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Multimedia Modules and Virtual Organization Website for Collaborative Research Experience for Teachers in STEM

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Abstract: Wireless enabled cyber physical systems and applications, highly interactive multimedia modules, and virtual organization tools and capabilities provide attractive avenues for boosting interest and improving teaching effectiveness of STEM courses in schools. In this paper we describe the Research Experience for Teachers (RET)–Hawaii program and present features of some of the developed multimedia modules for middle schools. It is shown that with the production of highly interactive modules that include virtual labs, virtual instruments, and virtual participation in practical applications, the RET-Hawaii program has grown and is presently being used in 28 schools across the islands of Hawaii. To help maintain teachers' connectivity, and facilitate exchange of information and sharing of implementation experiences, a virtual organization website was developed and is being used throughout the program. Features of the developed multimedia modules are described and capabilities of the developed virtual organization website are discussed. Outcomes from the RET-Hawaii program are highlighted to demonstrate some of the gained benefits from the program.

Keywords: Education, STEM, virtual labs, virtual instruments, cyber physical systems, multimedia modules.
Categories: L.1.5, L.2, L.2.3, L.3, L.3.6, L.6

1 Introduction

Progress in modern society will continue to heavily rely on technological advances and emerging technologies in areas such as wireless enabled cyber physical systems, nanotechnology, biotechnology, photonics, and material science. With this progress there will be continued demand for scientists, engineers, and technology-savvy workforce. High school students are the workforce in the near future and their proficiency in science, technology, engineering, and mathematics (STEM) fields will play a key role in how our society will benefit from these emerging technologies [NAE, 05; NCES, 09a, 09b]. Government agencies and private sector organizations are investing considerable financial and intellectual resources to boost interest and enhance effectiveness of STEM education in schools. Much focus is placed on high schools as it is expected that at this level students will have the background and intellectual maturity to understand and appreciate the role of STEM courses in emerging technologies and their real life applications in the society. It is postulated, however, that if students wait until high school to become interested in technology related fields, then they will already be behind the curve in their preparation for college education. In other words, to help boost interest in STEM college majors and careers it is important to start earlier than the high school level, and hence, considerable effort should be focused on working with students in middle or even elementary school levels. Clearly an integrated effort throughout the pre-college stage needs to be seriously considered as part of producing a technology-savvy work force in our society.

This paper describes the efforts of the “Research Experience for Teachers (RET)-Hawaii” teachers outreach program in developing educational material for the Middle School classroom. As part of the community outreach activities, the Hawaii Center for Advanced Communications (HCAC), in the College of Engineering at the University of Hawaii at Manoa, received a grant from the National Science Foundation (NSF) to use knowledge and applications of the wireless technology to help boost STEM education at the middle schools in Hawaii. The objective is to actively involve Hawaii middle school teachers in engineering research and provide them with the tools and experiences to bring that knowledge of engineering and technological innovation into their classrooms. A wireless curriculum was proposed and supported through the development of several multimedia modules that describe the fundamental knowledge and various applications of the wireless technology. HCAC has extensive experience with the development of highly interactive multimedia products [Baker, 10; Iskander, 92, 93a, 93b, 96, 02; Lu, 05; Sanz, 99; Fabrega, 98; Vidal, 97], and hence, HCAC faculty and graduate students worked with middle school teachers on developing this material at a level and on topics that fit the teachers’ classroom needs and that are consistent with the educational standards adopted in the State. Furthermore, wireless networks were installed in classrooms in over 28 schools participating in the program, and over 250 laptops, hundreds of personal digital assistants (PDAs), and a large number of water quality sensors were provided to the participating schools.

Figure 1 shows a list of the RET-Hawaii participating schools across the Hawaiian Islands. It is to be emphasized that this partnership is driven by the needs and requirements of individual teachers, and by technological advancements in engineering, specifically in advanced wireless communications. RET-Hawaii offers a unique opportunity for the teachers to initiate programs, request and help develop technology applications and lab curricula, and utilize wireless technology in a variety of classroom and field trip activities [Baker, 10].

