



# Science, Technology, Engineering and Mathematics (STEM): Combining Applied Technology Studies With Challenging Mathematics and Science

SREB

The world is changing and so must our schools. Students in an increasing number of middle grades schools, high schools and technology centers are being challenged with courses that combine applied technology studies with mathematics and science. Eleven states have joined SREB in the *Preparation for Tomorrow* initiative, designed to give schools access to relevant new career/technical programs to prepare students for college and careers. These STEM courses are filled with authentic projects that give students an understanding of what is required in the workplace of today and tomorrow.

## Engage Middle Grades Students in Real-World Learning Experiences Using Science, Mathematics, Engineering, Technology and Literacy



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### Competitive Events: Attracting Students to STEM Studies

**C**an anything compete with athletics in a community of 81,000? Students in Bay Minette, Alabama, are giving local residents something additional to cheer about.

Five years ago, **Bay Minette Middle School (BMMS)** began a STEM (science, technology, engineering and mathematics) program. The program and related competitions have become so popular that STEM students' accomplishments are being heralded along with football and other sports.

"There used to be a saying that academics is what you do if you don't do athletics," said **Bill Allen**, career/technical (CT) teacher at BMMS. "Now students receive recognition in the community if they are in the STEM program or the tech students' association or on the robotics team."

### STEM Block

The STEM program at BMMS is offered in a block of elective courses, including an engineering class, two science classes and a graphic arts class

that emphasize collaborative project-based learning with authentic assessment. In fall 2012, the STEM block was expanded with the addition of another teacher and another engineering elective, Project Lead The Way (PLTW).

Approximately 150 students (30 percent of total enrollment) at BMMS have chosen to participate in the STEM block. Students rotate randomly to work on different projects through the year. “We have developed a routine for graphic design projects in which the whole class participates in peer revisions with feedback and ideas designed to make all projects better,” said **John Hope**, graphic arts teacher.

Bay Minette is in an aerospace industry zone; students must acquire excellent mathematics, science and other academic skills to get high-skilled, high-wage aerospace jobs. The STEM block prepares students for this career field by requiring them to use 21st-century skills of critical thinking, problem solving and collaboration as they apply science and mathematics concepts in their projects.

Allen and Hope facilitate more than 100 different STEM project assignments annually. Six STEM projects (described below) represent the new model for a comprehensive team approach to competitive academics. All six projects are derived from the Technology Student Association.

- **Go Green Manufacturing** — Students design and develop a long-term plan to re-engineer a commercially found material or product from garbage into a new commercially viable product. Students develop a two- to four-minute marketing plan and use the engineering design process to document two prototypes.
- **Transportation Challenge** — Utilizing engineering design process research, students design and develop boats powered by rubber bands. They use materials unavailable commercially.
- **Multimedia Design** — Students produce an animated segment on the school dress code. The animation explains the do’s and don’ts without offense to gender, race or convictions.
- **Medical Technology** — Students conduct innovative research in medical and biomedical fields to identify the social, economic and ethical issues that can arise as the procedure or product is developed and implemented.
- **Leadership Strategies** — A team of student leaders develops several solutions to a relevant real-world crisis. The team debates the pros and cons and delivers the best solution orally and in writing to a panel of adults.
- **Systems Control Technology/Hardware Robotics** — Students research a real-world need that can be filled by automation to improve manufacturing, monitoring or productivity. Students present the source code, inspiration, marketing plan and documentation in a notebook and orally in a demonstration to a panel.

## Ready to Compete

Students are excited about the STEM classes, because they find ownership and identity in the collaboration and academic competitions. BMMS students compete alongside students from high schools as well as middle grades schools in district, regional, state and national STEM competitions each year.

