Abstract

This paper describes an innovative, new GK-12 STEM Fellowship Program that incorporates contemporary embedded real-time sensors and system design into the existing K-12 curriculum. Unlike other GK-12 programs, more focus is placed on Technology (T) and Engineering (E), and less focus is placed on Science (S) and Mathematics (M). The underlying goal of the program is to link real-time embedded systems research with science and technology curriculum and to create a community of learning, teaching, and mutual support between the higher and pre-college education participants from rural backgrounds.

Keywords: Education, embedded systems, inquiry, outreach, real-time sensor networks.

1 Introduction

There is a well-recognized national need to inspire K-12 students to prepare for and pursue careers in Science, Technology, Engineering, and Mathematics (STEM) disciplines. These disciplines are needed to support innovation and the information age. Virtually all engineering disciplines have seen an increased emphasis on the use of computing technology. It is important for us to increase the number of students from the K-12 level interested in pursuing STEM careers with an emphasis on computing technology. When students get excited about science and engineering as a result of experiences in school or informal education settings, they are more likely to pursue classes that properly prepare them for success in undergraduate and graduate programs in STEM fields. Thus, there has been an increased interest in developing programs that are designed to enhance teacher preparation and classroom support for the type of experiences and content themes that inspire students to view STEM fields as an achievable, exciting option for them.

There has been an attempt to better understand why there has been a decrease in the number of Computer Science courses taught at the K-12 level in the US [1]. The top three reasons cited by K-12 teachers include: the rapid changes in technology, a lack of staff support, and a lack of curriculum resources. As noted by Shreck and Latifi, it is important to develop an infrastructure in which teachers have adequate support and where they are able to change with the technology. This will help them to maintain the interest of K-12 students in Computer Science [2].

As these programs and curriculum resources are developed and assessed, it is important to disseminate the results of such initiatives so that those with similar goals can consider how to adopt or adapt the successful elements of other programs into their own programs. Although many of the details are omitted, the goal of this paper is to report on our GK-12 program and some of the innovative curriculum modules that have been developed and used successfully in a K-12 setting.

The U.S. National Science Foundation’s program to support Graduate Teaching Fellows in K-12 Education (GK-12) strives to improve graduate students’ communication, teaching, collaboration, and team building skills through professional training, interactions with faculty, and work in the classroom with K-12 teachers and students. By working with K-12 teachers to integrate their knowledge and research to enhance the classroom, graduate fellows and faculty members also have the opportunity to build partnerships with schools and teachers, and to enrich learning opportunities and increase motivation for K-12 students. The graduate fellows also serve as role models for the students that they work with, and they talk with the students about the diverse and exciting careers that can be pursued by those who are interested in STEM disciplines. Although the main focus of the GK-12 program is on the development of graduate students, this paper will focus more on the innovative aspects of the program and the modules developed to date for use in the K-12 classroom.
2 INSIGHT GK-12 STEM Fellowship Program

Infusing System Design and Sensor Technology in Education (INSIGHT) is the title given to an innovative GK-12 STEM Fellowship Program at Kansas State University. Our program focuses on integrating real-time embedded systems and sensor technology with computing and information science through a standards-based science, technology, and engineering curricula.

The underlying goals of the program are to: enhance the usefulness, practicality and relevance of sensor, computing, and information technology education by linking embedded systems research for fellows to science and technology curriculum, and practice for classroom teachers; support technology in rural Kansas through two of the most important aspects impacting rural life in Kansas: agriculture and health; improve the teaching and learning of technology and engineering design in elementary through high school classrooms; and create a community of learning, teaching and mutual support between the both the higher education and pre-college participants from rural backgrounds.

Project activities team GK-12 fellows with K-12 STEM teachers through summer and academic year training and orientation, and place the fellows in the classrooms of rural Kansas schools. In the summer, project staff provides fellows with training in hands-on sensor-driven systems, STEM concepts and development, Kansas Curriculum Standards, and classroom instruction methodology. Participating teachers also have two weeks of training and orientation focusing on real-time sensor technology, computing and information science topics, selected science and technology content areas and the use of appropriate pedagogical and assessment strategies.

During the academic year, fellows support two participating teachers in the classroom an average of two times a week in their area with content-specific sensor technology and computing and information sciences. Program staff provides semester-long professional development opportunities via guided research and investigations of practical applications of technology integration on agricultural farm fields and within the classroom. Weekly meetings between project staff and fellows provide supervision and feedback.

