AC 2008-2143: USING WIRELESS SENSOR NETWORK AS AN EDUCATIONAL TOOL FOR LEARNING SCIENCE CONCEPTS

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Using Wireless Sensor Network as an Educational Tool for Learning Science Concepts

Abstract

Wireless communication devices can be successfully used as an educational tool for teaching physics concepts to science major students through an engineering design approach. A group of science and engineering undergraduate students at Suffolk University was actively involved in joint work between academia and industry on the Portable Multi-Channel Gas analyzer with Wireless Data Transmission project using Tmote sky devices. In this project students worked on interfacing different physical and chemical sensors in the gas analyzer to Tmote sky modules, on programming Tmote devices for collecting data from the sensors and on wireless transmission of the data between gas analyzer and the main base station. To assess the effectiveness of this instructional approach we developed survey instruments. The results of quantitative and qualitative analysis of the data will be presented.

Introduction

Theoretical and experimental educational research indicates that traditional teaching methods are not very effective in helping students to understand science concepts and transfer the principles learned in the classroom to real life situations.[5, 32] Innovative interventions are needed to supplement science curricula and to improve students' understanding of the concepts through active engagement in the learning process. Using novel instructional technologies and involving students in project that is interesting to them helps to create an environment where they gain a better understanding of the physics concepts.

Wireless communication devices can be successfully used as an educational tool for teaching physics concepts to science major students through an engineering design approach. A group of science and engineering undergraduate students at Suffolk University was actively involved in the joint work between academia and industry on the Portable Multi-Channel Gas analyzer with Wireless Data Transmission project using Tmote sky devices. In this project students worked on interfacing different physical and chemical sensors in the gas analyzer to the Tmote sky modules, on programming Tmote devices for collecting the data from the sensors and on wireless transmission of the data between gas analyzer and the main base station. Since that time the student team's work on the project using a wireless data collection has been expanded to include wireless MICA2 motes (by Crossbow Inc.) with several different sensor boards, which allow inclusion of GPS coordinates to the data on gas concentrations, pressure, and temperature collected in different locations.

To assess the effectiveness of this instructional approach we developed survey instruments. The results of quantitative and qualitative analysis of the impact of students work on the project on their understanding of the relevant science concepts will be presented. Our previous research results on the effect of using wireless sensor communication project on student's engagement in the learning process will be correlated with the results of the analysis of the conceptual knowledge development.

Literature Review

Learning science concepts through engineering design activities has a strong effect on active students' engagement in learning related to science topics. Such an approach creates an environment that encourages students to actively participate in the learning process and enhance their problem solving skills. As stated by Hmelo et al. [8] and Kolodner et al. [13, 15], Design-based education is one of the approaches to creating a constructivist learning environment that is appropriate to deeply learning science concepts and skills and their applicability, in parallel with learning cognitive, social, and communication skills. Engineering challenges involve both the design and building of devices that satisfy constraints. Sadler [29] views design projects as helping to show the connections between science concepts and solutions to real world problems. Engineering design challenges range from asking students to make the time-constrained construction of a working device to solve a problem or have design challenges that engage students in problems for which no working model is ever constructed or tested and only the theoretical design is evaluated. Their findings indicate that "the design challenges contribute to a growth in science process skills and in student's realization of the unique aspects of the scientific process. Uncovering the causal links between changing parameters and the resulting performance demands that students discover how to vary one thing at a time. Design challenges help students develop skills in planning, construction, and testing". As research indicates, the practice of design projects generated engagement and excitement among students which is not always present in science classrooms. Several research initiatives showed the positive impact of design based learning on student's enthusiasm about the science content. [15, 9, 24]

Based on the research about learning science concepts through engineering design approaches, we think that engaging students in engineering projects that present them with real life problems should provide students with a rich learning environment for application of textbook science knowledge.

Methods

To determine how the work on this wireless sensor communication project affected students' interest, involvement in the learning process, and the knowledge of the related concepts they study in the core science and engineering courses, we developed survey instruments to assess the effect of this instructional approach.

Participants

This survey was given to a group of five undergraduate students at Suffolk University. Four students are majoring in Physics and one is in engineering. Students who took part in this study were involved in the project on the voluntary basis. The goal of this initiative is to help students get involved in the research collaboration between university and industry. Students provided written consent in response to explanatory letters that were given prior to the study.

