



Student-created water quality sensors

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Dr. Susan Lowes, Director of Research and Evaluation at the Institute for Learning Technologies at Teachers College, Columbia University, has conducted research at both university and K-12 levels, with a focus on STEM learning and on the impact of different technologies on teaching and learning. She has directed evaluations of multi-year projects funded by the U.S. Dept. of Education and the National Science Foundation, and served on Dept. of Education and NSF Advisory and Review panels. Dr. Lowes has co-authored papers and presentations on STEM learning in the sciences, engineering, and mathematics, including, most recently, "Robots Underwater! Learning Science, Engineering and 21st Century Skills: The Evolution of Curricula, Professional Development and Research in Formal and Informal Contexts," in B. Barker, G. Nugent, N. Grandgenett, and V.I., Adamchuk, eds., Robotics in K-12 Education (Hershey, PA: IGI Global, 2012) and (with Liesl Hotaling) of "SENSE IT: Teaching STEM Principles to Middle and High School Students Through the Design, Construction and Deployment of Water Quality Sensors," Advances in Engineering Education, vol. 3, no. 2 (Summer 2012). She is also Adjunct Professor in the Program in Computers, Communication, Technology, and Education at Teachers College, teaching courses on methodologies for researching technology in education and on online schools and schooling.

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Abstract- This paper describes the structure and impact of an NSF-funded ITEST project designed to enrich STEM education using educational modules that teach students to construct, program, and test a series of sensors used to monitor water quality. During the four years of the SENSE IT project, over 60 teachers across New York, New Jersey and Washington State were provided with equipment and professional development, and then implemented the modules in their classrooms with over 2,500 middle and high school students. Project evaluation results indicate that the curriculum was well received by teachers and students, could be integrated into several different subject areas and types of courses, and was effective for a wide range of students.

I. Introduction

This paper describes the development and implementation of the Student Enabled Network of Sensors for the Environment using Innovative Technology (SENSE IT, <http://senseit.org>), a carefully scaffolded set of curriculum modules tied to national education standards in science, math, and technology, which integrate fundamental science, technology, engineering and mathematics (STEM) principles while at the same time introducing students to the field of sensors and sensor networks in the context of assessing water quality.

Developing a sensor network for environmental monitoring creates a broad technology project which can readily provide a motivating context for a variety of science, math and pre-engineering classroom curricula. Sensors and sensor networks involve an information flow of the sensed quantities from the natural environment through the physics of the transducer and the electric circuit in which it is embedded, to a computer, to programs for data gathering and analysis and IT tools for data sharing, storage and display. Using SENSE IT materials, students build, calibrate and test a set of sensors and circuits in order to measure a variety of water quality parameters (temperature, conductivity, turbidity and depth). To build and understand their sensors, students must use a wide range of core knowledge of mathematics and physical science, as well as learn practical hands-on technology skills such as soldering and debugging circuits. Students then interface their sensors with computers, write programs to gather raw signals, implement calibration curves, and perform data manipulation and data logging. In later modules, students program their own communications protocols for wireless transmission of the sensor data and connect their computerized sensor stations together to form a distributed wireless sensor network. Additional modules explore the use and implications of this technology for biosciences and environmental research.

SENSE IT modules give students an opportunity to acquire and then use STEM skills while at the same time providing a real-world application of science (particularly environmental science), technology (pre-engineering and computing) and mathematics, all tied in a holistic way within the overarching theme of water quality. The project goals are to:

- To develop a sensor technologies curriculum for the high school classroom.
- To use environmental sensors to teach technology, engineering, mathematics, science, and critical workforce skills.
- To encourage learners to look at a local problem and local data with a global perspective.

- To promote awareness of sensor network-related careers and opportunities among high school teachers, students and guidance counselors.

The following sections will first address the question of why sensors are an excellent vehicle for such a curriculum, describe the curriculum and its participants in some detail, and then examine its impact on the students in terms of some of the specific skills and concepts that were embedded in the curriculum modules.

II. Why Sensors?

Sensors now play an important role in environmental research. The education of the 21st century environmental technology workforce therefore demands an understanding of sensor technology, as well as the ability to resolve complex environmental issues and to communicate findings to a broad audience. Developing and maintaining such a workforce calls for innovative educational programs that prepare future sensor technology professionals at a variety of levels and in a variety of environmental fields¹. This type of multidisciplinary, technology-based approach is not sufficiently reflected in our current educational programs.