Sensor systems are poised to revolutionize the way that the physical world is monitored and field experiments are performed with remote, automated real-time data collection and feedback replacing traditional manual methods. The development of cyber-physical infrastructure represents the next step in enabling applications wherein physical entities (humans with body parameters such as heart and respiratory rates, crops with different fertility and growth rates, etc.) and cyber-subsystems collaborate and interact to achieve a common goal.

For example, in health-care systems, the cyber-infrastructure can augment the capabilities of the hospital staff in patient monitoring, issuing alerts, and coordinating usage of resources. Likewise, in rural Kansas, remote monitoring can enable elderly residents to stay in their own homes safely for an improved quality of life and an on-site pharmacist is replaced with a robot that can dispense prescriptions to elderly patients and allow patients to consult with a pharmacist remotely.

As another example, although farm equipment operators can operate with a local visual view of the field, cyber and remote sensing infrastructure in the field can assist them by providing a correlated geographic information system (GIS), climatic and vegetation data to support variable rate application of chemicals with precision using the global positioning system (GPS). This results in both economic and environmental benefits [3].

![Figure 1. Variable-rate technology [SST Software]](image)

Typically, these systems are difficult to develop because their development requires knowledge about many parts of a complex system involving a number of heterogeneous subsystems and components [4]. Their design is often a multidisciplinary exercise involving a variety of domain experts with different views of the system, and there are few formal techniques that can be used to address the integration of individual components. Designers often work on subsystems without fully understanding its impact on other components and the rest of the system.
Design of such real-time embedded sensor systems has been the focus of researchers from several departments at Kansas State University.

This program represents a unique synergistic opportunity for us to collaborate with our K-12 colleagues in a similar manner, and create and strengthen mutually beneficial partnerships with the many rural school systems in Kansas. These partnerships enhance the education of K-State’s technologically-oriented graduate and undergraduate students while simultaneously advancing computing, science, and technology education in rural Kansas middle school and high school classrooms.

The program places an average of eight graduate students each year in up to eight different rural Kansas schools twice a week to assist an average of sixteen K-12 school teachers per year in integrating sensor, computing, and information technology into standards-based science and technology curricula and instruction. Participating teachers and fellows attend a two-week pedagogical summer institute in computing, problem solving, engineering and science. Participating teachers receive support in computing and technology content areas during the academic year. Science and technology teachers are selected from each of the participating schools and receive additional training and on-site support. During the five year program, approximately 2800 under-served rural and Hispanic students will benefit from the enhanced computing, science, and technology instruction. Sensor technology is the enabling element that pervades the entire science, engineering and technology curriculum, rather than as an entirely new and separate subject or curriculum area, whose introduction would be more problematic. Deductive reasoning, analysis and synthesis, algorithmic problem solving and design, and inquiry techniques are at the heart of each of these disciplines. Regardless of the scientific area, students must learn to formulate questions and hypotheses, plan experiments, conduct systematic observations, interpret and analyze data, draw conclusions and communicate results, using powerful classroom tools. Indeed, these skills are tested in a statewide assessment of students’ achievement in science, engineering and technology. Aligning instruction with science, engineering and technology standards requires significant changes to classroom practice, from content, activities, and assessment to classroom management, interaction with students and learning tools. This program has helped to establish hands-on engineering and technology development as a foundational skill for vocational agriculture, and other areas. Instead of focusing on Mathematics and Science, the novelty of this project is on its primary focus on Technology and Engineering. In the Environmental Science and Natural Resources Section in the Kansas Standards for Agricultural Education, an important new standard is on Sustainable Agriculture.

**Sustainable Agriculture**

3 2 1 0 1. Explain sustainable agriculture (LA)
3 2 1 0 2. Describe sustainable ag. practices (LA)
3 2 1 0 3. Describe the use of nutrient management (LA)
3 2 1 0 4. Explain site specific agriculture and the use of GPS (S)
3 2 1 0 5. Demonstrate GPS/GIS use (S, E)

Figure 2. State Agricultural Education Standard

Unfortunately, many of the rural school districts in Kansas don’t have the resources or technical expertise to go beyond the basics of just reading about sustainable agriculture. The PI of this project was a founding member of an innovative company devoted to information technology in precision agriculture, called the Site Specific Technology Software (http://www.sstsoftware.com/). In addition, researchers at Kansas State University have been at the forefront in developing sensor technology for agricultural and military applications.

One of the Kansas State Standards for Agricultural Education is on pest management:

**Performance Element: Develop and use a plan for integrated pest management.**

Develop pest management plans based on pest life cycles. Implement pest control plan with appropriate treatments. Evaluate pest control plan.

