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STEM Reform

POLICY BRIEF

Building the Foundation for an Integrative STEM Approach to Learning

Background, Rationale and Strategies for Implementation

This policy brief was developed by Public Works to support the California Mathematics & Science Partnership (CaMSP) program of the California Department of Education's Professional Learning Support Division's Science, Technology, Engineering and Mathematics (STEM) Office.

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SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (STEM) LEARNING

Renewed attention to improving mathematics and science education has reinvigorated the ideas of integrated and applied STEM (Science, Technology, Engineering and Mathematics) learning as both a promising approach to reforming public education and to better match the needs of the US economy to have a globally competitive workforce. From training STEM teachers through the 100kin10 initiative, which aims to recruit 100,000 STEM teachers over the next decade to Educate to Innovate designed to inspire boys and girls to pursue STEM careers, STEM preparation is a frequent topic of educational reformers, the business community and policymakers at all levels of government.[1]

A HISTORICAL PERSPECTIVE ON STEM REFORMS IN K-12 EDUCATION

Since the end of World War II, the status of the United States as a world leader in scientific innovation has supported our country's economic prosperity and political prominence. From the launching of Sputnik in 1957, the subsequent passage of the National Defense Education Act and the expansion of the role of the National Science Foundation in K-12 science education to the release of A Nation At Risk in 1983, global competition, public education and national defense have been intertwined. Despite the natural linkages of these issues at the top levels of policymaking, educators interested in understanding how preparation for STEM has the best chance of success must understand a maze of options that will work within the traditional confines of the education system.

While the reforms initiated after the launch of Sputnik by the USSR characterized deficiencies in the quality of mathematics and science education as a threat to national security and led to a fairly focused set of initiatives, national reform of public education in the United States has always been difficult, in part because of the great variation from state to state and district to district but mostly because of the complex governance structures that make large scale change from the top difficult, if not impossible.

In the decade following A Nation At Risk, systemic reforms of American education began in earnest emphasizing more consistent course taking patterns and graduation requirements. The standards-based reforms of the 1990s, followed by testing and accountability measures with real consequences have been characterized as having the unintended effect of narrowing the curriculum to those tests and measures and leading to the further separation of the disciplines rather than a broader, more integrated approach to learning that embeds problem solving and real world application—just what many believe is needed in an economy that is constantly innovating. Under the America COMPETES Act of 2007, which was reauthorized in 2010, the federal government signaled a commitment to broader STEM preparation that reflected a review and consolidation of the many programs and disparate efforts to support the STEM learning and workforce pipeline of both students and teachers.[2]

THE NEW RATIONALE MOTIVATING AN INTEGRATIVE STEM APPROACH

Integrative STEM education involves the explicit incorporation of technology and engineering practices into mathematics and science lessons to organically facilitate interdisciplinary student learning experiences.[3] While disciplines traditionally operate in isolation of one another, integrative STEM education uses engineering and technology to teach mathematics and science lessons that are synthesized through real-world applicability, integration of technology, problem solving and the like. Much of this change comes down to the collaboration of teachers, professors and others. In addition, teachers need to develop an understanding of individual disciplines and the themes or topics that cut across disciplines to build broader student understanding at all ages.

1 *Reported by Liana Heitin on November 25, 2014, Education Week, Curriculum Matters.*

2 *Kuenzi, J. J. (2008). Science, technology, engineering, and mathematics (stem) education: Background, federal policy, and legislative action.*

3 Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. International Journal of Technology & Design Education, 23(1), 87–102.

The Common Core State Standards for Mathematics (CCSS-M) and the Next Generation Science Standards (NGSS) further bolster the modern conception of integrative STEM, each with an emphasis on instructional practices that support looking both within and outside of specific disciplinary concepts to a broader understanding of mathematical and scientific literacy for students. With a common approach to standards for learning taking hold across the nation, the United States is beginning to address the variation of curriculum identified as a key source of the historical problems identified in critiques of our nation's public education system. These efforts are coinciding with a resurgence in support for integrative STEM approaches.