The classroom integration of sensor development is therefore not only topical but offers highly interdisciplinary subject matter, providing motivating scenarios for teaching STEM topics and skill sets. SENSE IT provides students with the opportunity to learn about sensor technology through a hands-on, collaborative process of designing, constructing, programming and testing water quality sensors. Design-based activities such as SENSE IT provide a rich context for learning and lend themselves to sustained inquiry and revision. Application of learning is a worthy learning objective and an effective route to greater retention of knowledge and depth of mastery. As Caine notes², “Children learn best if they are immersed in complex experiences and are given the opportunity to actively process what they have learned.” This emphasis on application through design has been informed by research on the use of design for learning complex and interrelated ideas^{3,4,5,6,7,8}. Design-based activities also bridge to many of the models of project-based learning^{9,10,11,12,13}. In addition, SENSE IT reflects the best practices for developing technical talent outlined in the BEST (Building Engineering and Science Talent) report¹⁴, “What It Takes: Pre-K-12 Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics”: (1) Defined outcomes; (2) Sustained commitment; (3) Personalization; (4) Challenging content; and (5) Engaged adults.

III. SENSE IT

A. Overview of the SENSE IT project

Using SENSE IT materials, students build, calibrate and test a set of sensors and circuits in order to measure water quality parameters (temperature, conductivity, turbidity and depth). When deciding what kind of sensors the students would build, care was taken to create sensor designs that were accurate enough for students to make meaningful measurements, but also simple enough that high school students could understand what they were building and how it worked. To build and understand their sensors, students must use core knowledge of mathematics and physical science, as well as learn practical hands-on technology skills such as soldering and

debugging circuits. Students then interface their sensors with computers, write programs to gather raw signals, implement calibration curves, and perform data manipulation and data logging. In later modules, students program their own communications protocols for wireless transmission of the sensor data and connect their computerized sensor stations together to form a distributed wireless sensor network¹⁵. Additional modules explore the use and implications of this technology for biosciences and environmental research.

B. The Curriculum

The SENSE IT curriculum is comprised of four educational modules (<http://senseit.org/curriculum.html>). In Module 1, “Sensor development,” students learn about the principles of transducers, design, analyze and calibrate electronic circuits around their transducers in order to make numerical measurements of environmental quantities in appropriate units. Initially students work with thermistors to build temperature sensors, but additional add-on lessons enable students to develop a suite of sensors including temperature, conductivity, turbidity and depth sensors.

In Module 2, “Sensor deployment and data gathering,” students learn how to interface their sensors with a microprocessor, in this case, the LEGO NXT microcontroller. They use mathematical skills to calibrate the sensors’ outputs and write programs to integrate these calibration curves and display sensed quantities on a screen in appropriate units. In additional add-on lessons, students learn how to write data-logging programs to log time-stamped data over a sustained period of deployment.

The balance of Module 2 leads students through the development of additional sensors, including conductivity, turbidity and depth sensors. The conductivity sensor involves passing a current between two lengths of copper wire and measuring the voltage between the electrodes to calculate the resistance, and then convert that measurement to a conductivity value. Students write a NXT program to collect conductivity measurements and calibrate their sensors.

The turbidity sensor consists of two main components, a light source (light emitting diode or LED lamp) and a light sensitive device (photo-resistor). The LED and the photo-resistor are fixed a short distance apart in such a way that water can flow between them. The more turbid the water, the less light from the LED lamp will reach the photo-resistor. The photo-resistor is a device which changes its resistance depending how much light falls on it. By measuring the resistance of the photo-resistor, students can measure how much or how little light reached it from the LED lamp, and therefore determine turbidity. Students construct and calibrate their turbidity sensor and write a NXT program to collect and display turbidity measurements.