Project Description

A group of science and engineering undergraduate students at Suffolk University is actively involved in work on the project incorporating Portable Multi-Channel Gas analyzer, known as PID102+ and Wireless Data Transmission using Tmote sky devices. This project had two goals: 1) Interfacing a microcomputer based radio transmitter/receiver and a GPS chip into an existing engineering device – the hand held gas sensor analyzer, known as the PID102+. (Figure1). 2) Development of a new system for dynamic monitoring and display of multiple gas concentrations at multiple locations in a large environment.

In this project the students worked on interfacing different physical and chemical sensors in the gas analyzer to the Tmote sky modules (*see* Figure 1), on sensors calibration and on testing the systems with different types of sensors (*see* Figure 2).

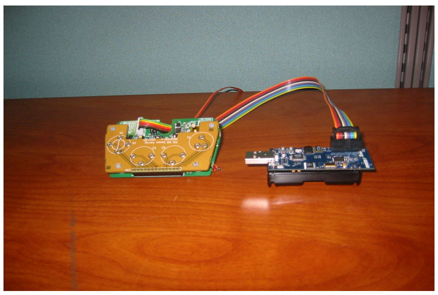

Figure 1: Interfacing 4 sensors board of PID-102+ to the Tmote sky analog inputs.

Figure2: Testing set-up with PID-102 (1-Photo-ionization detector and Tmote sky).

Data Collection

Students were given a survey to determine how the work on this wireless sensor communication project affected their interest, involvement in the learning process, and the knowledge of the related concepts they study in the core science and engineering courses. The survey was coded by researchers that were blind to the experiment. All five participants filled out the survey.

Evaluation Tool

We developed survey instruments to assess the effect of this instructional approach. The survey consists of 15 questions total. The purpose of the questions is to gather data on students' ideas about project-based learning and their understanding of science concepts relevant to their work. Some of the questions provided likert scale for answers or multiple choice options, other questions required written explanations.

Table 1 shows sample questions form the survey. The questions are categorized as Project-Based Learning and Content Learning questions.

TABLE 1: Survey Questions

Project-Based Learning	
Question 1	To what extent does the hands on approach interest you? Please, explain your answer. 1 = Not at all 2 = Very Little 3 = Somewhat 4 = Usually 5 = To a Great Extent
Question 2	Do you think that learning concepts in science and engineering through the hands on approach is useful for your understanding of the concepts? Explain.

	1 = Not Useful 2 = Of Little Importance 3 = Moderately Important 4 = Useful 5 = Very Useful
Question 3	Please, define which parts of this project listed below (if applicable) were the most helpful for your understanding of these concepts? (A) Collaboration with students and faculty (B) Analysis of the literature (C) Constructing the model (D) Testing and evaluation (E) Analysis of the data (F) Redesign (G) None of the above.
Content Learning	
Question 4	By participating in this project you were solving the problems of interfacing different kinds of sensors to the Tmote sky model. What kind of signal Tmote requires on the input? Select an applicable answer(s). (A) analog (B) digital (C) optical (D) chemical (E) electrical current (F) electrical voltage
Question 5	Assuming that mote requires 100 mA current from a 3V source during the transmission of data, what should be the capacity of the battery in Ampere-hour (Ah) to continue to transmit data during 1 week.
Question 6	Assume that mote takes 20 mA current when not transmitting the data. Estimate how often should you recharge the 5 Ampere-hour (Ah) battery to maintain the mote in the operational condition.
Question 7	It is known that sound waves propagate faster in the water then in the air Would it be feasible to try to increase the speed of transmission of EM signal using water as the media where the wave propagates? Please, explain your answer.

Results Discussion

Participants of this study indicated their interest in hands on approach to learning, especially in science disciplines (*see* Figure 3). Several participants pointed out that “learning by being doing” is the best way to understand the concept, because it reinforces class lectures by illustrating theoretical concepts. In response to the question on whether learning concepts in science and engineering classes through hands on approach is useful for the understanding of the concepts, 60 percent said that it is very useful, 20 percent said useful and another 20 percent stated that hands-on approach is not useful for them in learning science topics (*see* Figure 4). Such difference in responses could be indicative of different experiences with hands on activities that students had in science classrooms, the contexts in which these activities were presented and also could be credited to the differences in learning styles.