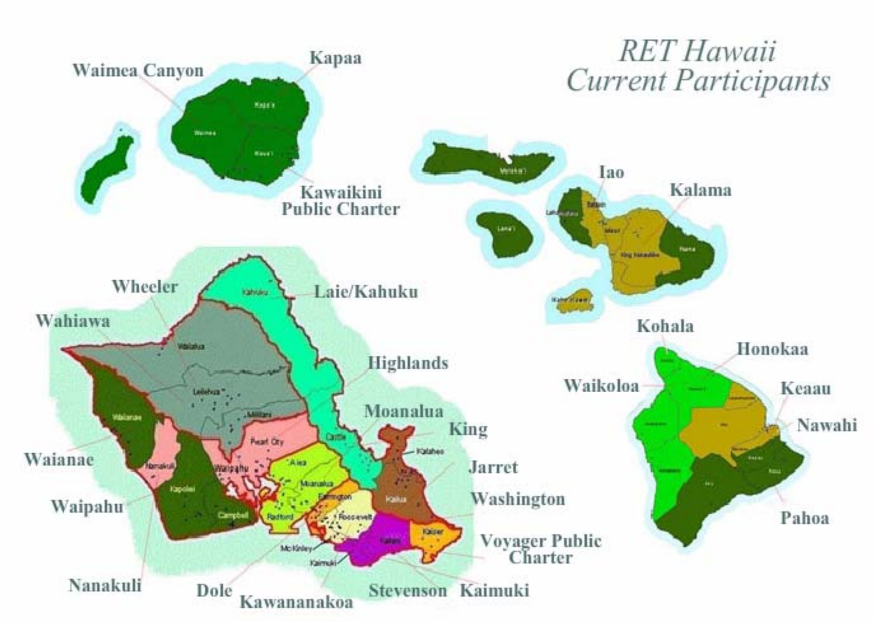


Figure 1: Names and distribution of schools participating in the RET Hawaii Program

To help build long-term and sustainable partnerships between middle school STEM teachers and university faculty and graduate students, and to enable teachers to translate those experiences and knowledge into relevant classroom activities, summer workshops, in-class visits and technical support and onsite training were provided for participating teachers. Furthermore, to help teachers share information about the RET-Hawaii program, and give them an online portal to communicate with one another, a virtual organization website was developed. This website was designated as a place that ideas are shared, information exchanged, and serve as a communication portal for advancing STEM in Hawaii's middle schools.

In this paper we briefly describe features of the developed multimedia modules for wireless education in middle schools, and highlight the structure and capability of the developed virtual organization website. Section II describes features of the various educational modules, while section III focuses on highlighting the structure and capabilities of the Virtual Organization website. In section IV we describe some of the projects outcomes, and conclude the paper with broader observations in section V. The references section includes a list of the longstanding HCAC activities in this area of technology enabled STEM education.

2 Multimedia Modules for Wireless Education in Middle Schools

The use of multimedia assets and ability to provide educational material in a variety of modalities including virtual laboratories, virtual instruments, animations and virtual participation in practical applications have presented avenues for developing effective educational materials both for classroom teaching and web-based training and courses [Iskander, 02]. Studies on benefits of technology based education have shown variety of benefits ranging from improved motivation and increase in learning rate and retention, to contributions in helping teachers manage large classes where their role changes from information provider to a coaching-type guide and facilitator. But, as it is generally known, the development of multimedia assets is expensive and time consuming; hence, focus needs to be placed on topics and products that benefit most from the advantages and capabilities of computer technology and wireless applications, and emphasis must be placed on topics that can benefit most from multimedia capabilities such as animation, visualization, and simulation aids.

The multimedia modules developed by the RET-Hawaii program are referenced in three categories, including wireless technology, biology & life sciences, and robotics. All these modules are available on the virtual organization website http://retserv.eng.hawaii.edu and the specific list of the developed modules includes the following:

Wireless Technology Area

- **Antennas:** This exercise includes learning the characteristics of dipole antenna and step by step instructions to actually construct your own working monopole antenna.
- **Circuits:** Learn the fundamentals of electricity and how to build basic electric circuits in this module.
- **Electromagnetism**: Students build simple electromagnetic using common household items and measure and analyze electromagnetic field data.
- **GPS**: Discover how the Global Positioning System uses satellites to determine your location anywhere in the world!
- **Magnetism and Applications:** Learn about magnets and their properties.
- **Motors and rotors:** Experience the wonders of magnetism by learning how it can be harnessed to build useful machines.
- **Pendulum**: Learn the fundamentals of frequency and period using the concept of pendulum motion.
- **RF Wireless:** Learn the basic fundamentals of AM and FM radio operations.
- **Spring Wave:** Visualize electromagnetic wave motion using Slinkies.
- **Wireless Mon:** Monitor wireless network details such as available networks and signal strength.

Biology and Life Sciences

- **PDA:** Learn the basic operation of a PDA in this lesson which describes PDA navigation, data entry procedures, and how to connect and transfer files to a computer.

- **Water Quality:** Learn the fundamentals of electricity and how to build basic electric circuits in this module.