Students at BMMS have represented the community well, earning a top position in STEM among all middle grades schools in Alabama. Recognitions include:

- American Cancer Society Spirit of Service Gold Level Award for Relay for Life fundraising, 2012
- Alabama Council for Technology in Education, state finalist, 2007-2012
- Alabama Technology Student Association State Leadership Conference, Most Outstanding Chapter, 2010, 2011, 2012; Student of the Year, 2011, 2012
- Alabama Technology Student Association State Leadership Conference, runner-up, 2009
- Outstanding Poster in the Education and Information Technology Digital Library, sponsored by the Association for the Advancement of Computing in Education, 2012
- Southwest Alabama Regional Technology Fair, Middle Level Champions, 2010, 2011 and 2012
- Technology Student Association Alabama, Chapter Excellence, 2011
- Technology Student Association National Leadership Conference, two national champions, 10 national finalists, 2012; 13 national finalists, 2011; 10 national finalists, 2010
- Technology Student Association State Superlative Membership Award, 2011

BMMS students who win competitions wear their medallions to school for two to three weeks. They also enjoy wearing the formal attire required by the Technology Student Association at leadership conferences.

## Support for the Program

The majority of classes have no official curriculum for the STEM block. Teachers develop the units and students raise money for needed resources. The students recruit local organizations and hold fund-raising events to underwrite STEM activities. Community stakeholders assist the students by donating materials. Parents, skeptical at first, are now supportive by assisting students and teachers in conducting fundraisers.

English/language arts (ELA) teachers as well as other teachers support the STEM program in a number of ways. BMMS participates in the Literacy Design Collaborative. As a result, teachers use prompts to get students to read, research and write about what they are learning in the STEM program.

For example, teachers provide authentic learning by allowing students to write about projects such as gliders, dragsters and robots. This practice encourages students to exert more effort while talking and writing about the subjects of greatest interest to them. Also, teachers collaborate with students to monitor and give feedback on competitive speeches, science reports, graphic arts, marketing and technical writing projects.

ELA teachers frequently use STEM projects as “carrots on a stick” for motivating students to complete classwork. “If you will do your literary prompts on time, you can leave your ELA class to build your boat,” one teacher promised. Another student

resisted keeping a journal for ELA until he realized that doing the journal would allow him to work on his STEM project.

Students who may have struggled in the past and were unable to participate in STEM projects are now working harder. Students often exert more effort in special education classes or extra-help sessions so they can go to the STEM block to do their competition work.

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## Students in Grade Seven Combine Literacy and the Physics of Race Car Driving

**H**allie Booth, science teacher at **Holmes Middle School** in Covington, Kentucky, wanted to create an assignment that would engage students in her seventh-grade classroom in reading and writing about science content. The answer was to design a variety of mini-lessons to visualize the overall concepts of motion, force and energy.

Booth decided to use the Literacy Design Collaborative (LDC) Task 2 for argumentation/analysis as the basis for the lessons and to focus on the dynamic sport of NASCAR auto racing:

*Should NASCAR’s drivers be mandated to follow proposed safety guidelines at all races? After reading the articles “Automobile Safety Regulation and the Incentive to Drive Recklessly: Evidence from NASCAR,” “Scientist delves into basic laws of physics in NASCAR,” and “NASCAR Safety Evolves: The number one rule of NASCAR is safety for fans, drivers and crew,” watching the video from Diandra Leslie-Pelecky on the science of NASCAR and listening to a presentation by a safety team from the Kentucky Speedway, write a proposal discussing NASCAR driver safety that addresses the questions, and support your position with evidence from the texts. L2: Be sure to acknowledge competing views. L3: Give examples from past or current events or issues to illustrate and clarify your position. Be sure to support your position with evidence from the texts.*

Booth first identified the science content — motion, force and energy — she wanted her students to explore deeply and then set out to engage students in enjoying, learning and participating in a rigorous topic.

When students first read the task, they responded all over the map: “What is NASCAR?” “I don’t know anything about it.” “It’s a boy thing.” “Why should I care?” “This is dumb.”

Booth began by giving the students an overview of the unit, the vocabulary involved and the steps to be taken in completing the task. It was the first time she had assigned an LDC task and the first time the students had tackled a rigorous reading and writing task. “I knew if the students failed miserably on the first try, the next task would be an uphill battle,” Booth said. “I also knew if students were successful on the first attempt, they would buy into more rigorous assignments in the future.”

