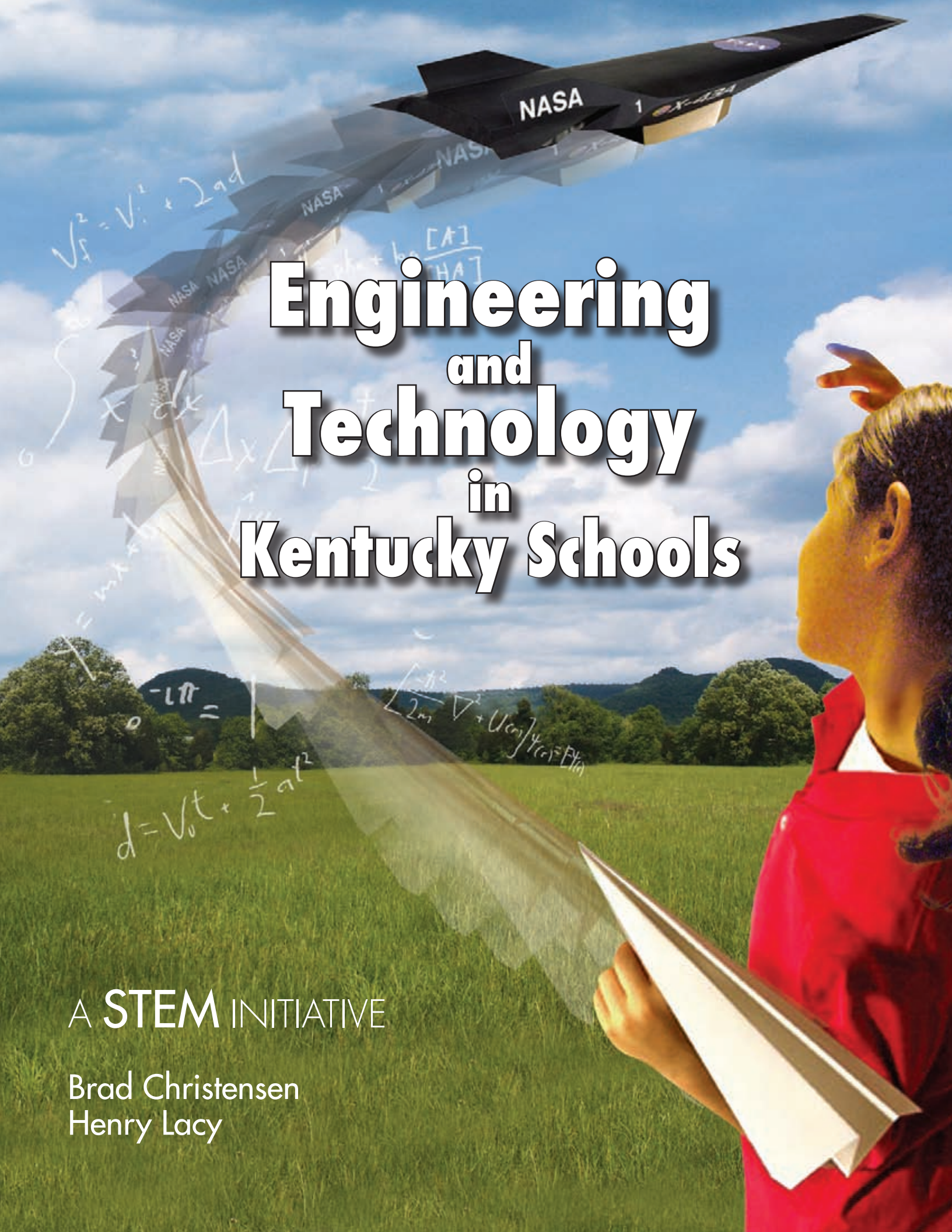
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Engineering
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in
Kentucky Schools
A STEM INITIATIVE
Brad Christensen
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This project is the result of many hours work by several people. The project directors wish to recognize and thank the following individuals for their contributions.

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A complete bibliography for the factual information contained herein may be found in The Engineering and Technology Program of Studies document.

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Introduction

We live in a world of rapidly advancing technological developments. It seems that every day we are presented with some new technological device or method. Learning new software or how to operate new equipment has become a common expectation at the workplace and at home. Although we may not always understand how "Software 3.1" is better than the "3.0" we had learned last month, we attend the training and adjust to the new systems without much complaint. The rate of change appears to be increasing without limit. Imagine the world our current elementary students will see upon graduation! With the proper exposure, instruction, and experiences, they will not struggle with change nearly as much as the previous generation.

Where does all of this new "stuff" come from and why do we keep making more and more of it? Is the "new" really better than the "old?" What effect does of all of this technology have on our environment? What about changes to our society caused by technology? Sometimes technology can create problems, such as privacy issues or controversial medical procedures. Is it worth the trouble? Can technology be controlled? While these questions are critical to our continued development as a technological society, they are usually not discussed until after implementation.

The process of making new technology is called "Engineering." The artifacts created, such as computers, automobile engines, medications, etc., are called "Technology". To prepare the next generation for the world they will inherit, schools must address the issues of the process, use, and impacts of the products.