Robotics

- **Introduction to Robotics**
- **Wireless Robotics**

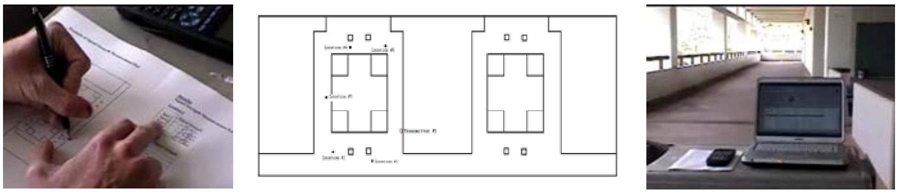
In this paper, and because of the page limitation, we will describe four of the modules used to teach wireless technology to middle school students and provide teachers with the tools needed to inspire and motivate students towards careers in STEM fields.

2.1 WirelessMon

This module introduces students to the technology, terminology, and practical implementation of wireless networks. Students use laptops equipped with wireless capability to perform lab experiments. The WirelessMon software application provides a display of the received signal strength from the wireless transmitters that are being received. In this laboratory exercise, as may be seen from Figure 2, students record the signal strength for their wireless network at different locations around the classroom, and from those measurements they determine the optimum location for the wireless router in their classroom to provide the best coverage and minimize or eliminate any blind areas. During this process, students analyze the factors that contribute to strengthening or weakening of the wireless signal in and around their classrooms. The equipment required for this module consists of a wireless equipped laptop, the WirelessMon signal measurement software, and a wireless router. The lesson goals range from simply demonstrating importance of selecting a proper location for the wireless router to explaining the mathematical concepts of logarithms and power measurement units such as “dBm”. In all cases, students utilize scientific method in constructing the experiment, recording the data, analyzing the data, and drawing conclusions from their analysis.

2.2 Antennas

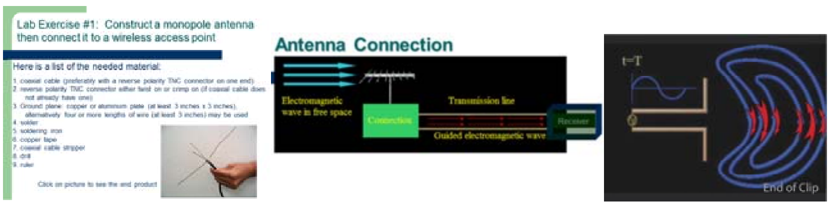
The antenna module provides an introduction into basic principles of antenna, different types of antenna, how they work, and some more details regarding how electromagnetic fields are actually created and separated from wire antennas. This module is specifically requested by one of the participating teachers, and the material is presented at a level appropriate for middle school students. The module discusses the use of antenna in modern devices that many students have access to, such as cellular phones, FM radio, satellite TV, GPS navigation systems, WiFi internet routers, and Bluetooth devices. Basic antenna types such as monopole, dipole, helical, and horn antenna are discussed along with the general operating characteristics and



(a) (b) (c)

Figure 2: Experimental arrangement (a), layout of wireless site under test (b), and data collection (c) in a typical WirelessMon experiment

applications of each. The module also provides detailed (yet grade-appropriate) discussion on how electromagnetic waves are transmitted by the antenna and propagate through free space. These concepts are explained through the use of animations and videos that depict current distribution in a transmission line and the separation of the electric and magnetic waves from the antenna wires and how the time-varying fields can continue to propagate and travel away from the wire (see Figure 3). The module then continues with a description of the reciprocal process, how an antenna receives electromagnetic waves from free space and feeds them into a transmission line. The hands-on activity in this module (Figure 3a) includes building a small 2.4 GHz monopole antenna that can then be analyzed using the wireless router and software described in the previous section. In this activity the students measure the signal strength of their classroom network router, then disconnect the router antenna and replace it with their antenna, and then re-measure the signal strength. The teacher also has the option of teaching the mathematics associated with wavelength, frequency, and velocity of propagation along with the design considerations in selecting the proper length of wire to achieve a desired operating frequency.



(a) (b) (c)

Figure 3: (a) Antenna experiment instructions, (b) Antenna Connections and (c) Animation illustrating electric field detachment from wire antennas

Another aspect of Antenna analysis within the program is the comparison of various antenna parameters. Figure 4 shows a portion of the source code from one computer program developed by an undergraduate student using the LabVIEW graphical programming language. This particular program was used for analyzing and comparing parameters such as S11 and VSWR for various antenna configurations.