The NASCAR assignment included mini-lessons to engage students in the task, analyze the task, scaffold the reading process, transition to writing and structure the writing process. Booth built checks for understanding into the lessons so that she could reteach the material if students failed to understand fully. She also used quick quizzes on concepts and vocabulary, quick responses, and written explanations of the concepts entered by students into their science notebooks.

“As students worked on the reading, they realized that if they took good notes, it would be easier to write the paper, more enjoyable to read the content and easier to explain in writing how specific design changes affect a race car’s overall performance,” Booth said.

Students particularly enjoyed a presentation on NASCAR safety by a crew from the Kentucky Speedway. “As students listened to the presentation, they took notes using a guided guest speaker sheet and were able to ask questions and clarify any conflicting points based on the articles they had been reading,” Booth said.



“As students worked on the reading, they realized that if they took good notes, it would be easier to write the paper, more enjoyable to read the content and easier to explain in writing how specific design changes affect a race car’s overall performance.”

**Hallie Booth,** Holmes Middle School

The students succeeded in mastering this rigorous task because they had an opportunity to tackle a difficult assignment, received the tools to master the task and were given time to practice their reading, writing and thinking skills.

“I am sold on the LDC modules and process,” Booth said. “I have personally seen students produce rigorous writing pieces with ease and confidence even though they had been apprehensive and had struggled with writing in the past. Now that the students have experienced success, they will be able to follow the process in completing other tasks in their academic, career and technical lives.”

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## **The Preparation for Tomorrow Initiative Develops STEM-Based Career/Technical Programs of Study That Align With a College-Ready Core and Promote Common Planning Among Counselors and Academic Teachers**

### **A Different Concept of Rigor: States Develop Career Pathway Courses That Challenge Students**

**T**he evidence is mounting that the United States needs to redesign its current career/technical (CT) programs to prepare students for an increasingly demanding work-place.

Business and industry need workers with STEM (science, technology, engineering and mathematics) competencies; analytical skills for finding “nuggets of truth” in data to explain to decision-makers in education, health and business; and problem-solving skills to handle dilemmas encountered on the job. The Deloitte Consulting and Manufacturing Institute has identified lack of problem-solving skills as the number one deficiency of today’s workers.

According to the Southern Regional Education Board (SREB) Senior Vice President **Gene Bottoms**, the Organization for Economic Cooperation and Development (OECD) lists the United States as the only G-20 OECD member with incoming employees less educated than those retiring.

### **New CT Programs**

SREB’s *Preparation for Tomorrow (PFT)* initiative is designed to develop new CT programs to equip students for postsecondary education and careers. Eleven states have joined SREB in a consortium to develop more rigorous, high-quality high school CT courses. Each course will feature authentic career-related projects that will require students to use academic knowledge and skills from the Common Core State Standards (CCSS) and other rigorous standards.

After meeting with representatives of business, industry, economic development and education, state leaders chose the following career areas:

**Alabama:** *Aerospace Engineering*

**Arkansas:** *Innovations in Science and Technology*

**Georgia:** *Advanced Manufacturing*

**Kansas:** *STEM Education and Training*

**Kentucky:** *Informatics*

**Nebraska:** *Food and Nutritional Sciences*

**New Jersey:** *Global Logistics and Entrepreneurship*

**North Carolina:** *Project Management*

**Ohio:** *Automated Materials Joining Technologies; Health Informatics*

**South Carolina:** *Clean Energy Technology*

**West Virginia:** *Energy and Power*

Each state has agreed to develop a number of materials and activities in carrying out the *PFT* initiative:

- A non-duplicative sequence of four high school courses aligned with the state’s current and future work force needs
- A syllabus for each course with identified authentic projects requiring students to use academic knowledge and skills aligned with the CCSS
- A fully developed project unit with daily lesson plans, end-of-project exams and a series of skeleton project units for each course to be fully developed after field-testing
- A professional development plan for preparing teachers in a two-week summer teacher training institute
- End-of-course exams for each course to assess academic and technical achievement
- A field test and revision of all materials, including syllabi, project units, exams and training
- A process for each state to receive all of the curriculum products developed by other states

### **SREB’s Commitment**

SREB is committed to assisting states in assessing state policies, designing and providing guides for career-area curriculum protocols, and providing a consultant to co-facilitate development and field-testing of exams for each course.