The Engineering and Technology program in Kentucky schools is carefully designed to provide skills and address issues connected to living in our technologically dependent society. As students gain an understanding of the basic principles of technology and its applications, the man-made world becomes much less mysterious and much less frightening. As students discuss the evolution of technology and explore the historical impacts of products and processes, they learn how technology can be controlled. Through instruction and lab experiences students will begin to see how they can participate in the creation, use, and control of their future.

But how does the Engineering and Technology program fit into an already full educational system? Since the launch of Sputnik

Imagine the world our current elementary students will see upon graduation!

$$\Delta x \Delta p \geq \frac{h}{2}$$

Photo by Bill Schneider, Kenton County Schools

The Engineering and Technology program in Kentucky schools is carefully designed to provide skills and address issues connected to living in our technologically dependent society.

in the early 1950s, society has demanded that students take more mathematics and science classes with greater rigor. The intent of this instruction is that doing so will produce more engineers, which will allow the United States to lead the world in technology. Over the past 15 years, however, there has been a significant decline in the number of students pursuing degrees in engineering.

In order to remain competitive in a technological world, experts predict the United States will have to graduate nearly 100,000 new engineers per year for the next decade. This is about 40,000 per year more than the current number. To make matters worse, over half of the engineers graduating with advanced degrees from US universities are not from the United States. Although some seek positions here, most return to their native country upon graduation taking their knowledge and skills with them.

Over the past few years, the challenges to American leadership in the area of engineering and technology have become apparent. The National Science Board, the Committee on Science, Engineering, and Public Policy, the National Governor's Association, and many others, have all responded with urgent calls to make STEM (science, technology, engineering, and mathematics) instruction a top priority. STEM instruction, however, is nothing new.

In the 1880s, as Dr. Calvin Woodward taught engineering at Washington University, he noticed that his students were unable to apply theory to practice. Also, since they were unable to use tools effectively, they did not fully understand how to solve design and manufacturing

Photo by Bill Schneider, Kenton County Schools

problems. He realized that math and science alone was insufficient. Dr. Woodward coordinated instruction in the math and sciences with practical application as students designed and built projects. He called this interdisciplinary instruction method "Manual Training." We know it as "shop class."

Over the decades, shop class took on many different forms. In nearly all schools across the nation it became vocational training with the goal of preparing students for specific jobs in local industries. By the 1960s the most common shop class was "Woodworking" where students spent a semester or more hand crafting a beautiful piece of furniture. Although this was valuable experience for many students, it was not consistent with the original intent. Dr. Woodward and other leaders in education saw the value of using tools to apply mathematical and scientific principles. This concept has now been revived with the nation-wide call for STEM education.

…leaders in education saw the value of using tools to apply mathematical and scientific principles.

Leaders from education, industry, and government in Kentucky responded quickly to the recommendations from the national committees. In 2006, the Council for Post Secondary Education formed the Task Force for STEM Education. In their final report, the task force outlined several recommendations for improving Kentucky's ability to compete in a global economy. One of these recommendations is to "Revolutionize how STEM subjects are taught, learned, and assessed and implement a statewide research-based STEM curriculum that is aligned with global workforce and academic standards." The Engineering and Technology program at your school is a major component of the STEM Imperative instruction. It is a state-wide, research-based curriculum aligned with global workforce and academic standards. It is also revolutionary in its scope, content, and pedagogy.

