Science, Technology, Engineering, Arts, and Mathematics

STEAM

at CCPS

Planning for the Plan

White Paper Presented to School Board, Chesterfield County Public Schools

August 27, 2013

STEAM Team Committee:

Donna Dalton, Chief Academic Officer
Dr. Juliette B. Myers, Director of Curriculum and Instruction
Ernest Longworth, Assistant Director of Curriculum and Instruction

Dr. Melanie Haimes-Bartolf, Science Specialist; STEAM Team Leader and Editor

Melody Bushley, Mathematics Specialist
Michael Gettings, Visual Arts Specialist
Barb Hancock-Henley, Career Development Program Manager
Dr. William Fiege, Vice-President of Academic Affairs, John Tyler Community College
Col. James White, Air Force Association

Last Revised: August 5, 2013

CCPS STEAM Logo designed by Lindsey Jackson, L.C. Bird HS, Governor's Academy for Engineering Studies

Our vision for STEAM education in Chesterfield County Public Schools

Our vision is to provide all our students with a Pre-K-16 STEAM education that is articulated with 21st century skills in curriculum, instruction, assessment, and enrichment, and that purposefully integrates science, technology, engineering, arts (language arts, fine and performing arts), mathematics, and social studies. To achieve this vision, our STEAM education plan uses project/problem-based (PBL) learning (how you teach) as its vehicle, engineering design/scientific method (processes) as its engine, technology, especially blended learning (tools you use), as its tool kit, and students as drivers to apply student-centered, inquiry-based instruction and learning through all content areas (what you teach) (Figure 1). Our project/problem-based learning and engineering STEAM education plan fosters problem-solving, creativity, critical thinking, collaboration, communication, and cooperation. It is the model for our *Rigor*, *Relevance, and Relationships Framework* (Daggett, 2005). Since every student takes science, equity for all students in STEAM is provided through science education. Our STEAM plan, informed by our vision, will increase STEAM literacy for all our students, provide them with a pipeline to STEAM advanced degrees, and empower them to compete successfully in a STEAM centric workforce.

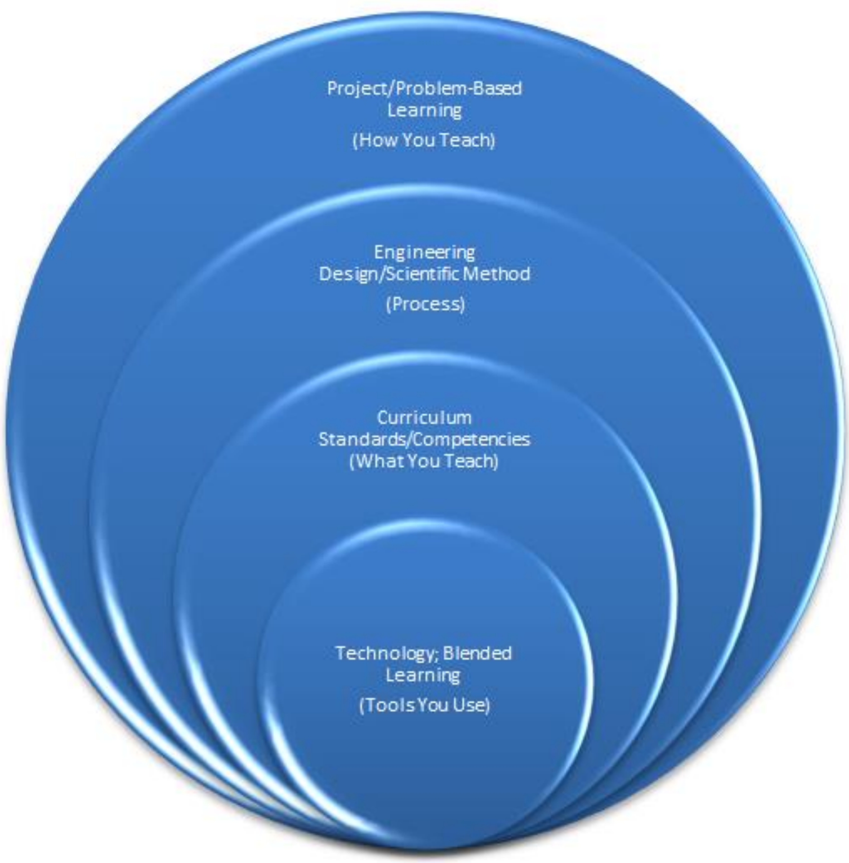

Figure 1: Our STEAM model for the *Rigor*, *Relevance*, *and Relationships Framework*

The Pre-K-16 STEAM pipeline

As students move through the Pre-K-16 STEAM "pipeline"—progressing from Pre-K to post-secondary education—they are first introduced to STEAM, then become literate in STEAM, and finally attain STEAM fluency (Figure 3). The term "Pre-K-16 STEAM" is used throughout this paper instead of "Pre-K-12 STEAM" to emphasize our goal of facilitating student progress through the entire STEAM pipeline.

