicate that assistive technology helps level the playing field in both education and professional employment (http://ehrweb.aaas.org/entrypoint/paths/index.html).

Information about types of assistive technology for use in science classes can be found on the NSF and Ability Hub Web sites (http://www.abilityhub.com/). Assistive technology tools include speech recognition tools, screen readers, touch screen technology, key boards with large print, text to speech, and mouse alternatives.

The NSF Research in Disabilities Education (RDE) program currently supports 29 grantees that are providing resources and services to increase the participation and achievement of students with disabilities in STEM education and careers. The grantees provide support to institutionalize accessible products and educational materials, enhance STEM learning experiences for students with disabilities, and disseminate information about effective products, pedagogical approaches, teaching practices, and research for broadening the participation of people with disabilities in STEM (http://nsf.gov/funding/pgm_summ.jsp?pims_id=5482&org=HRD&from=home).

D. Learning Styles and Strategies

The book *How People Learn: Brain, Mind, Experience, and Schools* (1999), provides new insights into the learning process and reinvigorated the national conversation on research and practice as related to problem solving, complex reasoning, and how skills and knowledge are acquired. As a result of this research, many student learning centers, such as the Louisiana State University Center for Academic Success have developed strategies and online resources (http://appl003.lsu.edu/slas/lsoweb.nsf/index) that help students to understand their learning styles and develop learning skills, including understanding:

- Right/left brain dominance
- Personality
- Sensory preferences

Skills development resources include:

- Test preparation
- Time management
- Note taking and comprehension
- Overcoming test anxiety
- College reading readiness

The College Board AP online resources include strategies for skills development, as well as tips about planning for college. College planning resources for high school students focus on developing college plans, high school courses needed for success in college, skills development, and tips for college success (http://www.collegeboard.com/student/plan/index.html).

E. Knowledge about the Science and Engineering Workforce and Mentoring

Most high school students and their teachers and parents or guardians know very little about the types of high school science and mathematics courses and training needed to be successful in a college and science mathematics major or the types of degrees needed in the STEM workforce. The 2005 Bayer Facts of Science Education Survey indicates the following:

- *Nearly six in 10 (59 percent) parents think an advanced degree beyond a college bachelor's degree is necessary to have a job in science and engineering.*

- *Two-thirds (64 percent) of parents were surprised to learn that, according to the National Science Foundation, seven in 10 Americans working in science or engineering today have a bachelor's degree or less education.*

- *Nearly nine in 10 (88 percent) parents say that now knowing seven in 10 Americans working in science or engineering today have a bachelor's degree or less makes them think science and engineering hold realistic job opportunities for their children.*

- *Another nine in 10 (88 percent) parents feel the S&E community needs to do a better job telling today's students about these job opportunities (http://www.bayerus.com/msms/news/facts.cfm?mode=detail&id=survey05).*

In addition, the 2006 Conference Board report *Are They Really Ready To Work? Employers' Perspectives on the Basic Knowledge and Applied Skills of New Entrants to the 21st Century U.S. Workforce* indicates that:

- *Young people need a range of skills, both basic academic skills as well as the ability to apply these skills and knowledge in the workplace. The survey results indicate that far too many young people are inadequately prepared to be successful in the workplace. At the high school level, well over one-half of new entrants are deficiently prepared in the most important skills—Oral and Written Communications, Professionalism/Work Ethic, and Critical Thinking/Problem Solving. College graduates are better prepared, with lower levels of deficiency on the most important* *skills, but too few are excelling. Only about one-quarter of four-year college graduates are perceived to be excellent in many of the most important skills, and more than one-quarter of four-year college graduates are perceived to be deficiently prepared in Written Communications (http://www.conference-board.org/pdf_free/BED-06-Workforce.pdf).*

Also, in a recent project on science and career workforce mentoring, AAAS identified skills that STEM mentors can help mentees to build, starting with the high school years (http://ehrweb.aaas.org/sciMentoring/research.php). These skills include:

- Development of abstracts and posters for science fairs and research competitions.
- Preparation of abstracts and oral presentations at conferences and research days.
- How to conduct literature reviews for science research and papers.
- How to formulate research questions.
- How to select appropriate methods for use in science research.
- How to use statistical and computational programs and modeling in research.
- How to prepare and review scientific research papers.

Mentors can also help students to understand:

- The patent process.
- Intellectual property.
- Ethics in research, including human subject testing and use of animals in research.
- How to set up and manage a lab
- How to develop a budget and write grants
- Science policy.

A couple of useful online tools are available to help with skills building or career advising in science, including the:

- Online Ethics Center for Engineering and Science, at Case Western Reserve University (http://onlineethics.org/). This site promotes learning and advancing the understanding of responsible research and practice in science and engineering.

- U.S. Department of Labor Occupational Handbook (http://www.bls.gov/oco/home.htm). This tool contains information on a variety of STEM jobs, including training and education needed, earnings, expected job prospects, what workers do on the job, and working conditions.

- Sloan Career Cornerstone Center. This Web site includes information for students by grade bands and it includes resources for teachers, counselors, and parents (http://www.careercornerstone.org/paths/shigh.htm).

- Career Voyages. This tool includes information about STEM jobs in industries and emerging industries. The site includes videos about types of STEM jobs and resources aimed at students, parents, and career advisors (http://www.careervoyages.gov/parents-main.cfm).