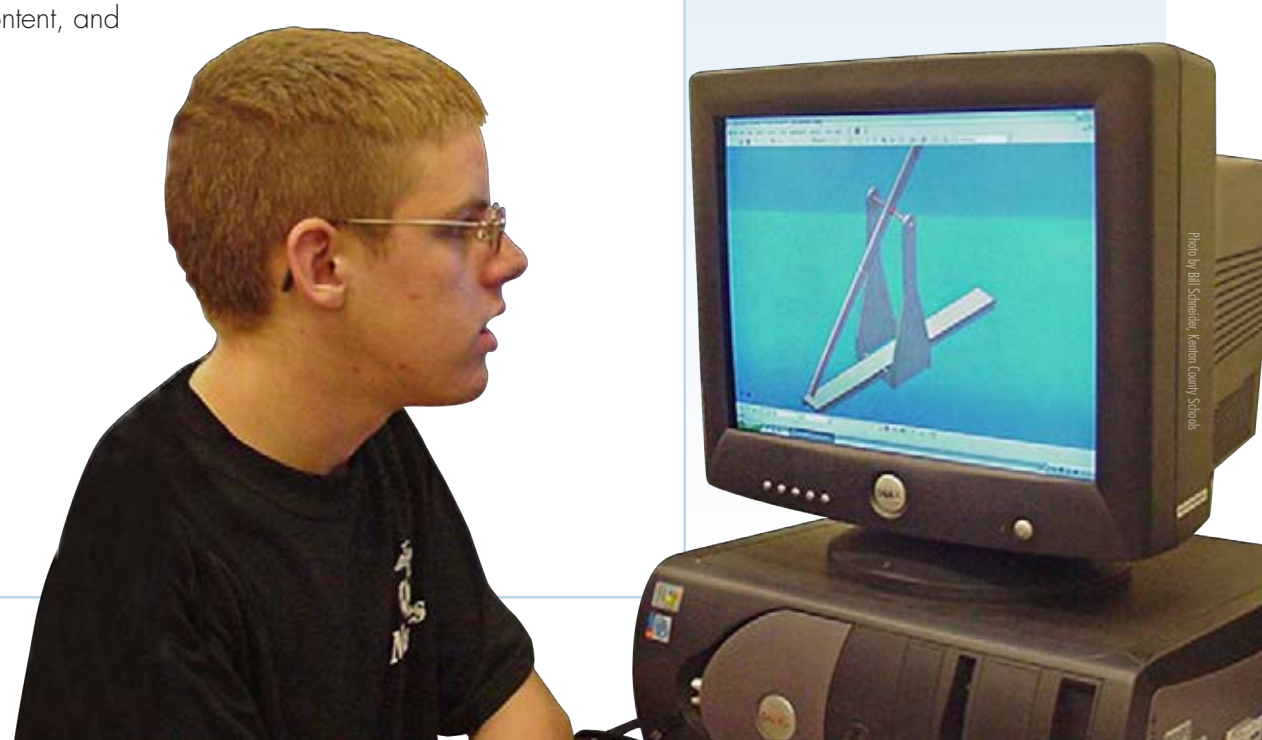

Photo by Bill Schneider, Kenton County Schools

The content of Engineering and Technology is defined by a set of internationally recognized standards.

The Content of the Engineering and Technology Discipline

Every academic discipline exists because of its distinct content. Most of us could explain what is taught in mathematics, or social studies, or language arts. We may struggle a bit, however, if asked to explain the content of Engineering and Technology. Yes, the Engineering and Technology program includes the application of many of the concepts taught in other courses, but also has its own distinct content. There are concepts taught in the Engineering and Technology discipline that are not addressed anywhere else.

The content of Engineering and Technology is defined by a set of internationally recognized standards. These twenty standards are identified as the **Standards for Technological Literacy (STL).** They were developed through several years of collaboration of many professionals in engineering, industry, and educational fields.

Standards for Technology Literacy

Students will develop an understanding of The Nature of Technology

This includes acquiring knowledge of:

1. The characteristics and scope of technology
2. The core concepts of technology
3. The relationships among technologies and the connections between technology and other fields

Students will develop an understanding of Technology and Society

This includes learning about:

4. The cultural, social, economic and political effects of technology
5. The effects of technology on the environment
6. The role of society in the development and use of technology
7. The influence of technology on history

Students will develop an understanding of ***Design***

This includes knowing about:

8 Attributes of design

9 Engineering design

10 The role of troubleshooting, research and development, invention and innovation and experimentation in problem solving

Students will develop ***Abilities for a Technological World***

This includes becoming able to:

11 Apply the design process

12 Use and maintain technological products and systems

13 Assess the impact of products and systems

Students will develop an understanding of ***The Designed World***

This includes selecting and using:

14 Medical technologies

15 Agricultural and related biotechnologies

16 Energy and power technologies

17 Information and communication technologies

18 Transportation technologies

19 Manufacturing technologies

20 Construction technologies

"Revolutionize how STEM subjects are taught, learned, and assessed and implement a statewide research-based STEM curriculum that is aligned with global workforce and academic standards."

Final Report of STEM Task Force, March 2007

Photo by Ginger Gardiner, Marion County High School

The learning becomes more interesting because it is more useful and applicable to the student's world.

Each of the standards includes benchmarks that indicate specifically what a student should know or be able to do at various grade levels (grades K-2, grades 3-5, middle school, and high school).

The Standards for Technological Literacy and the accompanying benchmarks have been translated into specific curricula. Many professional engineering organizations, such as the National Science Foundation and NASA have developed instructional materials available for use by the Engineering and Technology teacher. These materials are well written, well tested, and proven effective for instruction. Curricula for Engineering and Technology courses in Kentucky are based primarily on the Engineering by Design program developed by the International Technology Education Association and on the international *Project Lead the Way* curriculum program.

Engineering and Technology Program Levels

Elementary Focus

Even to the most casual observer the curriculum of the elementary school is full to overflowing; much is required of the teachers and students. Engineering and Technology content can appear to be "just one more thing" that must be covered by an already stressed system. Although that view is legitimate it does not have to be true. Elementary students have already experienced their technological world through their mini-van with the DVD player, Mom or Dad talking on the cell phone, computer generated animation of their favorite cartoon character, and through playing their latest video game system. They are well aware that 1 gigabyte is barely enough and that dial-up is way too slow.

The skilled elementary teacher can work with the Engineering and Technology teacher to weave the technological world of the child with the academic expectations of the school accountability program. Technology can be used as the vehicle for learning the required content. For example, instead of reading story problems from a mathematics textbook, the Engineering and Technology teacher can facilitate "real life" situations where students gather and analyze their own data as they design and develop products. The learning becomes more interesting because it is more useful and applicable to the student's world.