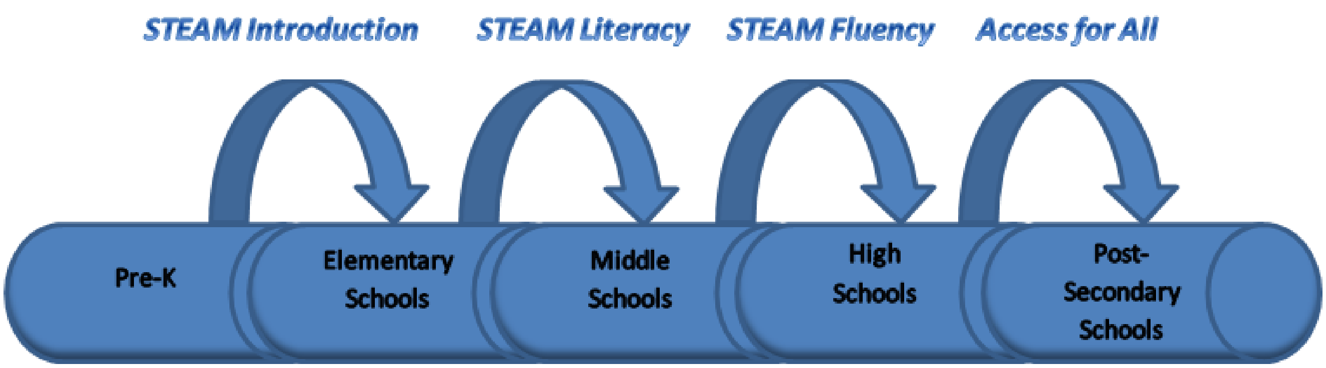

Figure 2: Building the Pre-K-16 STEAM Pipeline

STEAM Introduction--Students develop an understanding of:

- Characteristics of technology
- Basic engineering design briefs
- Creative design processes

STEAM Literacy--Students develop an understanding of:

- Characteristics, scope, and core concepts of technology
- Engineering design attributes
- Relationships among technologies and between technology and other fields of study
- Cultural, social, economic, and political effects of technology
- Environmental effects of technology
- Role of society in development and use of technology
- Influence of technology on history
- Roles of trouble-shooting, research and development, invention and innovation, and experimentation
- Engineering design process

- Different engineering fields and experiences including: environmental, mechanical, materials, geotechnical, aerospace, agricultural, bioengineering, packaging, biomedical, industrial, civil, acoustical, electrical, chemical, transportation, optical, and marine

STEAM Fluency--Students develop an understanding of and become able to select and use:

- Agricultural and related biotechnologies
- Medical, energy and power, information and communication, transportation, manufacturing, and construction technologies
- Technological products and systems
- Information to assess the impact of products and systems

Access for All

- Associate degrees (science, arts, applied science, applied arts)
- Certificates
- Bachelor degrees
- Advanced degrees

Rationale: What is STEAM?

STEAM is the acronym for science, technology, engineering, arts, and mathematics. The integrative nature of STEAM is stressed in the following definition from Sanders and Wells (2006): "…technological/engineering design-based learning approaches that *intentionally* integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, career technology education, etc." Note the use of the term STEM in this definition where we use the term STEAM to explicitly acknowledge the role that arts play in the process. In addition, when "STEAM" is used in this paper, its integrative nature is implied even when not specifically stated.

Key characteristics of an integrated, student-centered Pre-K-16 STEAM education have been classified into three categories: learning outcomes, scope, and pedagogy (Sanders 2012).

Under learning outcomes, students will be able to:

- Demonstrate STEAM knowledge and practices
- Demonstrate STEAM-related attitudes and dispositions
- Use grade-appropriate STEAM concepts and practices effectively in designing, making, and evaluating solutions to real-world problems

Under scope, an integrative STEAM education:

- Is available to all students
- Is implemented by one or more STEAM teachers in one or more classrooms and class periods
- Is implemented during and after the normal school day
- Is articulated thoughtfully and effectively across multiple grades

Under pedagogy, STEAM instruction:

- Uses current and accepted principles and methodologies in instruction and learning
- Uses interdisciplinary, transdisciplinary, or multidisciplinary approaches
- Engages students intentionally in scaffolded integrative thinking (Bybee, 2006)
- Assesses students purposefully in the application of grade-appropriate STEAM concepts and practices in designing, making, and evaluating solutions to real-world problems
- Provides a rigorous context for integrative STEAM related learning associated with all levels of the cognitive and affective learning taxonomies (Bloom et al., 1956)

Rationale: Why STEAM?

"Science, engineering, and technology permeate nearly every facet of modern life, and they also hold the key to meeting many of humanity's most pressing current and future challenges. Yet, too few U.S. workers have a strong background in these fields and many people lack even fundamental knowledge of them. This national trend has created a widespread call for a new approach to Pre-K-16 science education in the United States." This statement from the National Research Council's *A framework for PRE-K-16 science education: practices, crosscutting concepts, and core ideas* is a clear call for a new approach to science education (National Research Council, 2012).

The Chesterfield County Public Schools *Design for Excellence 2020* plan clearly outlines a system-wide action plan involving integration, innovation, and impact through the year 2020 to support student academic achievement, twenty-first century learning and technology, and citizenship and core values. STEAM instruction and learning, as described in this white paper, supports the following two goals in the *Design for Excellence 2020* plan.

