AC 2010-1798: POSTER, NASA-THREADS: A HANDS-ON, CONTEXT BASED APPROACH TO A HIGH SCHOOL STEM COURSE

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Poster, NASA-Threads: a hands-on, context based approach to a high school STEM course

Abstract

NASA-Threads is a hands-on, contextual approach to a high school STEM course. Teachers from three regional high schools and university faculty from STEM disciplines have developed a new, challenging, interdisciplinary junior/senior-level high school physics/pre-engineering curriculum.

NASA-Threads integrates fundamental science and mathematics courses taught with engineering applications and the appropriate use of technology into a physics/pre-engineering curriculum targeting the junior/senior year of high school. The threads of this curriculum include Fundamentals, Technology, Communication, and NASA Applications. The fundamentals, which are grouped into blocks of similar topics, provide the backbone of the educational experience. NASA applications are strategically introduced to provide timely, hands-on reinforcement of fundamentals, and the progressive development of technical knowledge and skills.

The rigorous curriculum is designed to guide students through a systems-level understanding of real-world applications of science and engineering. This project provides a hands-on, contextual approach to student learning, as well as teacher professional development. As part of the curriculum, data is being collected on student outcomes that quantify high school students' academic self-efficacy, real world problem solving, critical thinking skills, achievement in mathematics and the sciences, motivational and goal orientation, and vocational or career interests in STEM fields. Additionally, teacher outcomes, including self-efficacy, are being measured. This poster/paper will present the curriculum developed through the collaborative partnership between K12 schools systems and university.

Introduction

Numerous publications in recent years have expressed concern regarding preparedness of our students to pursue engineering and science degrees (for example, *Rising Above the Gathering Storm*[1], *The Engineer of 2020*[2], and *Educating the Engineer of 2020*[3]). Clearly, there is a well-defined need for increased enrollment in and graduation from university science, technology, engineering, and mathematics programs. Moreover, there is a critical need for partnerships between universities and K12 schools to increase the mathematics and science abilities of high school graduates – preparing them for any career path, particularly in STEM disciplines.

> "Science and mathematics education has truly reached a critical juncture. It is imperative that we find creative ways to improve the delivery of the fundamental math and science our children need in order to be competitive in the emerging global environment." – *Wayne Williams*
> Superintendent, WPSB

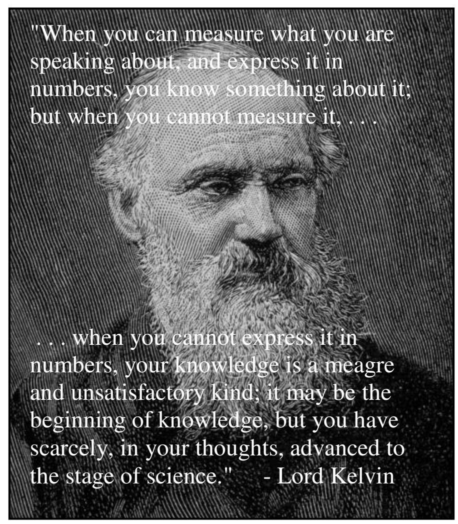
Two high school based curricula currently being used to address these concerns are Project Lead the Way and the Infinity Project. Project Lead the Way (www.pltw.org) has modules for introducing engineering topics to students in both middle and high school. However, high school teachers in our partner schools have indicated to us that they would prefer a more in-depth curriculum that ties together application and content. The Infinity Project (www.infinity-project.org) focuses on digital electronics, allowing for a rigorous approach, but is limited to a very narrow range of topics. Teachers have indicated to us that they like the rigorous nature of the Infinity Project, but would prefer a broader spectrum of topics which seamlessly integrate science, engineering, and mathematics across the curriculum.