While recent decades of reforms have been characterized as solidifying the isolation of subject matter and curricula, using the newly adopted CCSS-M and NGSS as the basis for an integrated and cross-curricular approach to learning across the spectrum of K-12 education is a powerful foundation for integrative STEM learning. However, concerted actions and programmatic decisions must be made to ensure that this happens for students as an intentional component of the school day, a challenge to be sure within the traditional structures of public education.

STRATEGY #1: ADOPT NATIONALLY AVAILABLE PROGRAMS & CURRICULA THAT INTRODUCE INTEGRATIVE STEM

While STEM is somewhat more established and available to high school students, educators today realize the need for introducing integrative STEM to students prior to high school, which is especially the case in programs designed to address the underrepresentation of women, youth who live in poverty and historically disadvantaged minority groups in STEM-based higher education. It is difficult for students to learn science with a "traditional" approach through eighth grade and then transition effectively to integrative STEM as they enter high school and prepare for college and the workplace. While there is a growing body of research and substantial investment of funding for the development of these initiatives, there are relatively few that are widely available, especially for elementary school students, and there are often substantial costs involved in full implementation including purchasing materials, facilities and professional development and teacher training.

- *Engineering is Elementary (EIE), National Center for Technological Literacy, Museum of Science in Boston*
- *Lego Mindstorms*
- *Vex Robotics IQ Curriculum and partners (Carnegie Mellon Robotics Academy, Project Lead the Way, Intellitek, Autodesk and Analytical Integrated Mathematics (AIM)*
- *Project Lead the Way (K-5 PLTW Launch, middle school PLTW Gateway and specialized high school programs in engineering, biomedical science and computer science)*

STRATEGY #2: TAP INTO EXISTING SCHOOL STRUCTURES TO REINVIGORATE STEM LEARNING

In part, because of efforts to reform traditional, comprehensive high school education, and in part, to improve career-technical education to better align with a new more global and technologically competitive economy, programmatic and curricular approaches for integrative STEM are more fully developed at the high school level. While not specifically designed to support STEM, there are many examples of high school approaches that offer opportunities for introducing students to integrative STEM in a structured way. More often than not, the implementation of these programs are based on local interest and the motivation of a small group of dedicated high school teachers, a few community partners and a willing principal. In some cases, networks of programs that provide broader support to these smaller scale programs have been built and give those engaged in the programs a forum for exchanging ideas and building program success. There is much to learn from this history of implementation to adapt and re-interpret STEM learning.

- *California Partnership Academies including the College & Career Academy Support Network (CCASN) at the University of Berkeley*
- *The National Academy Foundation information technology, engineering and health sciences*
- *Smaller Learning Communities*
- *Linked Learning pathways*
- *Magnet school programs*
- *California Career Pathways Trust*
- *California STEM Learning Network (CSLNet)*

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STRATEGY #3: FILL THE STEM PIPELINE THROUGH ACCESS TO CAREER & COLLEGE COUNSELING PROGRAMS

In a large school without specific STEM-focused programming, college and career counseling programs could play vital roles in aligning undirected middle and high school student learning with STEM career goals and/or continuation into postsecondary education. Existing programs are one source for making connections between students and the postsecondary STEM pipeline.

STRATEGY #4: USE TIME BEYOND THE SCHOOL DAY TO EXPOSE STUDENTS TO STEM LEARNING

According to the Afterschool Alliance: STEM & Afterschool report, K-12 students only spend one-fifth of their waking time in school, proponents of afterschool reform point towards extracurricular activities for its untapped potential for attracting and exposing students to STEM. Afterschool programming provides opportunities for college/career counseling programs, team-based competitions and the new "maker faire" movement. Nationally prominent examples include the Department of Energy National Science Bowl, the White House Science Fair and Maker Faire and the Google Science Fair