The final sensor is a pressure sensor, used to measure depth. Students figure out the mathematical relationship between pressure and depth, calibrate the sensor, and then write a NXT program which converts the pressure signals from the pressure sensor into a depth measurement. The program actually takes two measurements--it measures absolute ambient atmospheric pressure at the surface and simultaneously measures the absolute underwater pressure at depth. An electronic circuit then subtracts the atmospheric pressure from the underwater pressure reading to give a gauge pressure, with pressure at the surface being defined as zero. Because the sensor takes two measurements and calculates the difference, it is known as

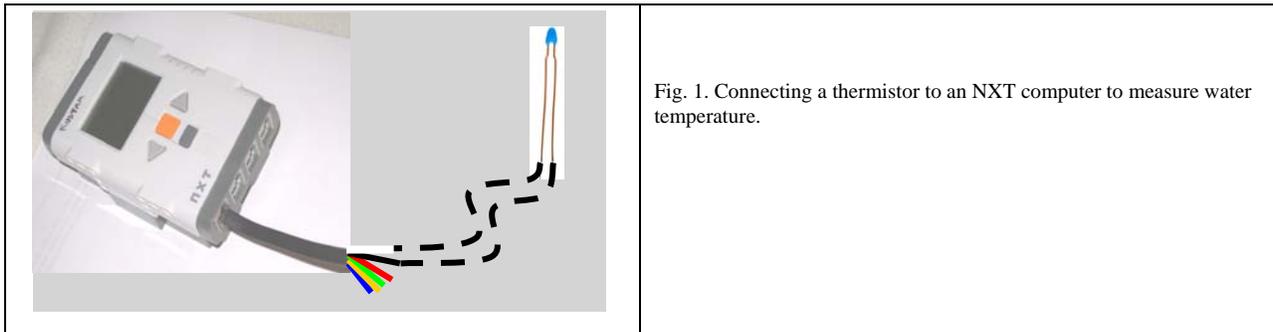
a differential pressure sensor. Students calibrate the depth sensor and write a program to record and display the depth measurements.

Module 3, “Environmental science,” puts the engineering activities in context by exploring environmental science issues that provide a meaningful motivation for the development and deployment of sensors. In this module, students work through a series of lessons that reveal water as a precious resource and demonstrate the importance of everyone doing their part to protect and manage that resource. Students investigate careers in environmental engineering that focus on the management of water and explore the sensors and sensor networks engineers are developing and deploying to monitor, manage and protect our water resources.

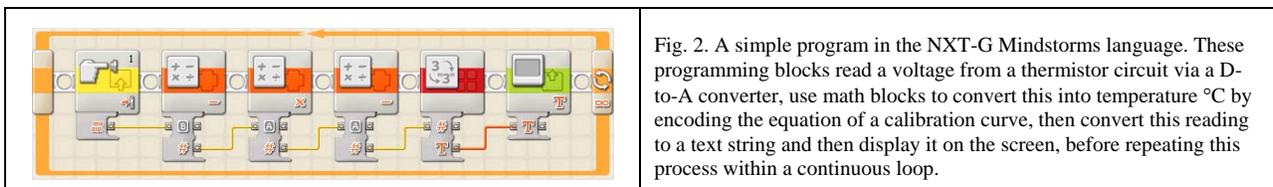
In Module 4, “Wireless sensor networks,” students learn about wireless communications and work in teams to build and program their own wireless distributed sensor network. Each sensor network consists of several remote sensor nodes, each node comprising temperature, salinity, turbidity and depth sensors, all built by the students. The students then program their own wireless communications protocols, so that each remote node transmits its sensed data back to a central hub, where it can be time stamped, logged and uploaded to a PC for analysis.

C. Materials

Students construct their sensors from scratch using standard off-the-shelf electronics components. Students are led step by step through the physics principles, circuitry and mathematical analysis required to build each sensor, with the aim of demystifying the “black box” effect associated with using commercially available probes in classrooms. Our thesis is that by building their own sensors, students will gain a better understanding, not only of how sensors work, but also of the meaning of the quantities that the sensors are used to measure.



Once students assemble a sensor, they connect it to a LEGO NXT microprocessor (see Figure 1). Students write programs on a PC and then download them to the NXT, where they are executed.



We used the NXT-G programming language, a very simple icon-based programming system that is easily assimilated by beginners with no previous programming experience. Despite its simplicity and speed of use in the classroom, this language is sophisticated enough for students

to use it to take readings from D-to-A converters, encode the equations of calibration curves using math blocks, write wireless communications programs using Bluetooth, and write data-logging programs to store sequences of time-stamped sensor readings in files (see Figure 2).