Goal 1 2013-14: Define and develop a Pre-K-16 integrated model of rigorous content and core performance standards that combines Virginia's Standards of Learning and national (Common Core)/international performance standards (International Society for Technology in Education).

Goal 1 2014-15: Increase STEAM opportunities for students.

A Pre-K-16 STEAM curriculum meets these calls to action by both the National Research Council and Chesterfield County Public Schools because it engages students by allowing them to discover and construct their own understanding of science and engineering practices by getting them to:

- Ask questions and define problems
- Reach beyond their capacities to explore playfully without a preconceived plan
- Attend to visual contexts more closely than ordinary "looking" to see things that otherwise might not be seen
- Picture mentally what cannot be directly observed and imagine steps to create
- Develop focus conducive to working and persevering at tasks
- Construct explanations and design solutions
- Plan and carry out investigations
- Develop and use models
- Obtain, evaluate, and communicate information
- Analyze and interpret data
- Engage in argument from evidence

- Think and talk with others about an aspect of one's work or working process
- Collaborate and cooperate
- Critique one's own work and working process and those of others
- Embrace opportunities to learn from mistakes

(National Research Council, 2012; Hetland et al., 2007)

Rationale: Workforce for STEAM

According to the National Academy of Sciences: "The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering … 4 percent of the nation's workforce is composed of scientists and engineers, this group disproportionately creates jobs for the other 96 percent (National Academy of Sciences, National Academy of Engineering and Institute of Medicine, 2011a, p. 4)." But according to the current president and director of the Museum of Science, Boston, Ioannis N. Miaoulis: "There is a widespread concern that our nation's preeminence in science and innovation is eroding," since "Only 5 percent of U.S. college graduates major in engineering, compared with 12 percent of European students and 20 percent of those in Asia (Education and the Workforce Committee, 2013)."

From 2010 to 2020, the U.S. economy is projected to add 20.4 million new jobs as total employment grows from 143.1 million to more than 163.5 million. The fastest growth is expected among healthcare, personal care, and community and social services. Job growth will be faster for occupations that typically need some form of post-secondary education (Lockard and Wolf, 2012c). Of the 20.4 million new jobs, 9.2 million will involve STEM practices (Education and the Workforce Committee, 2013). In 2010, there were 7.6 million STEM workers in the United States, representing about one in 18 workers. STEM occupations are projected to grow by 17 percent from 2008 to 2018, compared to less than 10 percent growth for non-STEM occupations. STEM degree holders earn higher wages, whether or not they work in STEM occupations (Langdon et al., 2011).

To address national, regional, and local concerns with preparing a qualified workforce, a new National Assessment of Educational Progress (NAEP) in technology and engineering literacy assessment is currently being piloted. The new computer-based assessment will help educators, the public, and policy makers learn what students know about technology and engineering, including if students have the necessary knowledge and skills needed for these areas. The 2011 NAEP scores in mathematics and science for 4th and 8th grade students in Virginia indicate an upward trend over the years and scores that are better than the national average (National Center for Education Statistics, 2012).

So, our mission is not only to help our students fulfill current academic requirements, but to assure that they are prepared to join the workforce of the future. We need to improve the

STEAM pipeline such that we contribute to STEAM literacy for all students and expand the number of students, including women and minorities, who pursue advanced degrees and careers in STEAM fields. Our district needs to sustain the momentum we currently have in place with a sustainable strategic Pre-K-16 STEAM Plan.

Strategic planning for STEAM implementation

Over the years, many elementary, middle, and high schools in Chesterfield County have integrated STEM (Science, Technology, Engineering, and Mathematics) instruction and learning across content. Activities through Curriculum and Instruction, Career and Technical Education, and individual schools have yielded impressive demonstrations of project/problem-based learning and applications of the engineering design process. Examples of these activities include children's engineering, science projects, and the annual STEAM Fair. To acknowledge the importance of the fine and performing arts in STEM activities and projects in the district, we are now calling our initiative STEAM, which is consistent with terminology in our district's *Design for Excellence 2020* plan.

Goals

It is evident from our 2012-13 research on the current level of STEAM participation in Chesterfield County Public Schools that the district needs to implement a more purposeful Pre-K-16 articulated and cohesive STEAM program. Therefore, we propose that the strategic plan specified in this white paper:
(1) increases STEAM articulation across grade levels and content areas,
(2) aligns STEAM lessons with state and national standards of learning,
(3) supports the district's ability to increase STEAM opportunities for all students by 2014-2016, and
(4) prepares students for the workforce and post-secondary education in STEAM fields.

Action Steps

In support of this strategic plan for articulated and cohesive STEAM practices in the district, the following actions should be taken:

- Specify STEAM implementation steps for Pre-K, elementary, middle, and high schools
- Articulate a spiral Pre-K-16 STEAM sequence of skills and processes that emphasize depth, not breadth, in content aligned to essential topics in the (1) Virginia Standards of Learning, (2) Common Core, (3) Next Generation Science Standards Framework, (4) Career and Technical Education Competencies, and (5) Technology Literacy Standards
- Develop STEAM units of study through (1) project/problem-based learning, (2) science, global connections, and technology education projects and activities, and (3) International

Baccalaureate Programme--theory of knowledge core and creativity, action, and service cores

- Consider all three models of STEAM-focused schools in which engineering and technology are taught--selective, inclusive, and Career and Technical Education
- Cultivate and support STEAM instruction for teachers with effective and sustained professional development over time
- Develop a system of formative assessment and accountability (student outcomes, teacher practices) for STEAM instruction and learning
- Support existing and cultivate potential STEAM enrichment opportunities
- Expand partnerships with community organizations in support of STEAM endeavors

A team approach to Pre-K-16 STEAM implementation

As detailed in Figure 2, at the heart of our vision is a team approach to implementation of the Pre-K-16 STEAM program that is centered in our schools and supported by Curriculum and Instruction, Career and Technical Education, the STEAM team committee, and our many community partners.