**Leslie Carson**, *PFT* director, said an authentic project must be large enough to cause students to acquire major technical, academic and personal skills; represent work that is done in the real world; challenge students intellectually; and engage students in interacting and sharing ideas about problems and lessons learned.

Projects must include 1) a **technical prompt** (design, build, analyze, investigate); 2) a **reading and writing prompt** (research or report on history, theory, etc.); 3) a **science prompt** (design and construct a theory of a testable hypothesis); and 4) a **mathematics prompt** (collect, analyze and graphically represent data).

Students will show that they have met the academic and technical standards of a project by producing a written paper and an engineering notebook. They will also demonstrate and explain what they have learned and take a written exam.

Carson continued, “If we are going to realize the vision of graduating 90 percent of high school students ready for college and prepared for entry and upward mobility in a career, we must develop a program of study that interests students who normally are not engaged in traditional, rigorous academic course work. Such students need high school courses that are meaningful, interest- and goal-oriented, and reveal a purpose for learning academic content. When academic relevance is clear for students, they will achieve.”

**Alabama** has more than 100 aerospace engineering companies and four universities with degree programs in aerospace engineering. Representatives joined high school teachers from academic and technical disciplines to choose the state’s *PFT* theme and embarked on course development. The state has field-tested its third and fourth courses. “I’ve never participated in a curriculum process as rigorous as *Preparation for Tomorrow*,” said **Craig Collins**, coordinator of the Career and Technical Student Organization (CTSO) in Alabama.

**Gene Coulson**, executive director of the Office of Career and Technical Innovation at the West Virginia Department of Education, said, “*Preparation for Tomorrow* enabled us to start at zero and begin to develop a curriculum based on West Virginia’s needs.”

Coulson described one authentic project from his state: “National Instruments developed a hand-held device that simulates an electrical power grid,” he said. “The grid attaches to a student’s computer through LabVIEW™ software, which is being used in industry. Students study power usage of a business by turning on lights through the software to register realistic and actual power consumption data. Students then use the data to make decisions about how much energy is needed to run a business.”

“American students need balance in their learning,” Bottoms said. “There has been too much sitting and listening in the classroom. Students need to be doing authentic projects that mean something to them now and in the future. The *Preparation for Tomorrow* initiative will provide standards-based career/technical programs to enrich students’ learning experiences and equip them for the demands of a challenging work environment.”

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## Embedding Rigorous Mathematics and Science Into Career/Technical Programs of Study

**C**areer/technical teachers are seeking better ways to embed mathematics and science standards into instruction. Currently, 11 states are partnering with the Southern Regional Education Board (SREB) in the *Preparation for Tomorrow (PFT)* initiative to design career/technical (CT) courses that teach academic and CT concepts through authentic learning projects.

The first step in the design process is to develop a project idea and an essential question — an open-ended question that invites students to solve a problem in the context of an authentic project. The problem is presented as a student engagement scenario composed of four paragraphs:

1. The first paragraph describes the job role and defines the problem.
2. The second paragraph describes the research to be completed by students before they make plans and begin work on the project.
3. The third paragraph defines the course of action to be completed after students conduct research and develop a design brief or work plan. This paragraph describes the mathematics and science concepts that students will experience.
4. The fourth paragraph describes the final technical report and presentation (oral presentation or business proposal) that students are required to present to an authentic audience.