D. Professional Development Experiences for Educators

The professional development model for the teachers planning to teach the SENSE IT curriculum adopts the Technological Pedagogical Content Knowledge (TPACK) framework, which sees content knowledge, technology, and pedagogy not in isolation but believes that good teaching requires an understanding of how technology relates to both the pedagogy and the content, and how all three are bound together⁸. To be effective, professional development must therefore be in-depth, take place continuously over time, and be in context. SENSE IT teachers completed 120 hours of professional development by participating in two summer institutes (two week institutes during two consecutive summers, the second week with students), four professional development days (one each semester for two years), and classroom support visits during implementation.

During the first week of the summer institute, the teachers learned the module content, with enough time to work through all of the lessons and begin to devise implementation plans for their own classrooms. During the second week, each teacher was invited to bring two students to participate in a teaching laboratory, with the teachers teaching the modules in a highly supported environment, surrounded by SENSE IT staff (see Figure 4). This opportunity to implement the materials with students gave the teachers an opportunity to review the materials again and to see how they worked with students. They found this a very effective approach, both in terms of the amount of additional time they were able to spend with the curriculum and in terms of how seeing their own students work through the modules increased their own confidence in their ability to teach the SENSE IT modules to entire classes.

The professional development days, led by SENSE IT staff, were used to share successes and challenges, as well as to develop additional sensors and discuss STEM career information and opportunities. During the classroom visits, SENSE IT staff offered support during implementation and also experienced first-hand any implementation issues.

In addition to the SENSE IT professional development, a webinar focused on STEM career awareness was offered to guidance counselors associated with the SENSE IT participating schools and to the parents and students who attend the schools. The webinar participants discussed future employment opportunities, career preparation pathways, and advice on what teachers and students should look for in STEM programs when applying to schools.

And finally, all of the SENSE IT modules and developed support materials were made available on the SENSE IT project web site (<http://senseit.org>).

IV. Project Impact

The background surveys showed that the content covered by SENSE IT was new to both teachers and students, while the pedagogy (group work, open-ended investigations) was not a

common practice among most of the teachers or common to the experience of most of the students. Implementing a complex set of problem-based learning modules was therefore likely to be a challenge for the teachers and learning the concepts and skills embedded in the curriculum was likely to be a challenge for the students.

A. Teacher Ratings

The teachers were asked to rate how SENSE IT helped their students in various academic areas, using a scale of 1 to 5, with 5 being the highest. The overall ratings for both student learning and student enjoyment were high, with the few teachers (2-3 each year) who gave lower ratings explaining them as being the result of their own failure to teach well. In terms of specific ratings, most teachers felt that the curriculum had helped their students learn about sensors.

Table 1
Percent of teachers who gave ratings of 4-5 by course in each year

	Year 2 (n=32)	Year 1 (n=41)
Helped your students learn the role of sensors	91%	85%
Engaged your students	84%	76%
Helped your students understand how sensors work	78%	76%
Helped your students learn about the environment	72%	56%
Helped your students learn to work well in groups	69%	71%
Helped your students learn the principles of electricity	66%	54%
Reinforced your students' existing math skills	56%	61%
Gave your students new math skills	34%	32%

In addition to the above, teachers saw many additional benefits in using the SENSE IT curriculum with their students, ranging from the very specific to the more general. In part, their view of the benefits depended on the course that SENSE IT was integrated into, but most wrote about the general benefit that came from giving their students an opportunity to engage in a hands-on project that was tied to real-world problems. In fact, it was notable how many of their comments about the benefits included the phrase “hands on.”

B. Student Ratings

In post-implementation surveys, the students were also asked to rate SENSE IT in terms of how much they felt they had learned and how much they felt they had enjoyed it, in their case using a rating scale from A to F, including + and -. The high school students' ratings were high for both (85 percent gave an A or B for enjoyment and about 75 percent gave it an A or B for learning), but the middle school students' ratings were higher (over 98 percent gave it an A or B or learning and 80 percent for enjoyment). Males at both levels were slightly more enthusiastic than females.

When asked what they liked most about the project, the items mentioned most frequently by the high school students referred to the hands-on aspects of the project. The middle school students also liked the building but their second highest choice was working in groups and their third was the fact that the project was hands-on.