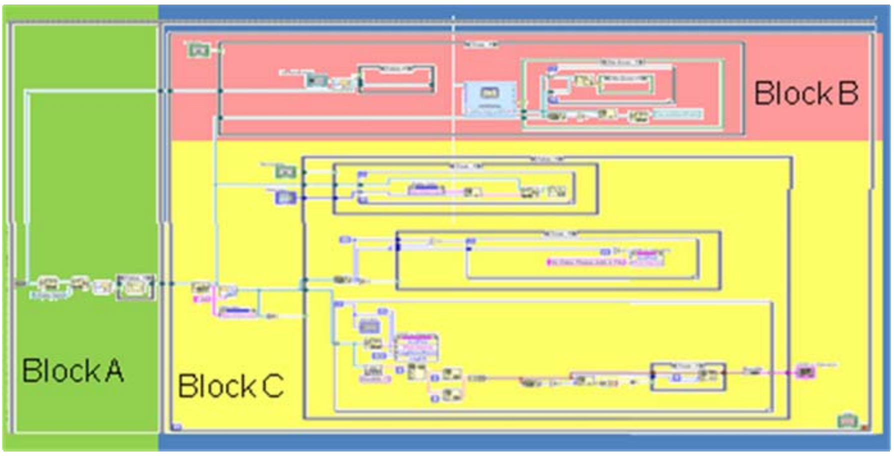


Figure 4: Overview of the student- created LabVIEW program for plotting antenna parameters from computer simulation data

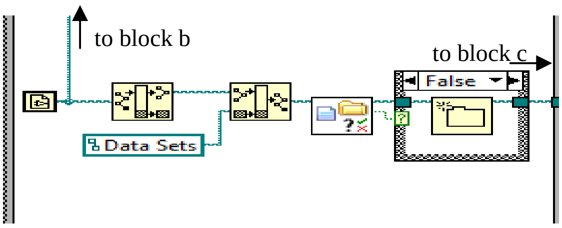


Figure 4a: Block A of the student- created LabVIEW program for plotting antenna parameters from computer simulation data

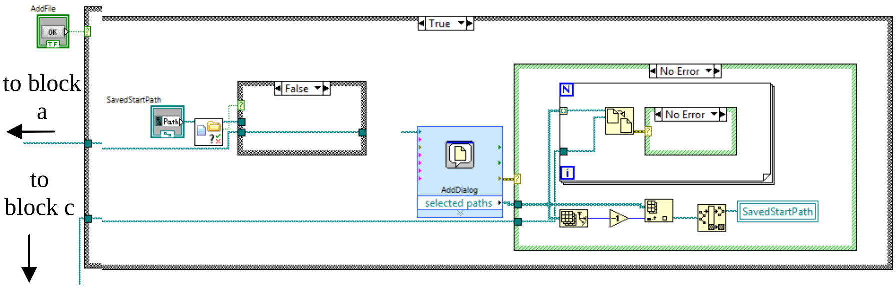


Figure 4b: Block B of the student- created LabVIEW program for plotting antenna parameters from computer simulation data

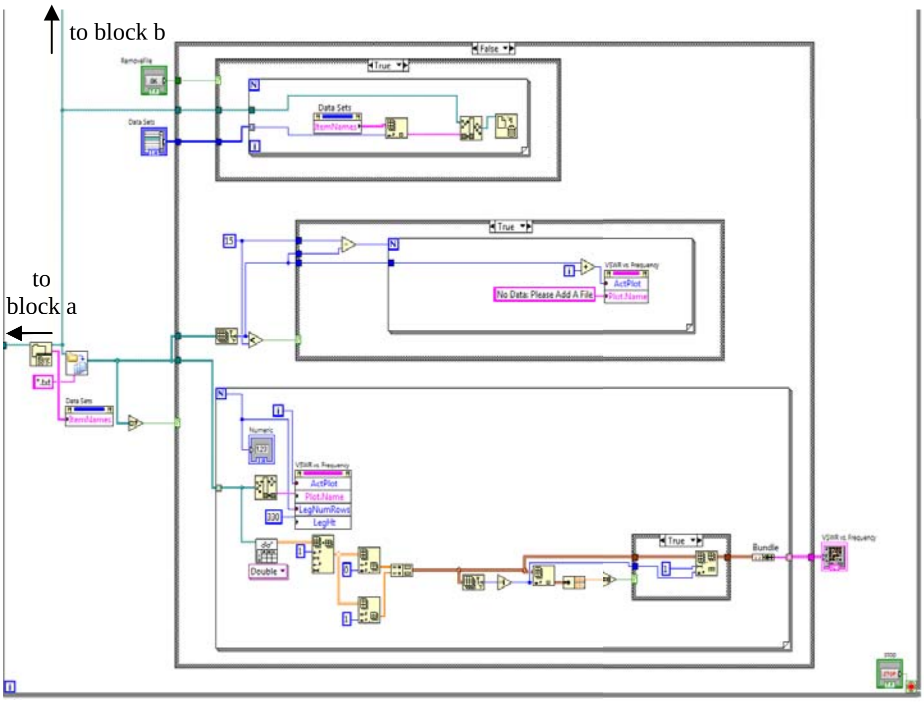


Figure 4c: Block C of the student- created LabVIEW program for plotting antenna parameters from computer simulation data