IV. Recommendations for Program Approaches and Strategies

None of the recommended program approaches and strategies are new; rather they are a reframing or extension of evidenced based science and mathematics strategies. In a sense, we have tested strategies that have worked in carefully implemented settings on a small scale. What has been harder for even highly qualified educators to do is to apply what they know to meet the particular needs of students that they are serving. In many cases, we know that implementation of strategies vary and less attention might be given to defining and setting measurable learning objectives and continually using assessment to guide student learning.

Also, many of the past and recent educational and workforce reports do not recognize the role that after school science can play in strengthening the skills and knowledge of students in advanced science and mathematics courses and preparing them as science-informed citizens or for the scientific workforce. Given this lack of recognition about the added value of after school programs and out of school learning, it is important to identify recommendations to build the knowledge, skills, and capacity of students in advanced science and mathematics for both science literacy and careers in science.

Leaders in after school science programs should:

- Encourage state and local education agencies to develop and implement clear and realistic benchmarks for increasing the percentage of twelfth grade students who complete biology, chemistry, physics, advanced math, and calculus with a grade of B or better. The ACT report *Rigor at Risk: Reaffirming Quality in the High School Core Curriculum* and the *Toolbox Revisited: Paths to Degree Completion from High School through College* both provide a compelling case for why after school science program leaders need to host events for policymakers, educators and parents to advocate for high school biology, chemistry, physics, advanced math, and calculus for all students.

- Mobilize department chairs or curriculum leaders in school-based efforts to study and align in school and after school science curriculum, content, instruction, homework, projects, and assessment. Departmental chairs or curriculum leaders should work with in school and after school teachers and staff to first study the science curricula and teaching strategies used, including using standards and item analysis of science questions on state and national assessments and college entrance exams to determine: (a) science topics that are critical and or optional in the curriculum and (b) what critical science topics students are having trouble comprehending.

  Second, findings from this study should be used to (a) adapt in school curriculum and teaching strategies, (b) guide professional development, and (c) guide both in school and after school science instruction and activities.

Third, department chairs or curriculum leaders should determine if the curriculum study is helping to improve students' understanding of the science concepts, their grades, and assessment scores. Similar studies of curricula have been used with successful college intervention programs for minority students in STEM fields, including the program at Xavier University of Louisiana, a Historically Black University and College (HBCU) (http://www.collegeboard.com/research/abstract/3877.html).

Also, it is important to periodically conduct this type of school-based curricula and assessment study, since both student and teacher populations within a school change along with the requirements of schooling.

- Advocate for in school grade credit for after school and out of school science activities. Similar to community service credit, in school grade credit should be given for participation in after school and out of school science activities. Giving in school credit sends a message about the value of supplementary science instruction and out of school projects. A rubric should be developed for determining in school grade credit for participation in after school and out of school science programs.

- Create supportive high school science study and social networking groups, similar to what happens in intervention programs for lower division college students**.** As pointed out in the College Board report *Priming the Pump: Strategies for Increasing the Achievement of Underrepresented Minority Undergraduates* (1999), carefully implemented, supplementary instruction programs that are integrated into the social lives of students (such as the University of California-Berkeley Emerging Scholars Program - ESP) are effective in increasing students' success in advanced science and mathematics courses. A key feature of this type of program is regular structured tutoring meetings for extended time periods, led by faculty or upper division or graduate students. A full report on ESP can be found at (*http://www.collegeboard.com/research/abstract/3880.html*). Also, technology can play a role in building social networks.

- Use engaging student centered teaching strategies, including technology (coaching tools, simulations, modeling, laboratory tools, and social networking tools). While access to technology might be problematic, the Internet is a powerful tool for authentic local and global problem-based learning and online research. In addition, the Internet is an important source of advanced science and mathematics teaching resources.

- Help students to understand their learning styles and to develop effective learning strategies. While it is important that educators understand research and practices related to how people learn, it is equally important for students to take the responsibility for understanding their learning styles and how they learn best?

- Provide college and careers days and occasional seminars for K-12 students and their teachers and parents. Career days should feature scientists from all employment sectors, particularly scientists who are female, racial/ethnic minorities, and persons with physical disabilities. The conferences and seminars should focus on high school courses and exams needed for a college science major, financial aid, pursuit of graduate school, and rewards and benefits of a science career. For females, discussions about children, work-life balance, and productivity are particularly important. College and career seminars should be offered in a variety of venues including churches, colleges and universities, and at the employment place. The biggest employers in most cities are often the local government (including the school district), colleges and universities, or local utility companies.

- Develop STEM workforce mentoring programs. These programs should focus on helping high schools students apply the skills they are developing, including skills related to problem solving and critical thinking, writing, presentations, ethics in science, literature searches, and fair use of intellectual property. High school students should also begin to learn about local and global science challenges.

- Provide on-going professional development for core after school science staff and educators. This training should build academic content knowledge and skills related to technology and communications tools, learning strategies, college planning, and mentoring.

- Give extra attention to the implementation of the after school science programs and activities, including setting measurable objectives and developing evaluations, that meet the standards and metrics set by the U.S, Department of Education Academic Competitiveness Council (http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf).

Although after school science programs vary in type, size, and duration -- staff and educators in these programs can all find appropriate strategies and program approaches to implement related to advanced science courses. Programming is needed at every level including advocacy, workshops, promotions, and full scale supplementary instruction. Given the "quiet crisis," policymakers and educational leaders should not continue to ignore the value added by aligning in school and after school advanced science teaching and learning.

Disclaimer statement – This report is the opinion of the author. Any interpretations and conclusions are those of the authors and do not necessarily reflect the views of the American Association for the Advancement of Science or its Board or Council.

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