- *The Mathematics Engineering Science Achievement (MESA) and the MESA Schools Project was originally founded in California in 1970, and has since been expanded and replicated in 11 state across the county. MESA uses strategies such as individual academic plans, career and college exploration, mini-competitions within the MESA network to support interaction among students and parent leadership development.*
- *The PUENTE project is another example of an existing approach to bridging high school and college connections, though not exclusively in STEM fields. PUENTE is coordinated through partnerships between 34 California high schools and the University of California system.*
- *The Advanced Placement (AP) STEM Access Program has been introduced as a simple but practical system for making STEM learning available to low-income students by providing funding for these courses in comprehensive high schools serving high poverty populations.*

A FOCUS ON INSTRUCTION AS THE FOUNDATION FOR STEM THROUGH AUTHENTIC EXPECTATIONS FOR STUDENT LEARNING

The *Common Core State Standards for Mathematics (CCSS-M)* emphasizes focus and coherence, laying out a logical sequence of student learning from grade to grade to lead to college and career readiness by the end of high school. The standards are organized in two parts: first, *traditional mathematical topics*—numbers and operations, algebra, functions, statistics and probability, and geometry—and, second, *mathematical practices* that describe different kinds of expertise with mathematics that should be developed in all students.

Next Generation Science Standards (NGSS) are aimed at fostering K-12 students' deeper understanding of science, in part, by asking them to use the same kinds of practices scientists use. Thus, the standards ask students to apply what they learn through the *practices of scientific inquiry and engineering design*. They weave together three dimensions: (1) disciplinary core ideas, (2) science and engineering practices, and (3) cross cutting concepts.

Problem based and *project based* learning are two approaches that are a good fit for both implementation of the new standards and for integrative STEM learning.
Problem Based Learning (PBL) is an approach to learning developed in the late 1960s to better address the shortcomings of traditional approaches to training in the field of medical education—since that time PBL has been more broadly applied in both K-12 and postsecondary settings.
The Buck Institute for Education (BIE) has become a national resource for teachers to implement and collaborate on project based learning as a way to prepare students for successful lives. The components developed by the Buck Institute that embody its approach include:

- Significant Content
- 21st century competencies
- In-Depth Inquiry
- Driving Question
- Need to Know
- Voice and Choice
- Critique and Revision
- Public Audience

CHALLENGES TO BROAD IMPLEMENTATION OF INTEGRATIVE STEM

The need to be STEM-prepared is in the news. Fitting a modern interpretation of STEM that balances innovating for the future with learning from our past means educators today must be active in anticipating potential challenges and identify strategies for both structuring programs to embed STEM critical thinking skills and content knowledge with building student interest in STEM.

Incorporating integrative STEM into more elementary- and middle school-level programs will be a crucial next-step for STEM reformers. At the high school level, accountability efforts and increasingly rigid course requirements for college admission make the broad adoption of integrative STEM difficult. If the goal of integrative STEM is to prepare more qualified STEM undergraduate students, then educators must build on existing structures and collaborate with postsecondary institutions.

About the California Mathematics and Science Partnership

The California Mathematics and Science Partnership (CaMSP) program began in 2004. CaMSP is funded by a statewide competitive grant program administered by the Professional Learning Support Division's Science, Technology, Engineering and Mathematics (STEM) Office of the California Department of Education (CDE) under the Improving Teacher Quality (ITQ) component of the No Child Left Behind Act of 2001. Since that time, over 100 partnerships of local school districts and universities have been authorized by CDE involving hundreds of schools and many thousands of teachers. More information can be found at: www.cde.ca.gov/pd/ca/ ma/camspintrod.asp.

About Public Works

Public Works is a non-profit corporation founded in 1998 dedicated to working with schools, government agencies and the non- profit sector by providing services and resources to organizations that educate and inform children, youth and families. Our mission is to put data into action, transforming statistics into information that informs decisions, improves accountability and communicates the impact of public policy. Public Works serves as the statewide and local evaluator of the CaMSP program. More information can be found at www.publicworksinc.org.

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