Figure 5: Experiment with an NXT robot

2.3 Wireless Robots

This module is the second in a series of modules on Robotics which covers wireless applications using the LEGO Mindstorms® NXT robot as a tool for teaching the basic concepts of robotics along with wireless technology and its applications in robotics. The LEGO Mindstorms® NXT (see Figure 5) makes a good platform for middle school students because most students are already familiar with LEGO construction techniques, and the NXT "brick" comes with Bluetooth® capability. In this module students learn how to program and utilize more advanced sensors such as color detection and magnetic field strength. They also learn how to establish a Bluetooth wireless link between a computer and the NXT brick allowing them to not only re-program the computer without cables but to wirelessly transmit and receive data and other information to and from their NXT robot. Figure 5 is a typical NXT robot configured with ultrasonic range sensor for navigating around large objects, a touch sensor for obstruction detection, a light detector used for following a line on the floor, and an RFID sensor for object identification and classification. There are many different types of sensors available for the NXT, making the educational applications practically limitless. Some sensor companies such as Vernier® have developed an NXT interface for their complete line of sensors along with the software drivers needed for programming. Although the NXT only has four input channels and three output channels, it still provides a popular and effective teaching tool that students of all ages respond to. Third-party products are also now available for multiplexing additional sensors to a single input channel. With built-in wireless capability, the NXT is also an excellent technology demonstrator for wireless applications. Figure 6 depicts one such demonstration for wireless applications in robotics. This program provides remote control of an NXT robot using the Bluetooth wireless link and was developed using the LabVIEW graphical programming language. Another option for programming the NXT robot is the NXT-G programming language. Figure 7 shows a screen shot of the procedure for sensor preparation in a color detection experiment using the NXT-G graphic programming language used by students. The NXT-G language provides middle school students a good introduction to programming in a graphical environment.

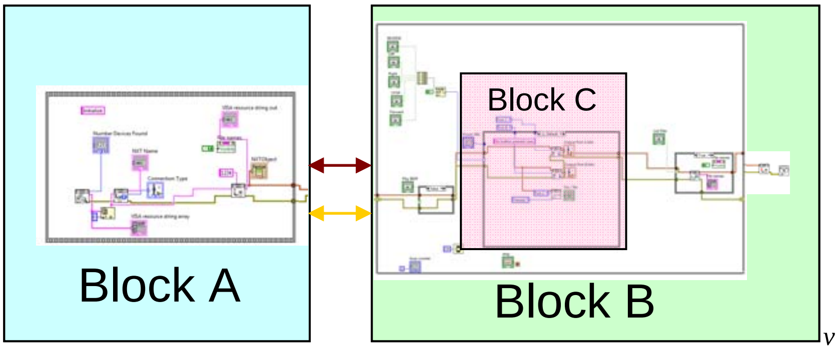


Figure 6: Overview of the student-created LabVIEW program for interfacing with and controlling the Lego NXT

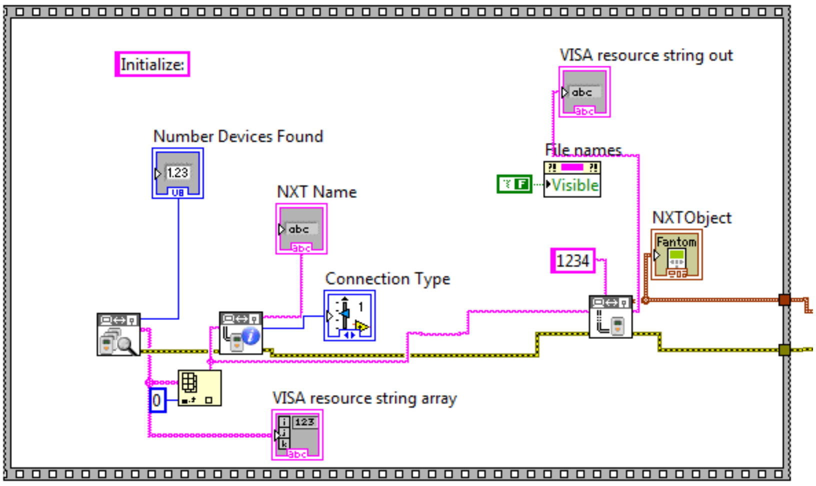


Figure 6a: Block A of the student-created LabVIEW program for interfacing with and controlling the Lego NXT