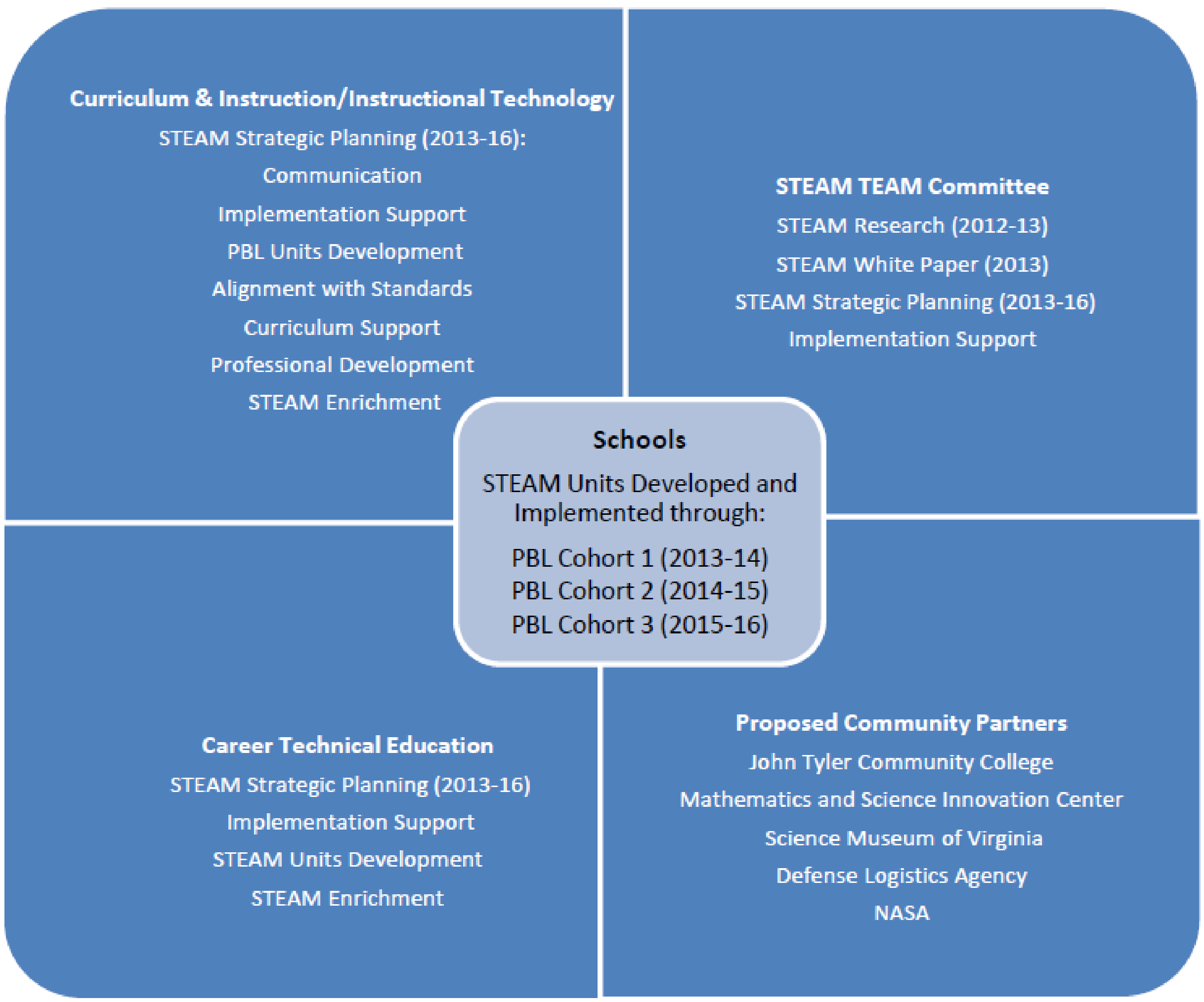

Figure 3: Responsibilities of Pre-K-16 STEAM implementation teams

Past successes and current practices in STEAM education in CCPS

Successful STEAM education takes place in comprehensive Pre-K-16 settings, including selective, inclusive, and Career and Technical Education STEAM-focused implementation models. Pre-K-16 STEAM practices need to capitalize on students' early interests and experiences, identify and build on what students already know, provide students with experiences to engage them in STEAM practices, and sustain their interests. Educational practices are essential to identify schools that focus on STEAM. Currently, our STEAM initiative also relates to three other *Design for Excellence 2020* initiatives: blended learning, twenty-first century curriculum (including Digital Age Literacy Standards already in our curriculum frameworks), and project/problem-based learning. Project/problem-based learning centered curriculum has the added advantage of being adoptable at the grade, content, or school level and does not force a connection in any particular area. Using the engineering design process and the scientific method (processes) to drive project/problem-based learning (how you teach) and blended learning and other technologies as tools (tools you use), the content areas (what you teach) serve as instruction and information platforms for students. Science classes then serve as the launch pad for project/problem-based learning units that are connected across the content areas as they currently do now in some of our schools.