"…it is very difficult to add STEM electives. … an approach which integrates STEM content within the core curriculum is significantly more viable than other, electives-based approaches."
- Marvin Nelson, Teacher, Benton High School

Project Description

NASA-Threads provides school systems with a rigorous program that showcases a systems-level understanding of real-world applications of mathematics, science, and engineering. Our previous experience has shown that long-term impact on K12 students comes through close collaborative relationships between teachers and university faculty[4-8]. NASA-Threads provides a hands-on, context-based approach to math and science professional development in preparing teachers to become the educators of the future.

The NASA-Threads curriculum consists of self-contained projects that integrate engineering, mathematics, and physics. These hands-on projects develop student ability to solve more realistic multiple-step problems and bring excitement into the classroom. NASA-Threads integrates NASA Applications, Fundamentals, Technology, and Communication through hands-on projects that are enabled by an inexpensive robotic platform called the Boe-Bot[9]. The Boe-Bot provides the enabling technology for projects such as a lunar rover. In addition to hands-on projects, online content describing current NASA missions showcase STEM applications throughout the curriculum.



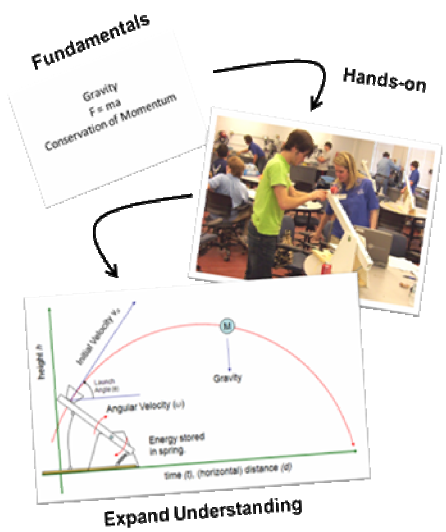
NASA-Threads is a partnership with school systems to design and implement a physics/pre-engineering curriculum patterned after Louisiana Tech University's Integrated Engineering Curriculum (NSF funded – Living *with* the Lab) (LWTL)[10-18]. The Living *with* the Lab curriculum includes a sequence of hands-on courses spanning the freshman year using a multi-course project to provide seamless integration of mathematics, science, and engineering topics. This curriculum consists of several interrelated smaller projects culminating in a complex process control system to maintain temperature and salinity in a container of water. Each of the smaller projects can also be viewed as a self-contained project that integrates engineering, mathematics, chemistry and physics. These projects seamlessly connect a multi-faceted problem which requires the systems-level thinking of integrated STEM professionals. By this approach, students are guided away from single-step problems and develop the ability to solve more realistic multiple-step problems.

NASA-Threads uses this approach, appropriately modified for high school students. In addition to developing technical expertise and self-reliance, this pedagogical approach provides an opportunity to stress the importance of communication skills and broader concerns such as environmental and ethical issues.

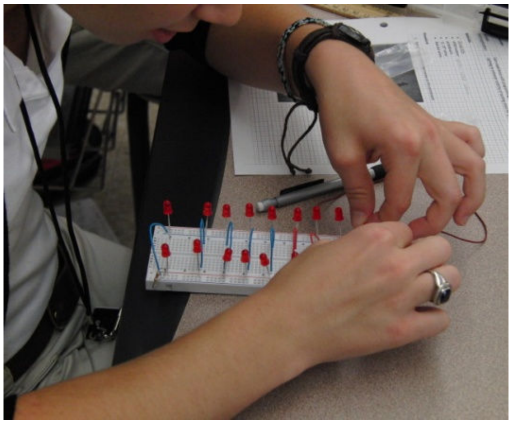
Curriculum

Building on our partnerships with K12 systems in the region, NASA-Threads integrates fundamental science and mathematics content with engineering applications and appropriate use of technology into a physics curriculum targeting the junior/senior year of high school. As mentioned, the threads of this curriculum include Fundamentals, Technology, Communication, and NASA Applications. These threads are continually linked together by the use of hands-on projects throughout the physics curricula. The fundamentals, which are grouped into blocks of similar topics, provide the backbone of the educational experience. NASA applications are strategically introduced to provide timely hands-on reinforcement of fundamentals and the progressive development of technical knowledge and skills.