In other classes, primary students may design and build habitats

to address the needs of a nomadic person or create signs that direct people to various parts of a building. At the intermediate level, students may design and develop an efficient transportation system for a given rural or urban site as part of a social studies unit.

Students will learn that engineering and the technology it creates involves problem solving, research and development, invention, innovation, and experimentation relevant to the world around them. They will see the application of important mathematical and scientific concepts. Regardless of the discipline, theme, or unit, students will see the connections between school and "real life."

Some schools are exploring the concept of an "engineering pipeline" that could be particularly effective with hands-on learners interested in how things work. As parents, we identify them as the child who can disassemble the toaster or the lawnmower but might not get their homework finished.

The skilled elementary teacher can work with the Engineering and Technology teacher to weave the technological world of the child with the academic expectations of the school accountability program.

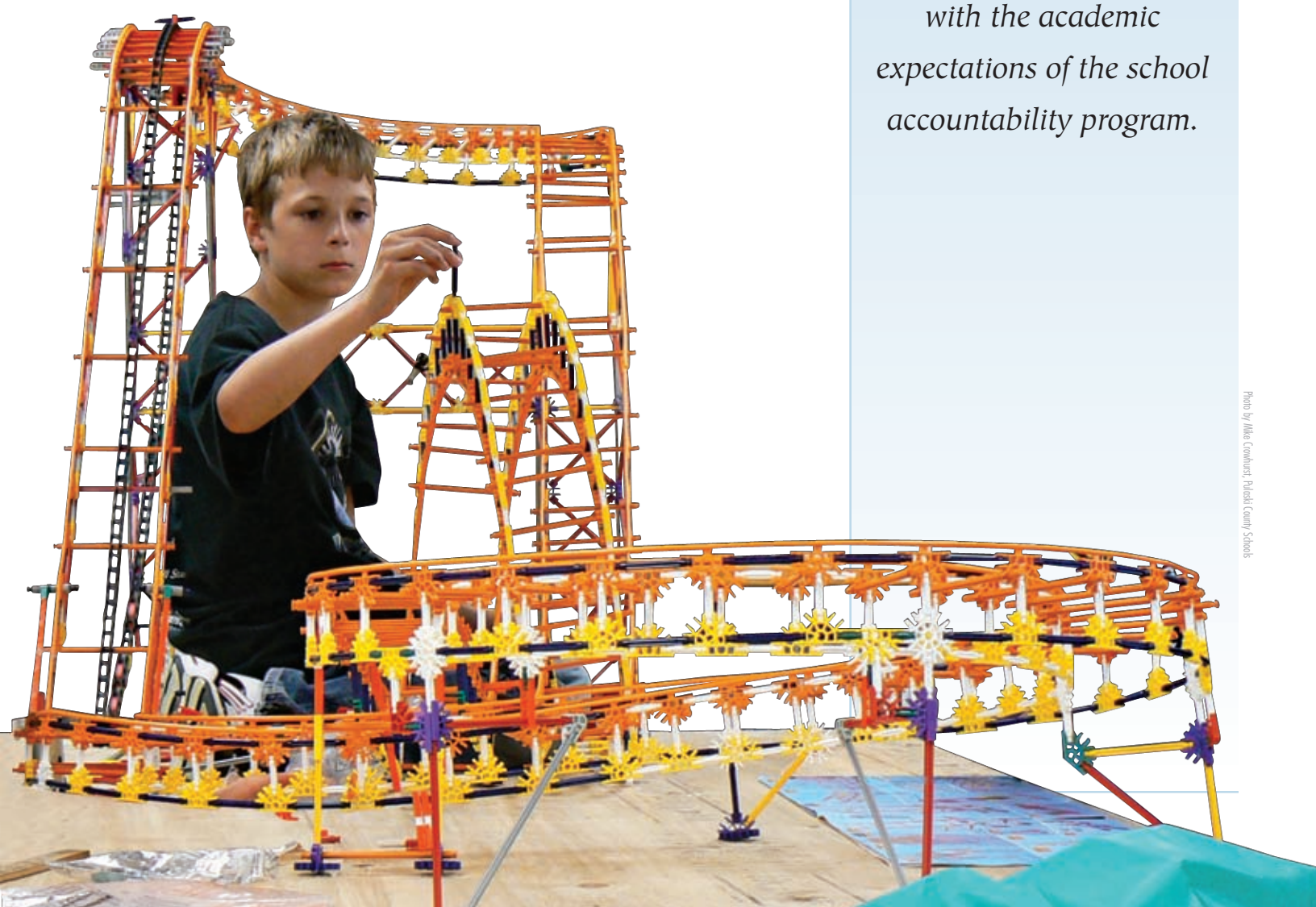

Photo by Mike Crowhurst, Pulaski County Schools

Students should see how technology connects and applies skills from other academic disciplines.