The following is what STEAM currently looks like in Chesterfield County Public Schools, including activities, project/problem-based learning initiatives, and STEAM-focused practices:

District

- Production of district-wide Pre-K-16 STEAM fairs in 2012 and 2013 at the Science Museum of Virginia highlighted by science and technology activities and exhibits
- Completion of graduate level course in children's engineering by over 200 elementary teachers and science specialist
- Participation in Engineering is Elementary, Museum of Science, Boston (project-based engineering units) since 2009
- Alignment of technology education methodologies with design briefs used in children's engineering and project-based learning
- Use of Edmodo and Google Docs for student collaborative activities
- Use of Google Sketchup and Autodesk by students for design projects
- Participation in Robotics and STEAM clubs at many elementary and middle schools
- Participation in FIRST Robotics at a number of schools
- Visit to Virginia Beach Public Schools Corporate Landing Middle School for STEAM program briefing
- Visit to John Tyler Community College Chester Campus

- Presentation of STEAM Instruction and Career Technology Education at Virginia State University by Science Specialist and Executive Principal of Chesterfield Technical Center (June 21-22, 2012)
- Presentations at national and state level STEAM conferences
- Formation of STEAM Team Committee consisting of Chief Academic Officer, Director of Curriculum and Instruction, Program Manager for Career and Technical Education, Manager of Technology Integration and Instruction, and Specialists for Science, Art, and Mathematics
- Compilation of information on state of STEAM in Chesterfield County Public Schools
- Compilation of research for STEAM, children's engineering, and interdisciplinary connections
- Creation of comprehensive STEAM "Planning for the Plan" –Strategic Plan (this document)
- Training in project/problem-based learning beginning in Summer 2013

High Schools
- Dual enrollment with career technology education programs at John Tyler Community College
- Governor's School of Engineering (selective) at L.C. Bird High School
- Mathematics and Science High School (selective) at Clover Hill High School
- Governor's Health Science Academy (selective) at Cosby and Monacan High Schools and Chesterfield Technical Center
- Technology courses at Manchester High School
- Governor's School of Engineering (L.C. Bird High School) Robotics demonstration at Inaugural STEM Day at the Virginia General Assembly (February 18, 2013)
- 21st Century Academy
- Career and technical education courses at Chesterfield Technical Center
- AutoCAD (Auto Computer Aided Design)
- Three D Printers
- School-based science fair projects
- Metro Richmond Science Fair
- Virginia Junior Academy of Science
- STEAM Fair

Middle Schools
- Technology courses
- Real-time utility monitoring systems – all Middle Schools
- School-based science fair projects
- Metro Richmond Science Fair
- Virginia Junior Academy of Science
- STEAM Fair

Elementary Schools

- Children's Engineering for Educators through James Madison University (activity-based)
- Engineering is Elementary (project-based units) through Museum of Science, Boston
- Robotics workshop at Clover Hill Elementary School
- Share Fair Engineering Day June 2011, featured on WCVE "Science Matters" at Hopkins Elementary School
- School-based science and children's engineering fairs
- Department of Defense STARBASE – 5^{th} grade (proposed)
- STEAM Fair

Pre-K

- King's Dominion Planet Snoopy –Contributed to STEM principles, parent/child activities
- "W Is for Worms" activity – Reams Elementary School

Next Steps for STEAM in Chesterfield County Public Schools

The following actions need to occur to implement purposeful and comprehensive Pre-K-16 STEAM practices district-wide:

Develop a Chesterfield County Public Schools strategic plan for STEAM implementation

- Implement a process for developing STEAM programs and pipeline
- Articulate a Pre-K-16 STEAM sequence of skills and practices with Ascending Intellectual Demand (scaffolding accomplished in incremental levels determined by formative assessments of the current level of students' thinking and ranging from novice to apprentice to practitioner to expert) (Tomlinson et al., 2002)
- Use Next Generation Science Standards Framework for Science and Engineering
- Establish a Pre-K-16 STEAM implementation by age group
- Use science classrooms as launching pads for interdisciplinary STEAM units

Develop curriculum mapping for whole curriculum (what you teach)

- Use engineering design process/scientific method (processes) as engine for STEAM units
- Use project/problem-based learning (how you teach) as vehicle for STEAM units
- Use technology and blended learning as tools (tools you use) for STEAM units

Identify early STEAM adopters in every school

- Facilitate school-based PBL committees/teacher coordinators/teacher trainers
- Provide on-time professional development to cultivate teacher capacity in best STEAM practices
- Provide sustained professional development

Develop STEAM enrichment opportunities

- Facilitate STEAM field trips
- Expand partnerships with community members to support STEAM endeavors
- Develop "STEAM in Chesterfield County Public Schools" monthly newsletter/blog