Their dislikes tell a great deal about why they like hands-on projects rather than more traditional forms of learning. In Year 1, the high schools students' complaints focused on the instructions, which they thought were too difficult to read, involved too much reading, or were unclear. In Year 2, after the curriculum modules had been revised on the basis of the Year 1 experience, the most-mentioned complaints were not related to the reading but to the math, which was mentioned by 45 percent of the students. The Year 2 middle school students also had the math, analyzing data, and using Excel at the top of their lists (50 percent, 44 percent, and 38 percent respectively), but for them, reading the instructions came in second (mentioned by 46 percent).

C. Student Learning

Assessing the impact of a complex and multi-part curriculum that is used in so many different situations poses challenges of its own. However, since a key goal of ITEST, and of STEM education projects in general, is to reach all students, whether middle or high school, in wealthy or poorer schools, academically higher or lower achieving, and male or female, the data reported here will focus on these groups in terms of changes in the key content knowledge and skills embedded in the curriculum related to algebra, electricity, water quality, and understanding of sensors. The algebra assessment was pre-test only in Year 1 (because it was designed as a readiness assessment) but a post-test was added in Year 2, while the water quality assessment was post-test only in both years. The electricity and sensor assessments were both pre- and post-test. In what follows, we look at Year 2 data only, since it can be assumed that the teaching was better in the second year. In all instances, high school and middle school are compared, since middle school students' scores on the pre-tests were always considerably lower than the high school students' scores. However, analysis showed that there were few differences by gender, so gender differences are not considered.

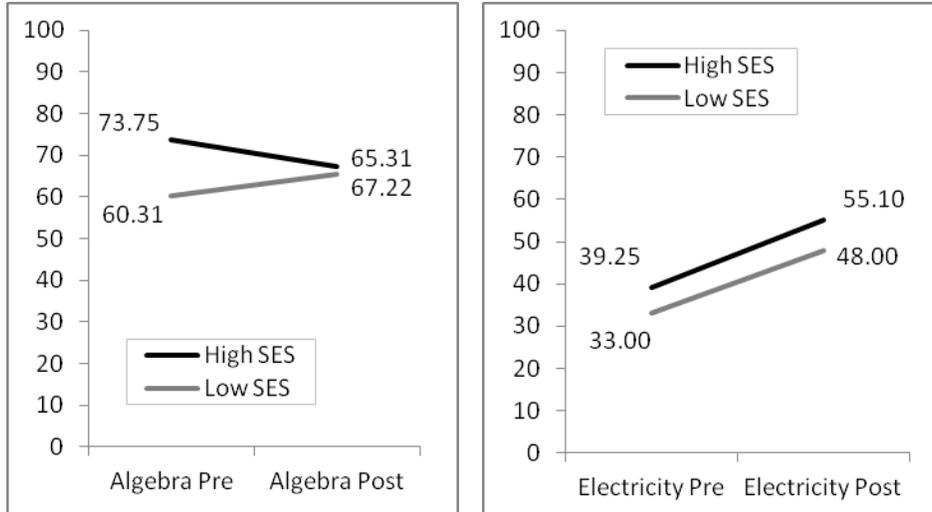
1) Socioeconomic Status (SES)

To determine SES, we used the percent of students at a school receiving free and reduced lunch, a common measure of the socioeconomic status of students. Since schools that have over 39.15 percent of their students receiving free or reduced lunch are considered low SES schools, all students in those schools were therefore considered to be lower SES—approximately 11 percent of the high school students and 50 percent of the middle school students.

As noted above, the teachers felt that the students struggled with the math needed for SENSE IT. The results show that students in higher SES schools did significantly better on the algebra pre-test, but not on the algebra post-test. As Figure 3 shows, the scores of students in higher SES schools declined while those in lower SES schools increased, thus narrowing the gap. This was not the case, however, for electricity, where the gap at the start, although narrower than that for algebra, remained. Note that all scores have been converted to a scale of 100 so can be read as percents.