Little guidance is given with respect to developing an appropriate plan or applying those treatments in a targeted fashion to reduce environmental impacts. An important goal for all citizens of Kansas is to make agriculture sustainable and to minimize the environmental impacts of chemical applications by using variable-rate technology and appropriate sensor technology. By using the hand-held devices and GPS/GIS software as shown above, students are
able to develop the skills necessary to generate site-specific prescriptions for pest or weed control and minimize the overall environmental impacts while improving the economics of a farming operation.

This project's focus on sensor, computing, and information technology education makes it an ideal vehicle to provide graduate STEM fellows with the opportunity to enhance their academic experiences. Students interested in investigating the integration of sensor technology and computing in science, engineering and other disciplines are the focus of our recruitment efforts. In addition to receiving financial support, the fellows gain hands-on experience in applying technologies that relate to their learning, research and future careers, while having an opportunity to appreciate the use of such tools in education, especially in rural K-12 settings.

The project provides graduate students with hands-on experience in the integration of sensor, computing, and information technologies in science, engineering and technology education while teaching teachers and students in active, standards-based technology education. This project allows us to continue working with the teachers and administrators at middle schools and high schools where we have already established successful collaborations. Fellows gain valuable instruction, communication, and interpersonal skills as they work with teachers and students in their classrooms to integrate sensors and computing into the curriculum. Participating teachers, many of whom are inexperienced in working with sensors and computing technology, receive contemporary instruction in sensors, computing and information technology, as well as support from university faculty and fellows. The presence of fellows in their classrooms two times a week assists teachers in the tasks associated with ensuring the coherent delivery of instruction. To facilitate the rural experience, we incorporate video conferencing, using Adobe Connect and Skype, with the most rural classrooms. Some classrooms are several hundred miles from campus, so it is not economically feasible to place fellows in those classrooms twice a week. Although, we do plan monthly visits, other contact will be through video conferencing using Adobe Connect. The added advantage is that recorded interactions can be used in other settings, and the curriculum resources that are developed continue to grow. Rural students acquire new skills and experiences that will encourage them to study the subjects necessary to pursue careers in computer science or technology.

3 Sample Curricular Modules

In this section, we give a brief overview of a few modules that have been developed and/or delivered by fellows in the K-12 classroom. Details can be found on-line at, http://gk12.cis.ksu.edu, through our GK-12 program web-site.

Water Filter

In this activity students were asked to create their own sediment water filter using a water bottle and some basic materials. Some of the materials include: flour, sugar, sand, gravel, plastic beads, cotton balls, etc. The students were only allowed to use three materials and it was up to them to create the best filter in the class based on the types of materials selected, and the order in which the materials were placed into the filter. The dirty water, shown in the upper-left corner in Figure 3, is stirred occasionally to keep the sediment suspended, and the sediment shown in the upper-right is used to test filtered samples.

Wireless Sensor Network to Measure Sediment

At the high school level, students take samples using a hand-held sensor (top left) and take readings using sediment sensors deployed in the field and connected by a three-tiered wireless sensor network.
A solar panel is used to power the middle tier of the wireless sensor network (lower right).

To measure sediment discharge, turbidity sensors developed here at Kansas State University are organized into a wireless sensor network, and they continuously monitor sediment discharge. The system is organized to automatically adjust sensor reading rates based on the data to limit the power requirements of the wireless sensors. The data is then transmitted to a wireless base station, and then on to a centralized database from which the data can be analyzed [5,6,7]. Sediment concentration is defined as the weight of suspended soil particles per unit volume of water. Turbidity is usually referred to as the weight of suspended/dissolved materials in water on transmitting, reflecting, absorbing, and scattering light. Thus, traditional turbidity sensors are not sediment-concentration sensors. A sediment sensor developed in this study uses LEDs that emit lights at three visible and infrared feature wavelengths, which were selected through a spectroscopic analysis, with light detectors arranged at different angles from the light sources. Statistical models established based on test data allowed the sensor to be basically insensitive to non-soil, suspended and dissolved objects, such as algae, organic matter, and various microorganisms, and less sensitive to soil texture. A prototype sensor was tested at combinations of four water types and five soil textures in the laboratory. Statistical and neural-network models successfully predicted sediment concentration across samples of all the combinations with $R^2$ values of no lower than 0.95. An outdoor experiment proved that the influence of ambient light on sediment measurement can be largely eliminated by modulating the lights. More than ten prototype sensors of different designs have been fabricated and calibrated. Several sensors were placed at low-water crossings at Ft. Riley and Ft. Benning for long-term, sediment-runoff monitoring [6]. The sensor case has been modified to improve its waterproof capability. Difficulties encountered during the long-term tests included signal drifting and occultation of the optical lenses by algae and soil particles. Modifications in sensors and software have been made to solve these problems [5].