The curriculum is broken into four main sections: Electricity & Magnetism, Work & Mechanics, Fluids-Waves-Light-Heat, and student projects. At the beginning of a typical high school physics course, the focus is on fundamental topics such as motion and Newton's Laws. NASA-Threads introduces Electricity & Magnetism at the beginning of the curriculum to provide a connection to the Boe-Bot (micro-controller) platform. By using a hands-on platform throughout the curriculum, students are able to work with "real" problems. This project-based approach allows the students to gain an intuition about how to solve problems, and helps them understand the fundamental mathematical equations that emerge in the modeling of physical systems. Additionally, by starting with Electricity & Magnetism students are exposed to measurement and data acquisition of real systems. This provides a background for introducing the idea of energy and power, which is expanded in the Work & Mechanics section. Instead of being exposed to mathematical equations without a context, students experience the application and see the need for the fundamentals.



NASA-Threads creates an educational experience where exciting hands-on projects drive students to learn more and to develop confidence in their abilities. At the same time the authors have recognized and taken great care to be sure that the course materials should not be intimidating or require excessive preparation time for teachers who employ the materials.



Consider the grouping of matter, electricity, and magnetism that is part of NASA-Threads. Atomic structure and the role of electrons in atomic bonding provide an opportunity to discuss electron mobility and mechanisms for the passage of electrons through materials. Electron flow leads to definitions of electrical current, resistance and voltage. As Ohm's law is introduced, students use multimeters to measure voltage and current in simple circuits constructed on the breadboard on their Boe-Bot[9]. Students then build circuits containing LEDs, and they write BASIC computer programs causing the LEDs to blink with specified timings. Students then extend their skills to develop a countdown timer that utilizes a seven-segment LED number display. Fundamentals continue to be taught in this active classroom environment as projects unfold.

As students' intuition for electricity develops, they are introduced to the coupling between electric current and magnetism and build a simple permanent magnet motor. This leads to the introduction of DC electric motors and provides an opportunity to discuss the physics behind the operation of the servo motors that are supplied with the Boe-Bot kit. Student ability to control the servos leads to the implementation of Lunar rovers which are programmed to navigate using dead reckoning programming strategies, providing an opportunity for in-class competitions. These hands-on projects build excitement and foster the development of student confidence and creativity.

While careful planning ensures that this curriculum is not intimidating to teachers, it is important that the curriculum be rigorous and challenging. Additionally, the authors recognize that it must be appropriate for and within the grasp of high school students and must meet local and state education standards. Collaborative partnerships developed with area high schools ensure that all of these conditions are met.

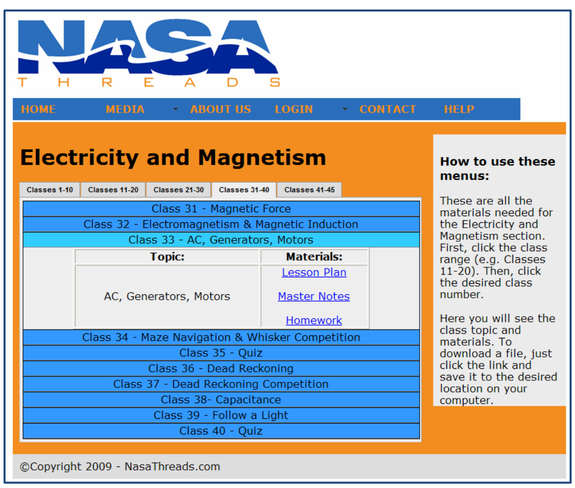
The crucial component of implementing a project-based hands-on curriculum in schools is the teachers. Master teachers for the pilot curriculum were chosen from three schools that have been leaders in Louisiana Tech University's STEM Talent Expansion Program (LaTechSTEP)[19]. These three teachers serve as teaching fellows who work closely with Louisiana Tech engineering and science faculty to develop the physics curriculum. These teaching fellows serve as guides to ensure that the curriculum is challenging but appropriately targeted for upper-level high school students. Furthermore, this project reaches schools which have differing economic and social demographics which is aiding in the development of the robust program that can be implemented in schools regardless of size, location, or economic status of the community.