“In completing a project, students not only research and plan,” said **Leslie Carson**, *PFT* director. “They also participate in instruction that provides the knowledge and skills needed to complete the project. This just-in-time instruction gives students a purpose for learning. It demonstrates that they are learning to solve a problem.”



“Students must have a purpose for learning. Project-based learning provides that opportunity. Once the purpose is understood, learning becomes a matter of applying — not simply absorbing.”

**Bob Moore**, SREB

**Mathematics** — In most cases, students will need to acquire and/or reinforce certain mathematics skills to complete a project. *Preparation for Tomorrow* uses the National Research Council for Career and Technical Education’s (NRCCTE) *Mathematics in CTE* formative assessment approach. This seven-step process involves 1) identifying mathematics in the project and introducing students to the mathematics lesson; 2) pre-assessment and feedback questions; 3) collaborative learning working through contextual problems; 4) holding plenary discussions — working through related contextual problems; 5) improving individual solutions to the assessment task; 6) applying what has been learned; and 7) assessment and accountability.

“Students are given a contextual problem, which serves as a pre-lesson assessment, with no preparation,” SREB consultant **Kenna Barger** said. “The teacher evaluates the students’ work and writes feedback questions designed to help students improve their solutions.”

Students then participate in solving a contextual problem followed by a whole-class discussion. After students have reviewed and improved their work, they participate in a general discussion based on the teacher’s observations of student difficulties. Additional practice may be needed. The feedback questions are given to students for use in improving their original work. From there, students apply what they have learned and should be prepared for items on the end-of-project assessment.

**Science** — This instruction includes learning the process of science and knowing science content. It involves using the technology design standard from the 1996 National Science Education Standards of the National Research Council. The five elements of this standard are 1) identifying a problem or designing an opportunity; 2) proposing, designing and choosing between alternate solutions; 3) implementing a proposed solution; 4) evaluating the solution and its consequences; and 5) communicating the problem, process and solution.

“Students must have a purpose for learning,” SREB consultant **Bob Moore** said. “Project-based learning provides that opportunity. Once the purpose is understood, learning becomes a matter of applying — not simply absorbing.”

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## States Develop Challenging Career/Technical Courses With Solid Academic Content

**A**s one of 11 states in the *Preparation for Tomorrow (PFT)* initiative with SREB, South Carolina is moving forward with its course preparation and field testing. The state has chosen Clean Energy Technology as its theme and is developing a four-course sequence that includes foundational courses on energy systems and energy applications for students in grades nine and 10 and advanced courses on advanced energy applications and energy research and development for juniors and seniors.

The purpose of *PFT* is to develop intellectually demanding career/technical (CT) courses for high-demand, high-skill, high-wage career fields with a college-ready academic core and a pathway/program of study.

Each state has agreed to develop curricula, assessments, instructional materials and teacher/counselor training that will provide more students with relevant and challenging CT courses. The curricula will be available to states outside the *PFT* consortium within three years.

“The knowledge that students bring to school today far exceeds the knowledge of previous students,” said **Donald Griffith** of the College of Engineering and Computing at the **University of South Carolina** in Columbia. “The technological knowledge of today’s students makes them hungry to apply their understandings to real-world problems.”

The five schools that will field-test the new courses in 2012-2013 also served on a panel of industries and schools that assisted South Carolina in developing the courses. The five schools are **Broome High School, Laurens 55 High School,**

### **Wagener-Salley High School, Anderson 1 and 2 Career and Technology Center and The Center for Advanced Technical Studies.**

The foundational courses are aligned to Algebra I, geometry, physical science, biology, English 9 and English 10. The advanced courses are aligned to Algebra II, trigonometry, pre-calculus, calculus, chemistry, anatomy/physiology, English 11 and English 12.

Course 1 on energy systems will involve students in studying motors and generators, portable power, a 100W solar panel, a passive water heater, a PV drip irrigation system and geothermal power. Course 2 on energy applications will focus on methane generation, microbial fuel cells, biodiesel, food versus fuel, crock pot yogurt, and H2 or batteries.