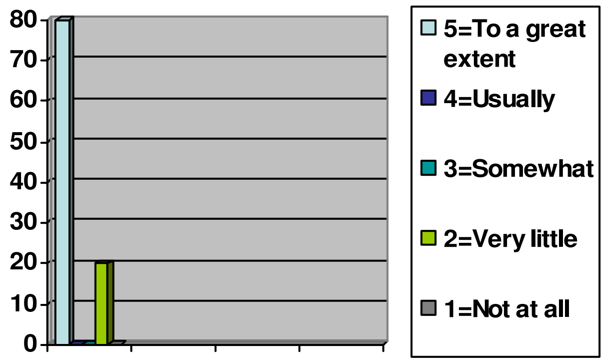

Figure 3: To what extent does hands-on approach interest you?

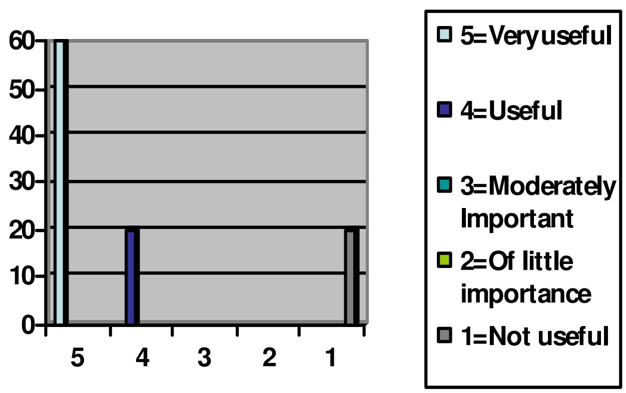

Figure 4: Do you think that learning concepts in science and engineering classes through hands on approach is useful for your understanding of the concepts?

Students supported their responses with the explanations which indicated the importance of using hands on approach as a way to introduce a concept from different perspectives. Some students said:

> "When you see it happening you can understand much better".
> "Seeing how a concept works in practice gives clearer sense of the concept".
> "It helps me to visualize everything I learn in class".
> "Projects have made me a much better student through practical application of knowledge".
> "Building a device illustrates a point much better than a page of equation does".

Additional questions were presented to the participants to measure the effectiveness of using wireless sensor networks as educational tool to help students better understand concepts related to the design of the project. One of the problems asked students to identify the kinds of signals that Tmote requires on the input. This question was appropriate to this group if participants, because in their work on the project, the students worked on interfacing analog outputs from different sensors (photo-ionization detector in PID-102, thermocouples, semiconductor temperature sensor LM335, battery voltage) to analog inputs of the Tmote's ADC. All of the students were able to identify the correct answer. They could gain this understanding from acquiring specific knowledge about the devices that allows them to answer this question.

Results of the quantitative questions targeting student's application of concepts of electrical power and energy to the particular situations devices in the project indicates need for including modeling and prediction of the results as an important part of the work on a project (*see* Figure 5).

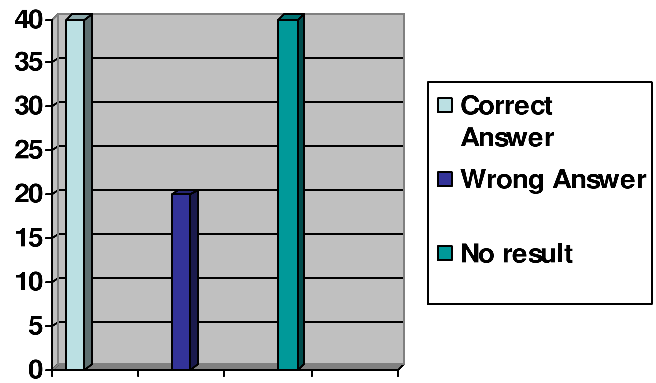

Figure 5: Assume that mote takes 20mA current when not transmitting the data. Estimate how often should you recharge the 5 Ah battery to maintain the mote in the operational condition.

The understanding of the concept of EM wave propagation is one of the fundamental topics included in physics and physical science textbooks. Participant of this study indicated that they took at some point a university physics course so they could explain this question based on their previous knowledge. It is also possible that participants gain an understanding through direct experimentation with the Tmote devices and some of the responses can reflect that. To test students' understanding of electromagnetic waves propagation they were asked the question whether it would be feasible to try to increase the speed of transmission of EM signal using water as the media where the wave propagates. It was assumed that the question will have Yes/No answer and in addition the explanation. All of the participants answered correctly to this question, indicating that it is not possible to increase the speed of transmission of EM signal in the water (*see* Figure 6). Their explanations for the answer showed variability (*see* Figure 7) in their understandings. The explanations varied from the perfect one, based on the electromagnetic theory, through the answers based only on their experiments in the context of the project, to incorrect statements.