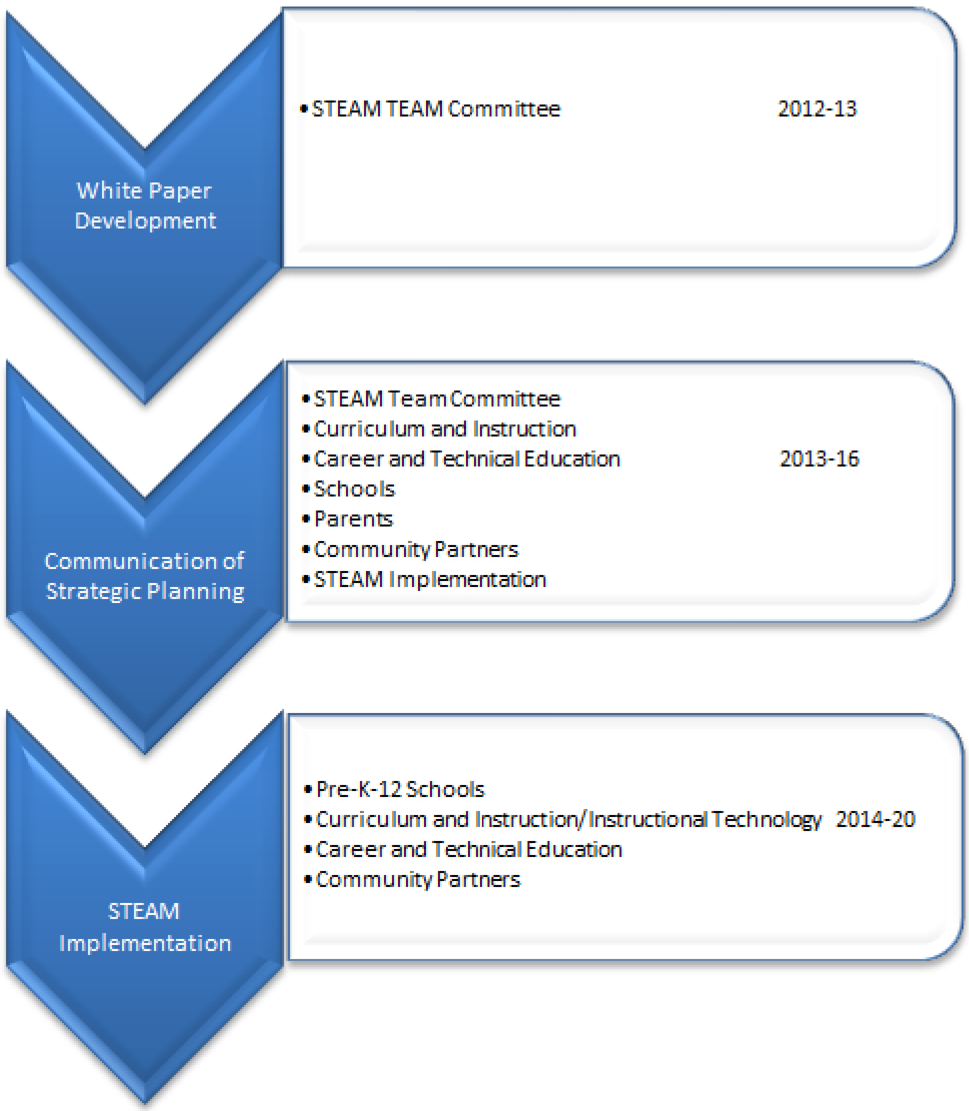

Figure 4: Pre-K-16 STEAM Timeline Overview

The STEAM research conducted for this white paper was projected to occur during 2013-14 in the *Design for Excellence 2020* plan. So, we are a year ahead of schedule and planning for STEAM implementation and opportunities for all students in 2014-16 (Figure 4).

Timeline

Goal	**Activities**	**Person(s) Responsible**	**Completion Date**
Plan for CCPS STEAM strategic plan	Form a STEAM committee	CAO Team	October 2012
Discuss and organize committee processes	Identify tasks and outcomes; Identify differentiation between STEM and STEAM	CAO Team STEAM Team Leader	November 2012
Identify STEAM initiatives currently in place in CCPS	Create STEAM Activities Matrix in Google Docs	STEAM Team, community partners, and school representatives	January 2013
Identify successful STEAM Practices	Compile past & current CCPS STEAM practices; Research Successful STEAM practices; site visits; white paper	STEAM Team, community partners, and school representatives	February - May 2013
Develop Strategic STEAM Plan; Curriculum Mapping for STEAM units	Examine whole curriculum, develop engineering driven Project/Problem-Based Learning units Pre-K-12	Curriculum and Instruction, CTE, teachers	June 2013 - December 2013
Develop Project/Problem-Based Learning/Engineering units	Pilot Project/Problem-Based Learning/Engineering units; obtain feedback	Curriculum and Instruction, CTE, Teachers	January 2014 - June 2014
Develop a communications plan focused on the STEAM strategic plan	Work collaboratively to develop a communications plan	CAO Team, Curriculum Instructional Specialists, Community Relations	June 2014
Implement STEAM initiatives	Support implementation in schools; Refine STEAM/PBL units; obtain feedback	Curriculum Instructional Specialists, CTE, teachers, and Community Partners	August 2014