Using motors and generators from the first course as an example, a physical science teacher will work with CT students to design, build and test an electric motor to demonstrate the concepts of magnetism, electricity, work, force, speed, distance, current voltage, resistance, power and efficiency. The students will research and create a report of key components and design constraints, prepare isometric sketches of the design, build a functioning direct current (DC) motor from the design, and write a lab report documenting construction, testing and motor/generator correlation.

“Students tell us these are the hardest courses they have ever taken,” Griffith said. “But the courses are the ones they relate to the most.”

The *PFT* initiative is a winning proposition not only for students but for teachers, schools, parents, employers, postsecondary institutions and communities. Students learn knowledge and skills needed to enter and advance in a particular career field. They have an opportunity to work with professionals in the field as they make a connection between what they are studying in high school and what they may want to do in the future. Teachers receive tested curricula and training supported by master teacher mentors. Schools can count on graduating more students prepared for college, careers and advanced training. Parents participate in helping students choose and pursue

programs of study leading to educational and career goals. Postsecondary institutions enroll more students prepared for college-level work and more students likely to complete their studies and graduate with a career goal in mind. Employers will have employees able to read and comprehend complex materials, use mathematics to solve real problems and understand the application of science in the real world. Communities will see higher graduation rates and fewer dropouts.

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## Physics Students Test Two New Energy and Power Projects in the *Preparation for Tomorrow* Initiative

**Kelly Wolf** and 22 honors physics students at **Jefferson High School** (JHS) in Shenandoah Junction, West Virginia, have contributed to the success of the *Preparation for Tomorrow* (*PFT*) initiative by completing two rigorous hands-on projects to be included in the state's four new *PFT* courses. The students found the experience to be enjoyable, practical, challenging and engaging.



**“I enjoyed assembling the pipeline and wiring the flow meters.” “The project challenged our problem-solving abilities.”**

**Students, Jefferson High School**

Each of the 11 states working with SREB on the *PFT* initiative is developing four intellectually demanding, project-based career/technical (CT) courses based on STEM (science, technology, engineering and mathematics) and containing high-level academic content. The courses align with the economic needs and interests of each state. For example, West Virginia chose Energy and Power as its focus.

Before two completed courses would be piloted in three West Virginia schools in 2012-2013, the West Virginia Department of Education asked Wolf and her students to classroom-test two projects in the first course. The JHS teacher selected Cooling (Heat Exchanger) and Pipeline Design as projects for her students to complete in April and May, 2012.

Earlier in the year, Wolf received training to become familiar with LabVIEW™ computer software, ordered supplies and received training on the individual projects. “The development of these projects was done by writing teams that included science, mathematics, English/language arts and electrical technology teachers,” Wolf said. “Engineers from American Electric Power were also involved to make sure the projects are authentic.” The concepts of each project are aligned with Common Core State Standards (CCSS).

**Pipeline Design Project:** For students interested in the career areas of energy, power and engineered systems, this project aims to answer an essential question: “Why are pipelines essential for fueling our country?” It also addresses the issue of how to increase the efficiency of pipeline systems.

Putting themselves in the role of a mechanical engineer working for an oil company, the students designed, built and tested a model. “They used flow meters to monitor the flow rate at the beginning and end of the streamline to determine losses in the system,” Wolf said. “The object was to determine the most efficient configuration for the pipeline and the loss within the pipe.”

Students praised the technical content of the project. “I enjoyed assembling the pipeline and wiring the flow meters;” “The project challenged our problem-solving abilities;” and “There were so many problems with construction that had to be fixed,” were among the comments made.

**Heat Exchange (Plant Cooling) Project:** The career areas for this project are energy, power and engineered systems. The essential question to be answered is: “Why are simple heat transfer methods (convection, conduction and radiation) essential to power plant sustainability and efficiency? In other words, how do we remove unwanted heat? ”

Posing as an engineering technician in a small power plant, the students addressed the problem of using service water from a local lake to cool vital plant systems and equipment. The project called for students to research heat transfer and heat exchangers, design an efficient heat exchanger system for the plant's service water discharge, and build and test a model. The students documented results from computer model/testing of the system, calculated the heat transfer equation from the computer testing model and recommended ways to increase the efficiency of the system.