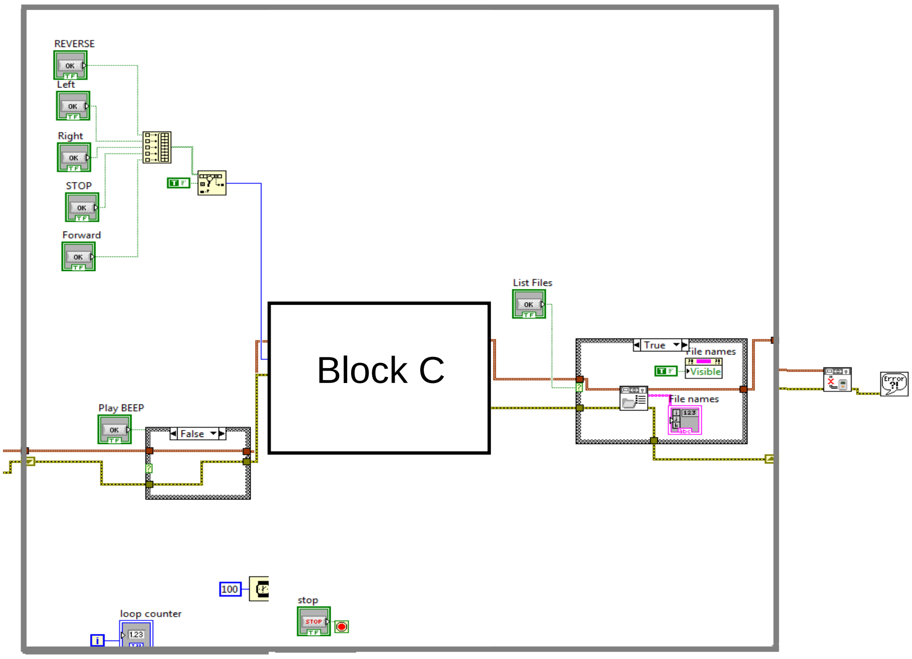


Figure 6b: Block B of the student-created LabVIEW program for interfacing with and controlling the Lego NXT

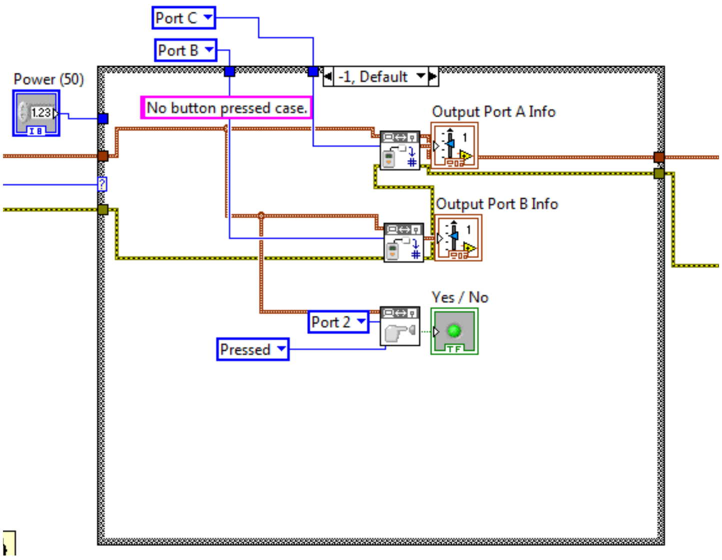


Figure 6c: Block C of the student-created LabVIEW program for interfacing with and controlling the Lego NXT

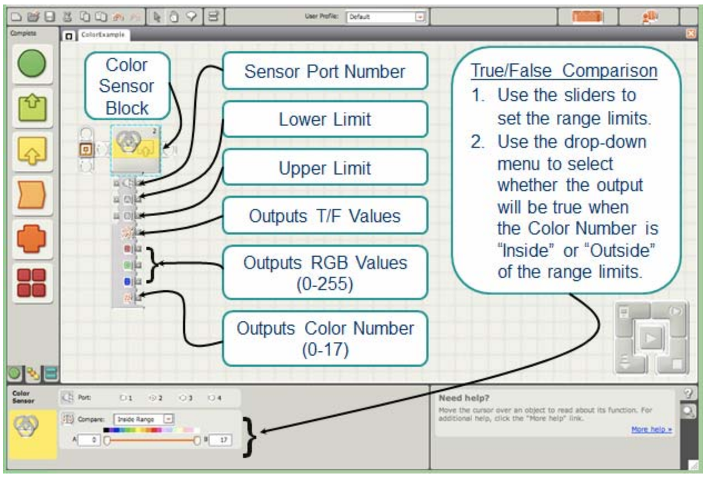


Figure 7: Screenshot of procedure for sensor preparation in a colour detection experiment

2.4 Global Positioning System (GPS)

This module was developed in response to teachers' requests because of the rapid growth and prolific implementation of GPS devices in household objects. Advances in device technology, circuit miniaturization, and reduced power requirements have allowed for GPS devices to be embedded in extremely compact circuits. As a result, GPS equipment is now being mass produced in many new-model cars, cell phones, and even wristwatches. This education module covers the basic concepts and principles for GPS operation, including satellite constellation, the importance of time measurements between the satellite and the GPS receiver unit, and the use of triangulation in determining geographic position based on reception from various satellites. Figure 8 shows two slides from the GPS module to provide an example of program modules.