Figure 5: Pre-K-16 STEAM Timeline

STEAM resources

- American Society of Engineering Education: http://www.engineeringk12.org
- American Society of Mechanical Engineers: http://www.asme.org
- CEE Children's Engineering Educators, LLC: http://www.childrensengineering.com/
- Engineering is Elementary, Science Museum of Boston: http://www.eie.org/
- Inquiry by Engineering Design: http://ibed.weebly.com/
- ITEEA National Standards and Benchmarks: http://www.iteea.org/TAA/PDFs/Benchmarks.pdf
- John Tyler Community College, Dr. William Fiege, Vice-President Academic Affairs
- KidWind: http://www.kidwind.org
- National Academy of Engineering-Engineer girl: http://www.engineergirl.org/
- Teach Engineering.org www.teachengineering.org/
- The S.T.E.A.M. Team is a trans-disciplinary group of eighth grade teachers at Pine Grove Middle School in East Syracuse, NY fostering 21st century learning through S.T.E.A.M. Education http://www.linkedin.com/redirect?url=http%3A%2F%2Fwww%2Esteam-ed%2Eorg&urlhash=cTyJ&_t=tracking_anet
- *Science*Insider Breaking news and analysis from the world of science policy retrieved from http://news.sciencemag.org/scienceinsider/2013/04/a-us-makeover-for-stem-education.html
- Virginia Children's Engineering Council: http://www.childrensengineering.org/
- VA SOL revised to national STEM standards http://www.exemplars.com/resources/alignments/national-stem-standards

References cited

Bloom, B. E. (1956). *Taxonomy of educational objectives: the classification of educational goals; Handbook I: Cognitive Domain.* New York: Longmans, Green.

Bruder, M.B. (1994). Working with members of other disciplines: Collaboration for success. In M. Wolery & J.S. Wilbers (Eds.), *Including children with special needs in early childhood programs* (pp. 45-70). Washington, DC: National Association for the Education of Young Children.

Bybee, W. R. (2006). *The BSCS 5E instructional model: origins, effectiveness, and applications.* Colorado Springs, CO: BSCS.

Chesloff, J.D. (2013). Why stem education must start in early childhood. *Education Week, March 6, 2013 Volume 32*(23), p. 32.

Daggett, W. (September, 2005). Achieving academic excellence through rigor and relevance. International Center for Leadership in Education. Retrieved from http://www.leadered.com/pdf/academic_excellence.pdf

Education and the Workforce Committee *Hearing highlights need for more effective STEM education programs* (April 10, 2013). Retrieved from http://edworkforce.house.gov/news/documentsingle.aspx?DocumentID=328081.

Gallagher, P.A. and Schober-Peterson, D. (2004). Collaboration with families and professionals. In R. Colarusso & C. O'Rourke (Eds.), *Education for all teachers* (p. 486). Dubuque, IA: Kendall/Hunt Publishing Co.

Hetland, L., Winner, E., Veenema, S., Sheridan, K.M. (2007). *Studio thinking: The real benefits of visual arts education.* New York, New York: Teachers College Press, Columbia University.

Hayes Jacobs, H. (1989). *Interdisciplinary curriculum: Design and implementation*. Alexandria, VA: ASDC

Hayes Jacobs, H. (1997). *Mapping the big picture: Integrating curriculum and assessment K-12*. Alexandria, VA: ASDC

Kolb, D. A. (1984) *Experiential Learning*, Englewood Cliffs, NJ: Prentice Hall. 256 pages.

Langdon, D., McKittrick, G., Beede, D., Khan, B., Doms, M. (July 2011). *STEM: Good jobs Now and for the future*. U.S. Department of Commerce Economics and Statistics administration.

Lockard, B., Wolf, M. (January 2012c). "Occupational employment projections to 2020." Monthly Labor Review. Retrieved from http://www.bls.gov/opub/mlr/2012/01/art5full.pdf

National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2011a). *Rising above the gathering storm revisited. Rapidly approaching category 5.* Condensed version. Washington, DC: The National Academies Press. P.4.

National Center for Education Statistics (2012). *The nation's report card: Science 2011 (NCES 2012–465).* Institute of Education Sciences, U.S. Department of Education, Washington, D.C. Retrieved from http://nces.ed.gov/nationsreportcard/tel/

National Research Council (2012). *A framework for PRE-K-16 science education: practices, crosscutting concepts and core ideas. committee on a conceptual framework for new PRE-K-16 science education standards.* Washington, DC: The National Academies Press.

National Research Council of the National Academies (2011). Successful PRE-K-16 STEM education identifying effective approaches in science, technology, engineering, and mathematics.

National Science Foundation. (2010). Preparing the next generation of STEM innovators: identifying and developing our nation's human capital. Washington, DC: Author.

NGSS (2012). Next generation science standards: standards for engineering, technology, and the applications of science. Retrieved from http://www.nextgenscience.org/sites/ngss/files/Standards%20for%20Engineering%20Technology%20and%20the%20Applications%20of%20Science%20May%20Draft%20FINAL_0.pdf

Sanders, M. (2012). *Integrative STEM education as "Best Practice."* 7th Biennial International Technology Education Research Conference, Queensland, Australia. Paper presented December 8, 2012. Virginia Tech University, Blacksburg, Virginia, USA.