Middle School Focus

Engineering and Technology instruction at the middle school level provides an introduction to technology as a specific field of study. Students should see how technology connects and applies skills from other academic disciplines. Activities and assignments allow students to experience the engineering process as they invent devices to solve various problems. Students learn system requirements, processes and controls as they wrestle with trade-offs due to design constraints. For example, they may be asked to design, build, and test a model boat that has to carry as much load as possible, yet still move through the water as quickly as possible using only a given amount of power. Through a variety of activities, students learn the proper and safe operation of some basic tools as their ideas begin to take shape.

Through the Engineering and Technology program, students begin to understand the forces that drive our technological society and how these forces can be controlled and directed. Instructional approaches vary, including problem solving/design briefs where students build projects, small or large group instruction and discussion, research, student presentations, and other engaging activities.

Many middle schools effectively use team teaching to reinforce and connect learning. Administrators are encouraged to include Engineering and Technology as an equal component of interdisciplinary team teaching. Engineering and Technology at the middle school level should include a Technology Student Association and can incorporate many of the TSA activities within the curriculum.

Middle School	Grade Level			
Course Title	**6**	**7**	**8**	**9**
Exploring Technology	●	●		
Invention and Innovation		●	●	
Technological Systems			●	●
Special Technology Topics	●	●	●	●
Gateway to Engineering	●	●	●	

Middle School Course Descriptions

Exploring Technology

In this course, students are introduced to the study of technology through various projects and other activities. They learn proper use and safety of basic tools as they design and build solutions to problems. They experience the engineering process of how technology is developed and used. Students also begin to understand the scope and nature of technology.

Invention and Innovations

Everything people make and use begins as an idea. Students in this course become familiar with the process of engineering design and how it leads to innovations. Students get first-hand experience in brainstorming, visualizing, modeling, constructing, and testing design ideas. Students will also investigate how commercially produced inventions/innovations impact us on a personal, social, economic, and environmental level. Students will develop skills in communicating design information and reporting results.

Technological Systems

Technology is almost always part of a system. It usually cannot function independently. For example, providing power for our homes, industries, and transportation, includes safe and environmentally conscious coal mining techniques, the careful refining of fuels, and efficient distribution systems. In this course, students explore technological systems; their design, development, and connections with other systems. They create, test, and evaluate systems, such as transportation, information, and biotechnology systems. Students learn that technology is made up of many systems that have positive and negative effects on society.

Special Technology Topics

Special Technology Topics allow the teacher to develop a course for in-depth exploration of technological topics. This course will allow students to gain a more comprehensive knowledge of a particular technology topic or explore specialized technology careers.

…providing power for our homes, industries, and transportation, includes safe and environmentally conscious coal mining techniques, the careful refining of fuels, and efficient distribution systems.

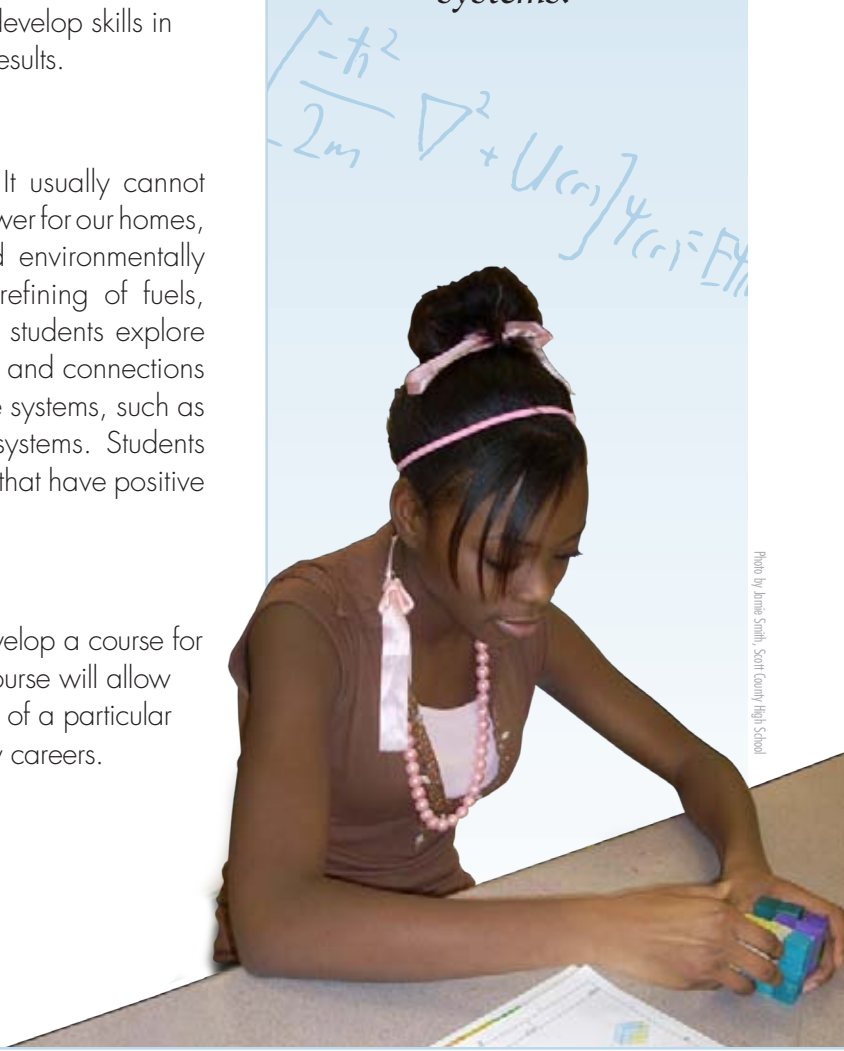

Photo by Jennie Smith, Scott County High School

*The Kentucky Curricular Framework … includes two pathway options; **Engineering** and **Technology**.*

The design, construction, and testing of various projects is critical for successful instruction.