**Water Sediment Concentration**

At the elementary level, sediment concentrations in water are measured manually using filter paper and drying equipment after collecting samples at a local lake. Students also compare the results they obtain with measurements taken using an electronic sediment sensor.

**Newton's Laws of Motion**

Seventh grade students, using Wii remotes, bungee cords, and toy trucks, test Newton's Laws of Motion and gain a better understanding of acceleration. There are four different variable stations: mass vs. velocity, friction vs. velocity, force vs. velocity, and
force vs. acceleration. Acceleration is measured using the accelerometers embedded in WiiMotes via Bluetooth and appropriate software.

Olympic Bar Acceleration during Bench Press

High school students in weight lifting classes at Wamego High School use Velcro to strap on a Wii remote to an Olympic bar to measure each student's bar acceleration in all directions while doing the bench press lift. A graph of the accelerometer values is projected onto the ceiling of the weight room so that students can watch their acceleration and movements during the lift. The red line represents the number of repetitions, the blue line represents the left/right acceleration, and the green line represents the up/down acceleration. It was a great experience for the weightlifting classes.

Variable Rate Technology

High school students analyze the effectiveness of applying pest-controlling chemicals at a variable rate to control pests, both in terms of economics and environmental impact. The power of the software lies within its innovative analysis functions, which allow producers to gain precise management information from field-level data stored in a Geographic Information System (GIS). GIS software links information to its location. Layers of information are organized, stored, analyzed, and queried for management decision-making. A farm field boundary is used to organize all pertinent information relating to the field, such as soil types, soil fertility, yield results, hybrid/variety selections, remotely-sensed imagery, aerial photos, chemical applications, field scouting, and more [3].

Access to this information enables people to make better management decisions, lower input costs, provide better stewardship of the land, and increase yields. Chemical applications can be selective and focused. Crop stresses caused by pests can be pinpointed long before they are visible to the naked eye. It doesn’t matter if you are approaching precision agriculture from the perspective of producer, retailer, agronomist, or consultant. If the technology is properly applied it can benefit everyone.

For the example hands-on classroom activity, students use a PDA (SST Field Scout) with built-in GPS to create a field boundary, and delimit well locations and other hydrologic features (terraces – yes, there are terraces in Kansas, even though it is flatter than a pancake). From point data gathered in the field and analyzed in a lab, or obtained from yield monitors on-board modern combines, the software can be used to compute acreage and generate yield and fertility surface layers in graphs as shown above. In addition, point in polygon analysis can be used to compute average yield by soil type or hybrid seed type, along with a host of more detailed statistics and enhanced yield data processing tools. These GIS layers can be combined with satellite imagery, aerial photography and orthophotos as base layers for field boundaries.

Based on the information gathered, the students can derive a variable rate prescription map to apply only the necessary chemicals at precise locations in the field to control the insect infestation. This prescription can be delivered to a farm input supplier to apply the chemicals at a precise variable rate across the field.
Scratch Programming

Middle school students learn the basics of object-oriented programming using Scratch, available for free from [http://scratch.mit.edu](http://scratch.mit.edu) [8].

![Figure 9. Scratch programming](image)

Styrofoam Cup Speaker

Eighth grade physics students learn about sound waves and electricity by building foam cup speakers. A similar foam cup speaker design can be found at: [http://cse.ssl.berkeley.edu/lessons/indiv/regan/speakerlab.html](http://cse.ssl.berkeley.edu/lessons/indiv/regan/speakerlab.html).

![Figure 10. Styrofoam cup speaker](image)

4 Conclusions

Overall, the INSIGHT GK-12 program has been very effective and we have received very positive feedback. In this second year of the program, we plan to provide a smoother transition for the participating teachers and fellows just joining the program. We believe that by having a cohort of veterans as mentors will smooth the transition for incoming participants.

Other programs, such as MOBILIZE, led by Dr. Debra Estrin from UCLA, allow students to pursue scientific studies through the use of participatory sensing technologies; e.g., cell phones. We also have several activities that involve the use of Android cell phones. Linking science to commonly used devices provides students with a concrete look at the power of computational technology in daily life [2]. This can also motivate students to realize how Computer Science is required to develop novel systems.

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References