Sanders, M. & Wells, J.G. (2006). *Integrative STEM education*. Retrieved from http://www.soe.vt.edu/istemed/

Tomlinson, C.A., Kaplan, S.N., Renzulli, J.S., Purcell, J., Leppien, J., Burns, D. (2002). *The Parallel Curriculum: A Design to Develop High Potential and Challenge High-Ability Learners.* Thousand Oaks, Calif: Corwin Press.

Glossary of Terms

articulation: Systematic coordination of course or program content within and between educational institutions to facilitate the continuous and efficient progress of students from grade to grade, school to school, and from school to the working world.

ascending intellectual demand: Instruction supported and accomplished in incremental levels that are determined by formative assessments of the current level of students' thinking. Levels range from novice to apprentice to practitioner to expert.

blended Learning: An approach to learning that combines face-to-face classroom methods with online delivery of content and instruction.

cohesive [education]: An educational plan or system in which teachers, policymakers, and administrators treat preschool, K-12, and post-secondary education as one system of related, interdependent components. Mutual expectations are effectively communicated concerning the knowledge and skills that students must master.

curriculum mapping: Curriculum mapping is a process for recording what content and skills are actually taught in a classroom, school, or district over the course of a school year. The data provide an overview, rather than a daily classroom perspective, of what is actually happening across grade levels and subjects (Jacobs, 1997).

engineering design attributes: Abilities, skills, and knowledge, such as critical thinking, problem solving, and decision making, that students apply to innovate and create.

engineering design brief: The technical document used by engineers and designers that: defines the problem to be solved, describes how existing products are used, states why a new product is required, specifies criteria for the new product, and lists tools and materials needed to develop the new product or create the new design.

engineering design process: The cyclical process used by engineers and designers to solve problems by using the following steps: ask a question, conduct research, specify requirements, brainstorm design solutions, select the best solution, plan, build a prototype, test and evaluate the solution, and improve the design solution (construction, test, evaluation, and improve).

expeditionary learning: An approach to learning that emphasizes real-world experiential learning through expeditions that may involve service learning, field and case studies, projects, presentations, and performances.

experiential learning: The process in which students construct understanding from direct experience (Kolb, 1984).

interdisciplinary, transdisciplinary, and multidisciplinary: Three approaches to teaching characterized and distinguished by the extent of coordination among curriculum areas.

> **Interdisciplinary:** A teaching approach where members of an educational team coordinate the objectives of multiple disciplines to produce a more relevant, aligned, and stimulating learning experience (Jacobs, 1989 p. 10).
> **transdisciplinary:** A teaching approach where members of an educational team share roles, contribute knowledge and skills, collaborate with each other, and collectively determine the outcome across discipline boundaries (Bruder, 1994 p. 61).
> **multidisciplinary:** An educational approach where members of a team share information, discuss and plan together, but one in which individual disciplines remain discrete with no formal collaboration among team members (Gallagher & Schober-Peterson, 2004 p. 486).

inquiry-based learning: A student-centered, teacher-facilitated learning approach in which students investigate real-world questions generated from their own experiences, perspectives, interests, and curiosities. Students acquire and analyze information, develop and support propositions, provide solutions, and design technology and arts products that demonstrate their thinking and make their learning visible.

pre-K-16 STEAM: An articulated approach to STEAM education that emphasizes the goal of facilitating student progress from Pre-K through high school and beyond to post-secondary school. Chesterfield County Public Schools offers dual enrollment and AP college level courses that implement STEAM principles

problem-based learning (PBL): A student-centered, experiential learning approach in which students develop viable solutions to ill-defined ("messy") real-world problems. Students conduct research, integrate theory and practice, and apply skills and knowledge.

project-based learning (PBL): A teacher-facilitated learning approach in which students go through an extended process of inquiry organized around an open-ended *driving* question, problem, or challenge. Students learn key academic content, practice twenty-first century skills, and create high-quality, novel products to present to a public audience. While allowing for student *voice and choice*, rigorous projects are carefully planned, managed, and assessed by teachers.

project/problem-based learning (PBL): An inquiry-based learning approach to STEAM education that is organized around an open-ended project or problem through which students learn academic content while applying their skills and knowledge to answer a question, create a product, or solve a problem.

real-world: Reality in everyday life, experiences, and phenomena.

scaffolded: As students move from novice to expert in their skills and abilities, teachers offer individualized instructional supports for only those skills that are beyond the students' capabilities. As students move beyond the novice status, the teacher gradually removes scaffolding to encourage students to work independently.

scientific method: A process of critical thinking that uses observations and experiments to investigate testable predictions about the physical universe. The systematic approach involves identifying a problem to solved, formulating a hypothesis, testing the hypothesis, gathering and analyzing data, and making conclusions.

spiral curriculum: As students are exposed to a concept multiple times throughout their education, new learning is related to prior learning, complexity of content is increased, and information is reinforced and solidified.

student-centered learning: Learning in which students are active, responsible participants in their own learning and where the focus is on each student's learning style, abilities, needs, and interests.

twenty-first century skills: In Chesterfield County Public Schools these skills include Digital Age Literacy, Inventive Thinking, Communication and Collaboration, and Global Connections.