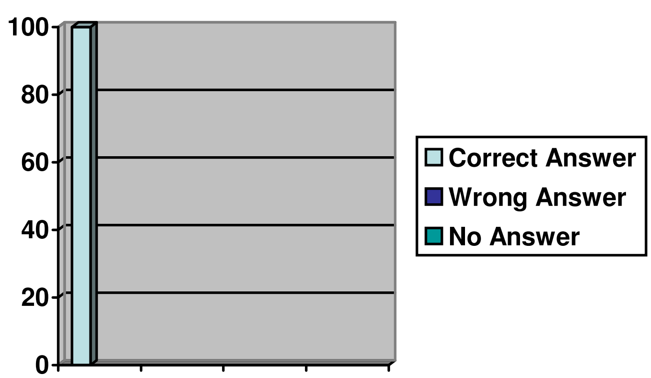

Figure 6: Responses to the Yes/No part of the question

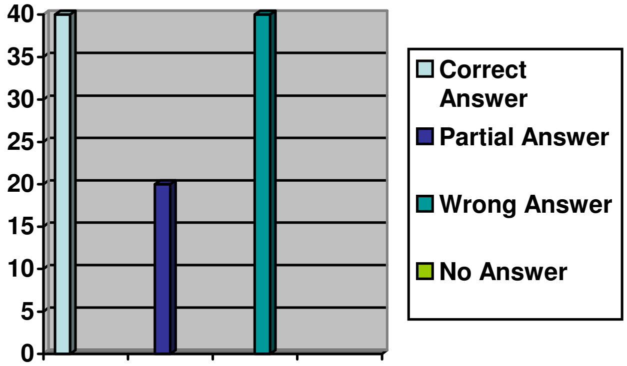

Figure 7: Responses to the conceptual explanation

Additional questions were presented to the participants to measure the effectiveness of using wireless sensor networks as educational tool to help students better understand concepts related to the design of the project. Participants pointed out that throughout their work on the project they developed a better understanding of the principles underlying engineering design process, such as collaboration with students and faculty, analysis of the literature, model construction, testing and evaluation, data analysis, and redesign, which are rarely taught in traditional classrooms. One student wrote:

> "I really enjoyed collaborating with the faculty and constructing the model. I had never soldered anything before this. I learned how to create the circuits and test them in the field. The process was great".

Another student indicated the importance of literature search for his work:

> "Constructing of the model and analysis of the data were most beneficial to me. However, analysis of the literature was useful in a different way; primarily that I had little literature searching experience prior to this project".

Other students also pointed out that they had to do additional readings in order to progress in the project.

> "I had to do research on voltage regulation, batteries, solar cells, and many other topics dealing with powering the motes. Also calibration and construction of temperature sensors".
> "My project resulted in substantial additional research in wireless propagation, antenna and waveguide theory, basic electronic design, and computer programming".

Overall, the participants thought that wireless sensor networks can be used as an educational too for learning science concepts and 60 percent indicated that they would definitely recommend this hands on approach to be included in a science course.

Conclusion

Our study indicated that innovative interventions are useful to supplement science curriculum and to improve students understanding of the concepts through active engagement in the learning process. Using novel instructional technologies and involving students in a project that is interesting to them helps to create an environment where they gain a better understanding of the physics concepts. Work on a project with wireless sensor networks for data collection, processing and analysis offers students opportunity to apply concepts of physics and engineering to real life design applications and involves them in deeper study and understanding of the course materials through making the content meaningful to them. Based on the theory of situated cognition which promotes transfer of knowledge to day-to-day real life situations, the work on Multi-Channel Gas Analyzer with Wireless Data Transmission is effective in improving student's interest and active engagement in the learning process. The study also indicates that that using wireless communication devices as an educational tool is beneficial for learning of science principles through applications. It enriches the learning process by providing practical experiences of real situations. With situated learning, students are better able to construct meaning in practical ways so that knowledge can be applied outside of classroom settings.

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