Demographics

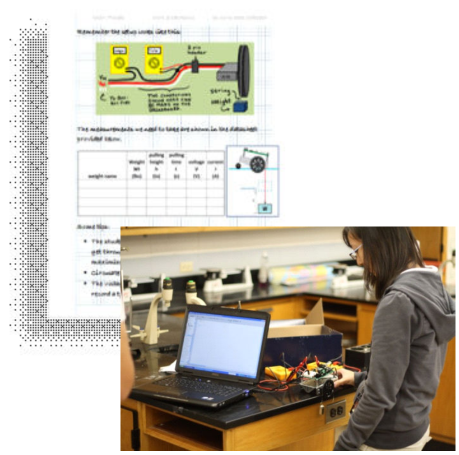
The three key schools involved in the project are Ruston High School (Ruston, Louisiana), Benton High School (Benton, Louisiana), and Lovejoy High School (Allen, Texas). These schools also represent a healthy diversity in terms of student demographics.

- Ruston High School (RHS) is a relatively large High School located in north Louisiana (near Louisiana Tech University). The pilot class at RHS has a total of 18 students (8 Female, and 10 Male). 61% are from under-represented STEM groups. 17 of the students are seniors and 1 student is a junior.
- Benton High School (BHS) is a smaller rural school just north of Benton, Louisiana. The pilot class at BHS has a total of 14 students (3 Female, and 11 Male). 29% are from under-represented STEM groups. 8 students are seniors, 1 student is a junior, 3 students are sophomores, and 2 students are freshman.
- Lovejoy High School (LHS) is located in the north Dallas metroplex. The pilot class at LHS has a total of 35 students (1 Female, and 34 Male). 6% are from under-represented STEM groups. 9 students are seniors, 12 students are juniors, 12 students are sophomores, and 2 students are freshman.