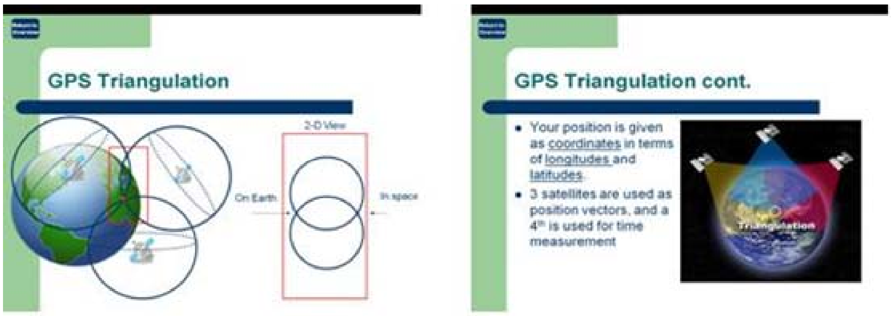


Figure 8: Example slides from the GPS module

3 Virtual Organization Website

The RET-Hawaii program started as a collaborative effort between two teachers at the Prince David Kawananakoa Middle School, on the island of Oahu, Hawaii, and then expanded to four schools including Keaau Middle School, Keaau, HI, Honoka'a Middle School, HI, and Dole Middle School, Kaneohe, HI. Two of these schools (Keaau and Honoka'a) are on the big island of Hawaii. As the program continued to expand, as previously shown in Figure 1 (it now includes 28 schools from five islands, Kauai, Maui, Hawaii, Molokai, and Oahu), it became increasingly difficult and particularly costly to effectively address the much-needed in-class services and teacher training, and more importantly it made it difficult to provide timely teachers' interactions and sharing of information and experiences. To help overcome this limitation and provide a flexible network for sharing skills, knowledge, and experiences, a Virtual Organization website was developed. Figure 9 shows the main features of the website. As it may be seen, the website provides ample opportunities for the teachers to cooperate and share experiences. Specifically, it provides an online resource for accessing all developed multimedia assets, avenues for teachers to post updated PowerPoint presentations and revisions, video clips of activities, and even a chat room for sharing experiences. There is an open part of the website for general viewing of all available capabilities and for posting timely events and recognitions. For accessing the developed multimedia assets as well as to participate in chatting and discussion, users are required to login with approval from the site administrator.

Figure 9: Screenshot of the RET-Hawaii Virtual Organization website

4 Project Outcomes

Outcomes from the RET-Hawaii program are many; starting with one participating school, expanding to four, and then growing to 28 schools from across the islands as a result of the State of Hawaii Support (ACT 111), presents a significant recognition and appreciation of the program's activities and associated benefits. Over 70 teachers participated in the program, and with NSF, State Of Hawaii, as well as matching funds from industry, the program delivered over 250 laptop computers, 80 Lego NXT Education kits, and more than 150 PDAs for data collection in field trips to the participating middle schools in addition to establishing wireless networks in over 30 classrooms. The RET-Hawaii Program also delivered multimedia content and hand-on exercises covering a wide range of STEM topics to schools. Teachers' training sessions and workshops were also organized to demonstrate and train them on RET experiments using provided hardware and software teaching aids for field trips and classroom exercises. These hardware and software teaching aids were also demonstrated in individual visits to schools when requested by teachers. A typical training session includes hands-on training for LabQuest (Vernier) data collection system with PDAs, introduction to WirelessMon, training with GPS and use of web camera and Skype for making Internet video calls. Training is also provided on the effective use of the RET-Virtual Organization website, including file upload and download, to facilitate information exchange and sharing of experiences.

Examples of field trip experiments include water quality measurements, data collection in Hawaii fish ponds and marshes, lava tube analysis on the big island, and native Hawaiian bird sound recording and identification in Kauai. Every effort was made to emphasize the use of the wireless technology in these field trips.

Figure 10: Students taking water quality measurements using electronic probes

Figure 11: Students tour Antenna Chamber

For example, during a school field trip to Kawainui Marsh near Kaneohe Bay (see Figure 10), students measured and recorded water quality data including temperature, acidity, and salinity. Students used wireless tools to transfer data from the various sensors to a laptop where they analyzed their data in the classroom and produced reports on their observations and conclusions.