Gateway to Engineering

This course is specifically designed as a preparation for the Engineering Pathway courses at the High School level. The content can be arranged into several units of instruction, allowing this course to be taught multiple times to all middle school grade levels. Each section of this course will address a different aspect of the multiple fields of engineering.

High School Focus

Engineering and Technology at the high school level is a broadbased program addressing many aspects of our technologically dependent society. Through various activities and assignments, students gain knowledge and skills concerning the function and operation of various technological devices. The High School Engineering and Technology program immerses the student in decisions concerning technology, analyzing its the impacts, and assessing various technological issues. These educational goals can be accomplished through a variety of methods such as research and presentations, discussions, and field experiences. The design, construction, and testing of various projects is critical for successful instruction.

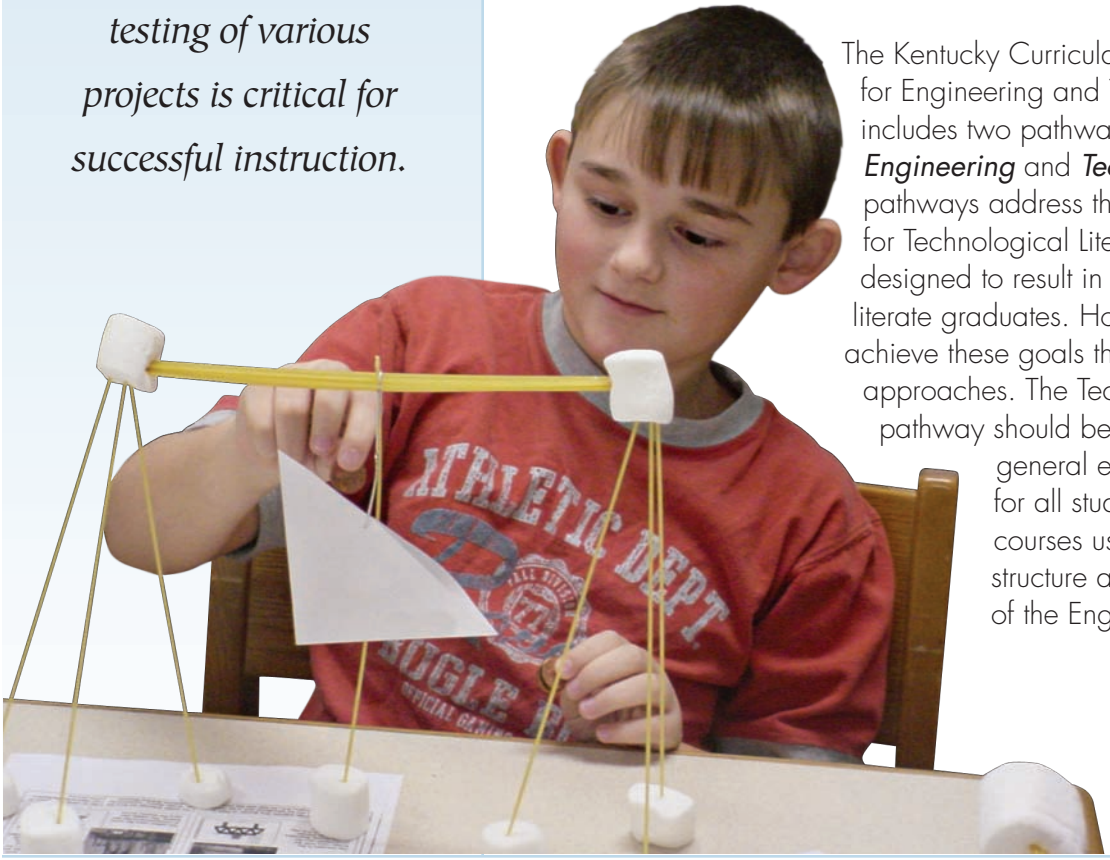

Photo by Mike Crawhurst, Pulaski County Schools

The Kentucky Curricular Framework for Engineering and Technology includes two pathway options; ***Engineering*** and ***Technology***. Both pathways address the Standards for Technological Literacy and are designed to result in technologically literate graduates. However, they achieve these goals through different approaches. The Technology pathway should be considered general education for all students. These courses use the structure and content of the Engineering By

Design curriculum program produced by the Center for the Advancement of Teaching Technology and Science (CATTS) under the leadership of the International Technology Education Association (ITEA).