Curriculum Samples

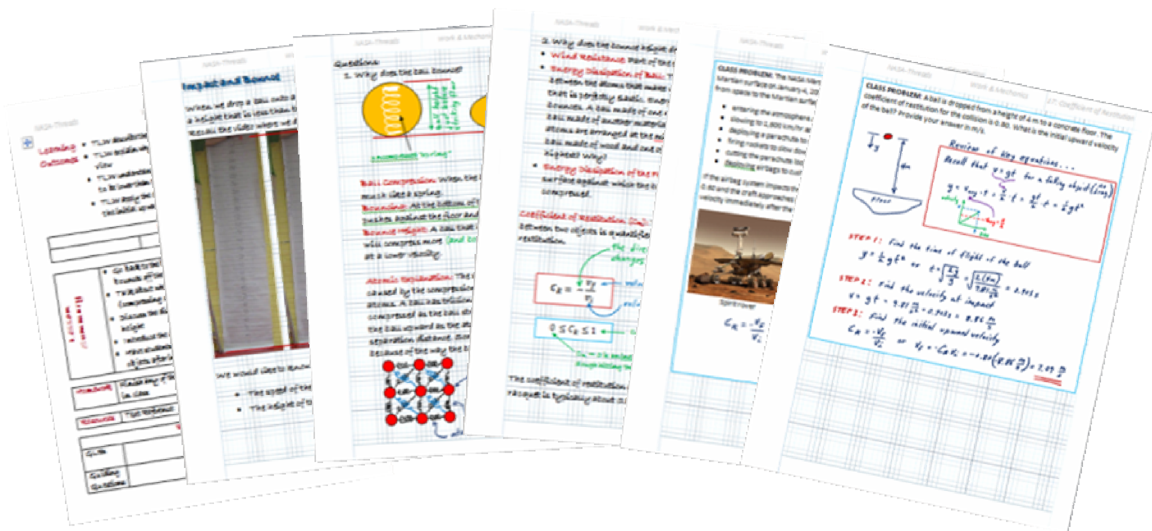


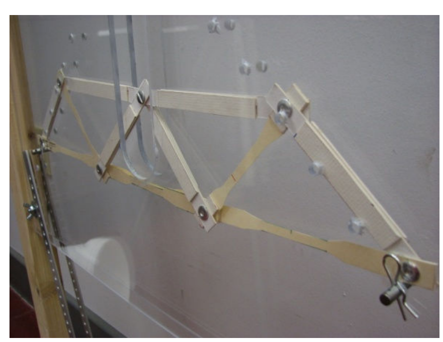
An online curriculum (www.nasathreads.com) complete with physics fundamentals, detailed project descriptions, and course assignments are provided freely via the Internet. The online content eliminates the requirement of a textbook, reducing overall curriculum cost to the materials and supplies for the projects. In addition, teachers and students have access to high quality media that helps both students and teachers visualize difficult or abstract concepts.



From the online curriculum, each day's lesson plan, master notes, and supplemental materials are easily accessed by the teachers. The curriculum is interlaced with many innovative projects throughout each unit. Towards the beginning of Work & Mechanics, the idea of efficiency is introduced. Students use the Boe-Bot to quantify the electrical energy input and the mechanical work output of a servo as it operates under 4 different loads. The students lay the Boe-Bot on its side, fasten a string to a modified wheel connected to the servos, and tie various weights on the string. The servos essentially act as a pulley lifting the weight over a period of time. Using a multimeter, stopwatch, tape measure, and scale the students collect the necessary data needed in order to find the efficiency of the servos. This lesson builds on previous concepts presented in Work & Mechanics such as work, power, and energy conservation. Additionally, concepts learned in Electricity & Magnetism, such as electrical power, are used to link fundamental topics.

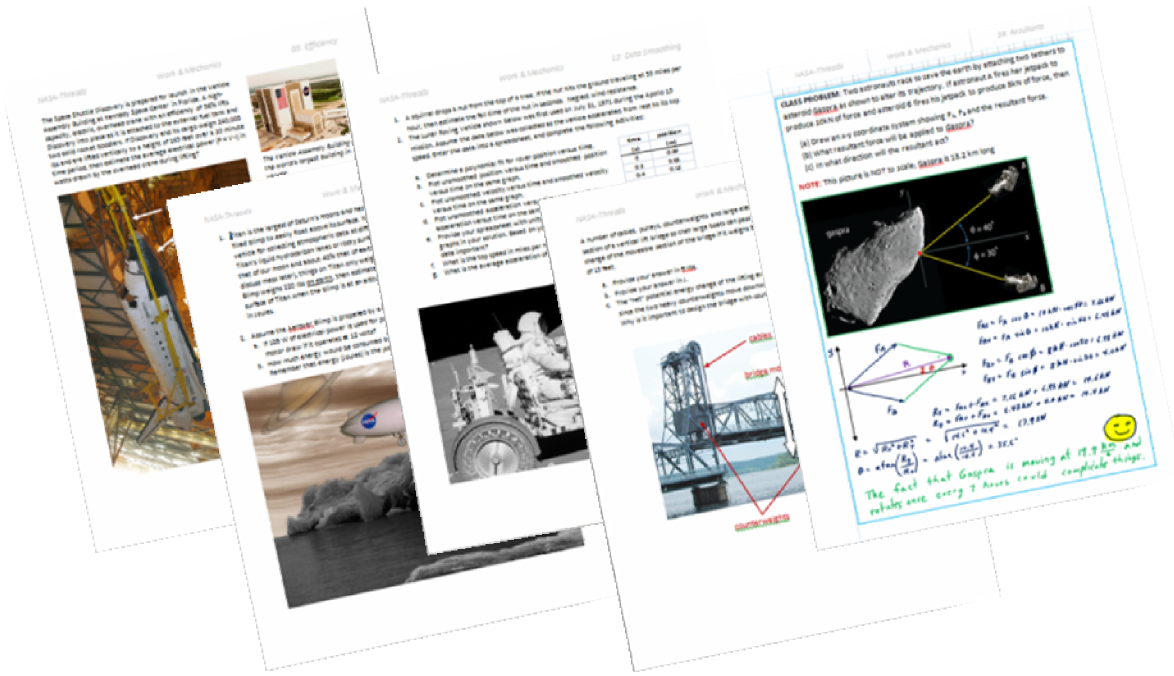
A sample of curriculum materials available shows the lesson plan and master notes from Lesson 17 of the Work & Mechanics unit. The sample master notes shown link to and expand on an earlier project conducted on Lesson 10 of Work & Mechanics. Lesson 10 leads students through calculating the Earth’s gravitational constant by using a digital camera to capture the position of a dropping ball at various time intervals. Expanding upon this project, Lesson 17 (shown below) introduces coefficient of restitution.