“The Heat Exchange Project combined aspects of science, mathematics and English/language arts,” Wolf said.

Students praised the technical content of the project and were enthusiastic with feedback. “The project required you to be technologically savvy as you figured out ways to rewire devices and manipulate computer settings,” one student said.

The JHS students learned by doing and reflecting on what they had done. For both the cooling and the pipeline projects, they found problems with some of the equipment and had to redesign the equipment to complete the project. In one case, they had to change to different sensors interfaced with computer software to obtain relevant readings.

“The bottom line is that students learned a great deal from the projects and the associated trouble shooting,” Wolf said. “Many students volunteered time to work on the projects during lunch and after school — which testifies to their level of interest and engagement.”

Two more *PFT* courses will be developed in 2012-2013 with support from energy companies and the West Virginia University College of Engineering. All four courses will be available to schools in 2013-2014.

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## Engage High School and Technology Center Students Intellectually and Emotionally in STEM-Related Career/Technical Pathways Through the Development of Authentic Projects

### STEM- and Project-Based Learning: Students Create Engaging Projects That Work

**T**he **Buck Institute for Education** (BIE) in Novato, California, is dedicated to improving teaching and learning by creating and disseminating products, practices and knowledge for effective project-based learning (PBL). “Schools using PBL show a high increase in student engagement, improved problem-solving skills, and effective collaboration and communication skills,” said **John Larmer**, director of product development at BIE.

Larmer emphasized the importance of including the Eight Essential Elements for PBL in projects designed by teachers or others to encourage students to become actively involved in learning. They are:

- Significant content
- 21st-century skills
- A need to know
- A driving question
- Student voice and choice
- In-depth inquiry
- Revision and reflection
- Public audience

Many examples exist of how STEM (science, technology, engineering and mathematics) principles can be taught in the context of PBL. STEM projects are used at **High Tech High School** (HTHS) in San Diego, California, where the philosophy is to emphasize projects in the belief they represent an effective pedagogy for students with varying learning styles and academic experience. The BIE website ([http://www.bie.org/project\\_search](http://www.bie.org/project_search)) contains a number of examples of HTHS science and physics projects.

- **Get Bent** — This project uses three-dimensional geometry, calculus, physics, art and woodworking skills to design, explain and build chairs and lamps and to write a book about the experience. (See [www.jeffrobin.com](http://www.jeffrobin.com) for this and other projects.)
- **Pool Hall Junkies** — Physics and mathematics combine as students create a fully functional small-scale pool table.
- **It’s About Chime** — Students explore the mathematics and physics behind sound waves and wind chimes.
- **Pinhole Photography** — Students use mathematics and science as they learn about the optics involved in cameras and the chemical reactions that occur in taking and developing photos.

The **Wing Project** is a mathematics and engineering project performed by students at **Aviation High School**, an aviation- and aerospace-themed school in Des Moines, Washington. Students work in teams to build, test and rebuild paper wings by using better designs for each revision. (See a video of the project at [http://www.bie.org/videos/video/wing\\_project\\_overview\\_1\\_of\\_2](http://www.bie.org/videos/video/wing_project_overview_1_of_2).)

Larmer gave examples of two driving questions for a STEM-related project: “How do architects use geometry?” and “How can we design a pool that meets specifications and falls within our budget?” Larmer said the first question is too broad and is not engaging for students. “The second question is better because it focuses on a specific challenge and contains parameters that will require critical thinking,” he said. This project involved geometry students in designing a swimming pool with exact dimensions and a cost analysis. “Since the school was planning to build a new pool, the project was very authentic,” Larmer said. “The students presented their ideas to the school board.”