The Engineering pathway is more specific to those students planning a career as an engineer. It uses course material from the Project Lead the Way program. PLTW is a not for profit corporation that develops and implements pre-engineering courses at the middle and high school levels.

Technology Pathway	Grade Level			
Course Title	**9**	**10**	**11**	**12**
Foundations of Technology	●	●		
Technological Design	●	●	●	
Technological Issues and Impacts		●	●	●
Advanced Design Applications			●	●
Advanced Technological Applications			●	●
Engineering Design (Capstone)				●
Special Problems in Technology	●	●	●	●
Special Technology Topics	●	●	●	●

The Technology pathway should be considered general education for all students.

The Engineering pathway is more specific to those students planning a career as an engineer.

High School Course Descriptions for Technology Pathway

Foundations of Technology

All technological devices operate from the application of basic concepts and processes. Students in this course will learn these concepts as they design products and engineer solutions to problems. They will also learn that technology is fundamental to human existence. They will begin to understand the impacts and issues created by the development and use of technology. Connections between technological devices and concepts in mathematics and science are explored.

…examines how energy and power systems can be made more efficient and how they may be utilized in problem solving.

Technological Design

In this course, students will conduct individual and team design activities. They will be presented various problems dealing with transportation, communication, medical, agricultural, or other technological contexts. Students will apply the technological problem solving process and develop critical thinking skills. These skills are applied in the researching, designing, prototyping, testing, and the modification of product(s).

Technological Issues and Impacts

This course addresses the positive and negative impacts of technology. Students will see that the use of technology often has intended and unintended results. Students will investigate and analyze critical historical and emerging issues affecting the creation, development, use, and control of contemporary and future technology. For example, one assignment might be to research how the use of e-mail has affected the Post Office and what changes may be necessary in the future. Laboratory activities will allow students to propose and implement alternative solutions such as how to design a package to reduce the amount of waste material. Students will measure, quantify, assess, and communicate the impacts of these proposals.

Advanced Design Applications

This course consists of four units of instruction. The ***Manufacturing*** unit examines the advance that maintain manufacturing efficiency, how human consumption affects manufacturing, how manufacturing affects the standard of living of various peoples, and how processing and changing raw materials can produce more desirable products. The ***Construction*** unit examines a number of the factors influencing the design and construction of permanent and semi-permanent structures. The practice related to construction maintenance, alterations, and renovation, and the functions of the primary systems installed in those structures. The ***Energy and Power*** unit explores the relationship between energy and power technologies and all other technologies and how modern energy and power systems impact cultures, societies and the environment. It also offers an examination of how energy and power systems can be made more efficient and how they may be utilized in problem solving. The ***Transportation*** unit examines the complex networks of interconnected subsystems that each transportation system comprises and the roles of these components in the overall functional process of the system. It also analyzes the

improvements and the impacts of transportation technologies on the environment, society, and culture.

Advanced Technological Applications

This course is divided into four units of instruction. The ***Information Technologies*** unit examines how technology facilitates the gathering, manipulation, storage, and transmission of data, and how this data can be used to created useful products. It also provides students with opportunities for developing communication systems that can solve technological problems. The ***Agriculture and Bio-related Technologies*** unit explores how agricultural technologies provide increased crop yields and allow adaptation to changing and harsh environments, enabling the growth of plants and animals for various uses. It also offers an analysis of the various uses of biotechnology and the ethical considerations of those uses. The ***Medical Technologies*** unit provides an analysis of how medical technologies are used to increase the quality and length of human life, and require public debate. Students will also examine tools and devices used to repair and replace organs, prevent disease, and rehabilitate the human body. The ***Entertainment/Recreation*** unit provides a study of technological entertainment and recreation systems, with an examination of the differences between these technologies, of how their use enhances human leisure-time performance and of the social, cultural, and environmental implications of their usage.

Engineering Design

Engineering scope, content, and professional practices are presented through practical applications in this course. Students in engineering teams will apply their knowledge of technology, tools and materials to solve engineering design problems. Students will research, develop, test, and analyze engineering designs using criteria such as design effectiveness, public safety, human factors and ethics. For example, students in this course may be asked to design, build, and test an electric car. Not only would it have to work, but it would have to also be safe, attractive, and affordable.

Photo by Ginger Gardiner, Marion County High School

Special Technology Topics

Special Technology Topics allows the teacher to develop a course for in-depth exploration of

technological topics. This is a laboratory-based course designed to study a technological system or topic, and/or a recent technological advancement. This study should include how this advancement affects society and/or the environment. This course could, and probably should, result in the completion of a large, complex project. It should include research, design, construction, analysis, writing, and presenting.

Special Problems in Technology

This independent-study course is designed to allow a High School student to study in-depth a technology topic or issue. The experience will enable the student to gain a more comprehensive knowledge of a particular technological context. A variety of instructional strategies could be used, including multiple resources, specialized laboratories, and collaboration with mentoring experts. This would be an excellent opportunity for collaboration with local industry experts and engineers. Independent studies and/or internships could be utilized.

…an excellent opportunity for collaboration with local industry experts and engineers.