Following the Work & Mechanics lessons on forces, students are introduced to the concept of vectors. As an application of these fundamentals, the truss project tasks students with analyzing and building a 2-dimensional truss using mat board and manila folders. Supply materials are individually tested to aid in the design of student built trusses. Students then implement the method of joints in order to analyze and predict the forces associated with each member. A testing apparatus is used to validate the ultimate force that the truss can withstand.

In addition to the many innovative projects found within the curriculum, students are supplied with supplemental homework and worksheets to help solidify their knowledge of fundamental topics covered. In most cases, real world applications are used as supplemental problems. When possible the problems are related to NASA.



Survey Results

Students participating in the pilot NASA-Threads course were surveyed to determine students' academic self-efficacy, real world problem solving, critical thinking skills, achievement in mathematics and the sciences, motivational and goal orientation, and vocational or career interests in STEM fields.

Results show that student feedback is positive for all survey questions. The two highest ranking questions ("I enjoyed working with the hands-on projects in the NASA-Threads course." and the "NASA-Threads course provided more project-based learning than other courses.") were both related to the hands-on project-based instruction in the classroom. It is also interesting to note that the survey data reflects a somewhat neutral trend for interest in STEM disciplines. However, student comments suggest that the curriculum has influenced many students in their career direction. This includes some students that have a greater appreciation of STEM topics even though they are not planning to pursue a STEM degree.

Table 1 – Results of student survey

	strongly disagree 1	somewhat disagree 2	neutral 3	somewhat agree 4	strongly agree 5	**mean**
I have a better understanding of what engineering is now that I am in the NASA-Threads course.	0	4	6	29	10	3.9
I find science more interesting in the NASA-Threads course than I did in other science courses.	1	3	14	17	14	3.8
I feel confident that I can apply the topics discussed in NASA-Threads to everyday situations.	2	5	20	16	6	3.4
I am more confident in my other courses because of the NASA-Threads class.	2	8	17	21	1	3.2
My critical thinking skills were better developed through the NASA-Threads course.	1	2	10	30	6	3.8
I enjoyed working with the hands-on projects in the NASA-Threads course.	0	0	5	15	29	4.5
I see how the Boe-Bot relates to concepts in physics.	1	7	9	22	10	3.7
I feel confident in solving fundamental physics problems because of the NASA-Threads course.	1	5	11	27	5	3.6
NASA-Threads course provided more project-based learning than other courses.	0	2	5	18	24	4.3
The project-based nature of the course helped me to better understand the fundamental concepts.	1	3	12	17	16	3.9
I am confident in my ability to perform well in higher education due to the NASA-Threads course.	0	3	17	22	7	3.7
Because of the NASA-Threads course, I am more interested in pursuing higher education in a Science Technology Engineering and Mathematics based field.	4	3	15	14	13	3.6

Student Comments

"The project-based curriculum helps give me a better understanding of the application of physics and mathematics, which entices me to follow a career in engineering."