On another occasion, one middle school held a robotics week. Students worked in small teams where they designed and built robots to accomplish assigned tasks. As part of robotics week, over 130 students enjoyed a field trip to the University of Hawaii where they toured the HCAC research labs in the College of Engineering, including a visit inside the antenna anechoic chamber (see Figure 11), the communications test lab, a hands-on training session in underwater robotics, and campus tours of UH-Manoa.

The program and developed capabilities also helped established a close and personal relationship between participating teachers and HCAC faculty and graduate students. Graduate students (see Figure 12 and Figure 13) visited each RET middle school to do a wireless site setup, which included installation of wireless routers to cover the classrooms, establishing a network of RET provided laptops, as well as answering any questions the teachers may have had about using the RET modules and website.

Figure 12: Wireless training in middle school classroom

Figure 13: HCAC graduate student demonstrating PDA data collection software

This relationship was enhanced by the Virtual Organization website which provided a smooth process for teachers to collaborate with each other, provided a resource for asking questions about technical and educational topics, and to request support from HCAC. Typical support requests to HCAC included asking for a graduate student to assist with classroom exercises and field trips to the development of customized teaching aids in response to teachers' needs.

In addition, HCAC hosted a teacher workshop at the University of Hawaii in which graduate students led teachers through training with the RET modules. The gathering of both newer and senior RET middle schools allowed for the more experienced RET teachers to present their classroom experiences and feedback with newer RET teachers about reaching students with STEM topics through the modules. Graduate students from HCAC were also invited to serve as judges at one school's science fair, where the successes of the RET-Hawaii program could be observed firsthand. Several of the exhibits were based on RET topics previously taught in the classroom, such as one exhibit of a working telegraph system constructed from household items (electromagnetism) and one exhibit on water basin and fishpond analysis (water conservation). In another example, a middle school on the island of Maui invited HCAC graduate students to assist with their wireless networking experiment (using WirelessMon of Figure 2) where students mapped out the strength of wireless network signals in their classroom and around the campus, identifying areas of weak or no signal, and analyzing possible causes for those areas, and also determining where the best locations for wireless routers would be to provide maximum coverage for their school.

5 Assessment

To help assess the value of the RET program in improving the classroom environment and specifically in boosting interest in STEM course, a formal survey was sent to all participating teachers and the received evaluation from 78 responses is a follows:

a. **Have you attended any RET Workshops or Seminars this year?**
   Response: 75 % of the RET respondents attended to RET workshops or seminars and 25 % did not
b. **Have you received any RET in-class support this year?**
   Response: 54 % of the respondents had technical support, 46 % did not have wireless access and had wireless networks installed, and 58 % of the respondents had additional laptops and probe measurement support at their schools
c. **In your opinion, is the level of technical content of RET material appropriate for Middle School students?**
   Response: 86 % of the respondents indicated that the technical content of RET material is appropriate while 14 % were undecided.
d. **How would you rate the applicability RET program material towards enhancing STEM topics?**
   Response: On a scale (1poor, 5 excellent), program material was rated 4.38
e. **Would you recommend the RET program to other teachers and/or schools?**
   Response: 100% of the teachers indicated that they would recommend RET program to other teachers.

As for comments, many of the participating teachers found the program and provided material to be very helpful, but requested more multimedia topics in the life sciences area, and also asked that teachers should share experiences more, say by email

6 Conclusions

This paper describes a National Science Foundation and State of Hawaii funded Research Experience for Teachers (RET-Hawaii) program that adopted wireless communication technology and its wide variety of applications as a theme for stimulating the teaching and learning of STEM courses at middle schools in Hawaii. A collection of multimedia modules were developed for in-class demonstrations as well as for use in field trips and laboratory experiments. Figures 10-13 depict some of the field trips where Middle School students travelled to different islands or toured University of Hawaii HCAC research facilities including the indoor anechoic chamber antennas test facility. Developed modules are pre-installed on laptops, delivered to middle schools, and other software and measurement capabilities such as measurement probes, PDAs, etc. were also provided to the schools. A Virtual Organization website was developed to provide an online community for sharing thoughts, ideas, and expertise between teachers from across the Hawaiian Islands. The RET-Hawaii Virtual Organization Website http://retserv.eng.hawaii.edu provides a central location where teachers can upload and download their own content, share teaching experiences particularly regarding the use of the multimedia modules, download updates to the multimedia modules, participate in discussion forums, and find links to additional resources. It also provides a central point of contact for teachers seeking support. The modules have been utilized in middle school classrooms across the State of Hawaii and based on preliminary assessment we believe that it has been successful in stimulating interest of students and in extending teachers' capabilities and effectiveness in teaching STEM related areas.

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