Engineering Pathway	Grade Level			
Course Title	**9**	**10**	**11**	**12**
Introduction to Engineering Design	●	●	●	●
Principles of Engineering	●	●	●	●
Digital Electronics		●	●	●
Computer Integrated Manufacturing			●	●
Civil Engineering Architecture			●	●
Aerospace Engineering			●	●
Biotechnical Engineering			●	●
Engineering Design and Development (Capstone)				●
Special Topics in Engineering	●	●	●	●

High School Course Descriptions for Engineering Pathway

Introduction to Engineering Design

This course teaches problem-solving skills using a design development process. Models of product solutions are created, analyzed, and communicated using solid modeling computer design software.

Principles of Engineering

This course helps students to understand the field of engineering/ engineering technology. Exploring various technology systems and manufacturing processes help students learn how engineers and technicians use math, science and technology in an engineering problem solving process to benefit people. The course also includes concerns about social and political consequences of technological change.

Digital Electronics

In this course, students will use theory, various laws and formulas, and tools to design and build electronic circuits and devices. Computer simulation software is used to design and test digital circuitry prior to the actual construction of circuits and devices.

Computer Integrated Manufacturing

Students in this course will learn and apply principles of robotics and automation. The course builds on computer solid modeling skills developed in Introduction to Engineering Design, and Design and Drawing for Production. Students use CNC equipment to produce actual models of their three-dimensional designs. Fundamental concepts of robotics used in automated manufacturing, and design analysis are included.

Civil Engineering and Architecture

This course provides an overview of the fields of Civil Engineering and Architecture, while emphasizing the interrelationship and dependence of both fields on each other. Students use state of the art software to solve real world problems and communicate solutions to hands-on projects and activities. This course covers topics such as: The Roles of Civil Engineers and

…includes concerns about social and political consequences of technological change.

Photo by Sara Poeppelman, Lewis County High School

All educational programs in Kentucky schools are required to make provisions to meet the needs of disadvantaged and disabled students.

Photo by Ginger Gardiner, Marion County High School

Architects, Project Planning, Site Planning, Building Design, and Project Documentation and Presentation.

Aerospace Engineering

Through hands-on engineering projects developed with NASA, students learn about aerodynamics, astronautics, space-life sciences, and systems engineering (which includes the study of intelligent vehicles like the Mars rovers Spirit and Opportunity).

Biotechnical Engineering

Students in this course will design and construct relevant projects from the diverse fields of bio-technology, bio-engineering, bio-medical engineering, and bio-molecular engineering. Their experiences will enable them to apply and concurrently develop secondary-level knowledge and skills in biology, physics, technology, and mathematics.

Engineering Design and Development

This is an engineering research course in which students work in teams to research, design and construct a solution to an open-ended engineering problem. Students apply principles developed in the four preceding courses and are guided by a community mentor. They must present progress reports, submit a final written report and defend their solutions to a panel of outside reviewers at the end of the school year.

Special Topics in Engineering

Special Topics in Engineering allows the teacher to develop a course for in-depth exploration of specific engineering topics. This is a laboratory-based course designed to study an engineering challenge, and/or a recent technological advancement. This study should include how this advancement affects society and/or the environment. A culminating project integrating one or more of the contexts of the field of engineering and the Kentucky Core Content is encouraged. It should include research, design, construction, analysis, writing, and presenting. Instruction should be enriched through participation in Kentucky Technology Student Association or other engineering-related organization.

Program Implementation Issues

Accommodating Students with Special Needs

All educational programs in Kentucky schools are required to make provisions to meet the needs of disadvantaged and disabled students. If the nature and severity of the disadvantage or disability is such that the student cannot benefit from program participation, a separate or modified program may be developed. In either case, the program provided shall be consistent with the student's Individualized Education Program Plan (IEP).

Assessment of Student Progress and Program Effectiveness

The Kentucky Department of Education has implemented a State-level assessment of technological literacy. Currently this assessment is administered to all students who have completed two Engineering and Technology courses. The content of this assessment is based on the Kentucky Skill Standards, which include the Standards for Technological Literacy and certain academic and employability requirements.

Conclusion

Engineering and Technology courses develop and enhance students' understanding of how technological systems function and impact society, the environment, and the global economy. Engineering and Technology is activity based and includes topics related to invention, intervention, and innovation. It provides opportunities for students to understand technology's impact on their lives. Engineering and Technology will enable students to better manage and cope with change. Students learn to apply tools, materials, processes and concepts efficiently. In addition, students develop and apply creative problem solving techniques and critical thinking skills as they apply their knowledge of Kentucky Core Content to solve realistic problems. Students will become wise consumers of technology and will also become aware of the multitude of careers involving engineering and technology. Their education in Engineering and Technology will provide knowledge and skills necessary for a productive life in a technologically dependent society, promoting economic strength for Kentucky and the nation.

Their education in Engineering and Technology will provide knowledge and skills necessary for a productive life in a technologically dependent society, promoting economic strength for Kentucky and the nation.

Photo by Ginger Gardiner, Marion County High School