"Because of this course, I feel I am more likely to study engineering in college."

"I like being able to use my hands to understand engineering."

“I feel that even the simplest projects have greatly helped me understand the fundamental concept of physics making it less confusing and more fun.”

“I have never liked physics until I took this class. It has made me like physics more than before.”

“This curriculum has influenced me positively because I realize how much more interesting a subject is when it's a lot more hands-on work, and that’s what the STEM courses offer.”

“The NASA-Threads curriculum has broadened my view of science and engineering. I look at it in a different way and even though I'm not interested in pursuing the science field, I have a greater appreciation for it.”

“I hated project-based learning before this class, but I love the projects in here. Working with the Boe-Bot made me decide to major in Computer Science instead of English.”

“NASA-Threads is engaging and provides a challenge which most students enjoy.”

“I am not very interested in these subject concepts, but I find the course more interesting than I expected.”

“I already wanted to be an engineer, but this class made me realize how difficult it will be.”

“The NASA-Threads curriculum has shown me how STEM concepts can actually be useful instead of just learning a concept for a test. I enjoy the challenge the curriculum provides because in other classes there are fewer opportunities to critically think.”

“I liked this program because I work better in groups and this allows me to do that. The hands-on projects make it easier to understand physics concepts, in most cases.”

“The NASA-Threads curriculum has given me a firsthand look into the world of science technology. It has helped me see that this is not the career path I should take. However, I enjoyed the class.”

Teacher Comments

The teachers that are implementing the pilot curriculum were asked to provide feedback on the implementation of the NASA-Threads program. Because of the small sample size of the pilot (3 teachers), quantitative data is not statistically sufficient. However, qualitative comments provided by the teachers provide insight into the program.

“Hands on real world projects inspire students more than textbook/problem based curriculum. Robots and video applications are more relevant than old style Physics labs.”

“We needed a curriculum that would not require significant additional staffing or multiple courses, as we are not a large school and our STEM students often have very packed

academic and extracurricular schedules. NASA-Threads has been a perfect fit for us. It has given us a model for how to provide a really relevant, project-based curriculum that is also rich in the fundamentals. The curriculum connects the technology that students will need to know with the underlying principles in math and science. NASA-Threads has really opened our eyes to what can be done when you step away from traditional textbook and lab exercises and teach in a way that is more collaborative, hands-on, and project-based."

"We are piloting NASA-Threads as a STEM elective. This gives us some flexibility to gain experience in teaching the course and to complement, rather than replace physics. We are strongly considering replacing our physics course with NASA-Threads in the near future (possibly next school year). This will open the curriculum up to a large number of students, and make room in our scheduling for additional STEM electives."

"This course allows us to integrate Physics and Engineering in ways that are applicable to the real world. This NASA-Threads Physics course takes the "plug-n-chug" out of physics and forces students to understand the underlying concepts in order to complete the projects. The incorporation of engineering projects in the physics curriculum allows students to see and experience engineering. Most of my students were surprised to see how easily Physics and Engineering mesh into a cohesive curriculum."

Future Plans

Following the 2009-2010 pilot year, teaching fellows will collaborate with university faculty to complete revisions to the NASA-Threads curriculum. Following this curriculum revision phase, math and science teachers from 15 partner schools (two from each school) will join us for a two-week professional development workshop held at Louisiana Tech University to gain experience in implementing the curriculum in the next academic year. During the 2010-2011 academic year, teachers from the partner schools will have the opportunity to fully implement the NASA-Threads curriculum.

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