The BIE website contains summaries of research on the effectiveness of PBL. The National Middle School Association reported in 2010 that PBL is consistent with the association’s framework for more effective schooling: Students and teachers are engaged in active learning; PBL has a curriculum that is relevant, challenging, integrative and exploratory; multiple learning and teaching approaches respond to student diversity; and assessment and evaluation programs promote quality learning.

“The process students use in a good STEM project is the same one used by real-world professionals,” Larmer said. “PBL teaches not only content but skills students will need the rest of their lives.”

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## School Takes Action to Raise Mathematics Achievement Across the Curriculum

**R**ocky Torres, mathematics teacher leader at **Farmington High School** (FHS) in Farmington, New Mexico, recognized the need for schoolwide action to raise mathematics achievement. FHS enrolls more than 1,300 students. The demographics are 38 percent white, 36 percent Native American, 24 percent Hispanic and 2 percent “other.”

The first step was to gather research on mathematics literacy. In doing so, Torres found a wealth of information to support his belief in the power of mathematics to make a difference in someone’s life.

*“Mathematical literacy implies that a person is able to reason, analyze, formulate and solve problems in a real-world setting. Mathematically literate individuals are informed citizens and intelligent consumers. They have the ability to interpret and analyze the vast amount of information they are inundated with daily in newspapers, on television and on the Internet.” (Martin 2007)*

What the student should be doing	What the teacher should be doing
Actively engaging in the learning process	Choosing “good” problems — ones that invite exploration of an important mathematical concept and allow students to solidify and extend their knowledge
Listening and reacting to others’ thinking and solutions to problems	Assessing students’ understandings by listening to discussions and asking students to justify their responses
Using a variety of representations, such as pictures, tables, graphs and words for their mathematical thinking	Challenging students to think more deeply about the problems they are solving and to make connections with other ideas within mathematics
Communicating their mathematical thinking orally and in writing	Creating a variety of opportunities, such as group work and class discussions, for students to communicate mathematically
Building new mathematical knowledge through problem solving	Modeling appropriate mathematical language and a disposition for solving challenging mathematics problems

A.J. Mirra 2003

After completing the research, Torres and the numeracy team wrote an objective: “to implement numeracy across the curriculum not only to build students’ content knowledge but also to provide teachers with the support and means to demonstrate the application of mathematics skills in a variety of contexts.” Ultimately, these skills will deepen students’ understandings of all curricula involved as they make connections between them.

“It was important to monitor growth in our efforts, so we developed a pre-test that was given to all students on campus on a day early in the year via LimeSurvey.org during advisement period,” Torres said. Students averaged only 51 percent on the pre-test. “This is an average percentage of correct answers on the numeracy test using the spreadsheet produced by LimeSurvey,” Torres said.

The school's AYP mathematics scores showed that 9.5 percent of students were in the beginning steps; 41.1 percent were nearing proficiency; 40.8 percent were Proficient; and 8.2 percent were Advanced. The remaining fraction represents students whose tests were exempted for a variety of reasons such as not tested, absent or voided tests.

"The results of these assessments indicated a significant lack of understanding of mathematics concepts," Torres said. Tables, charts and graphs proved to be particular areas of weakness.

"We decided that the most manageable way to address numeracy across the curriculum was through tables, charts and graphs, since they are applicable to all disciplines," Torres said. As a result, teachers across the curriculum participated in professional development on how to use tables, charts and graphs in all content areas.

The numeracy team presented its proposal to the FHS staff at a meeting early in the 2011-2012 school year. The team developed lessons to be taught by all teachers during advisory every other Tuesday. In weeks when a lesson was not prescribed, teachers agreed to use a table, chart or graph in a lesson and submit a copy of student work to an evaluator to show numeracy activity in the classroom. "Teachers used *USA Today*, Google and FHS mathematics teachers as resources for the tables, charts and graphs," Torres said.

"The school experienced a 12 percentage-point growth in achievement between the pre-test and the post-test," Torres said. "This was encouraging for the first year and gave the team a starting point for the second year."

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