Figure 3

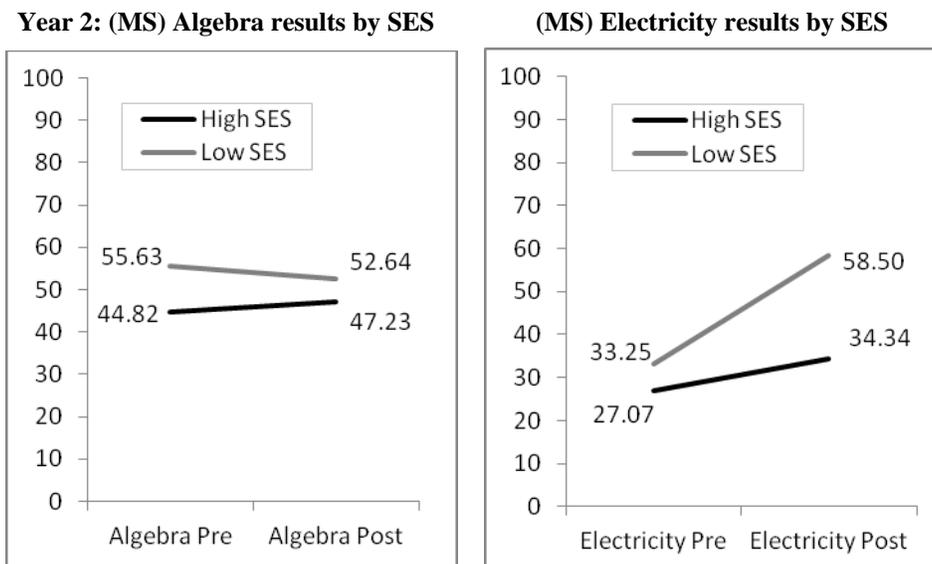
Year 2: (HS) Algebra results by SES Year 2: (HS) Electricity results by SES



It is not clear why the algebra scores for the high school students in higher SES schools declined, but it may have had something to do with students nearing the end of their senior year.

At the middle school level, in contrast, students in lower SES schools did *better* than students in higher SES schools on the pre-tests for both assessments. However, while the results of two separate analyses of covariance show that the two groups were not significantly different on algebra post-test, students in lower SES schools performed significantly better than those in higher SES schools on the electricity post-test (see Figure 4).

Figure 4

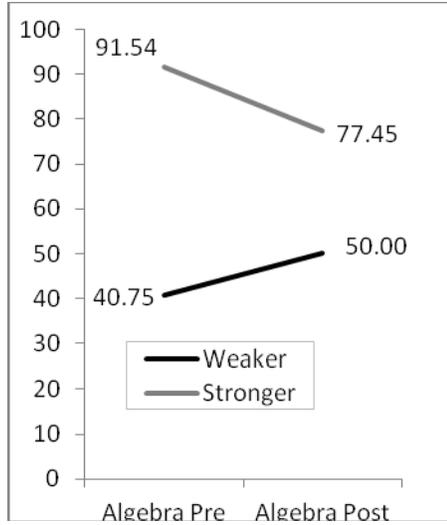


2) Weaker compared to stronger students

There was a similar pattern when weaker and stronger students are compared. Weaker and stronger students were defined according to whether they scored above or below the mean scores for each test: high school algebra (71.82), high school electricity (38.43), middle school algebra (47.84), and middle school electricity (29.37). Approximately 40 percent of high school students and 55 percent of middle school students fell below the mean.

Figure 5

Year 2 (HS) Algebra results:
weaker/stronger



Year 2 (HS) Electricity results:
weaker/stronger

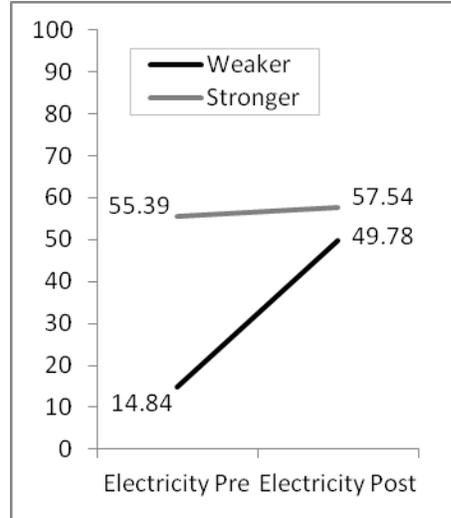
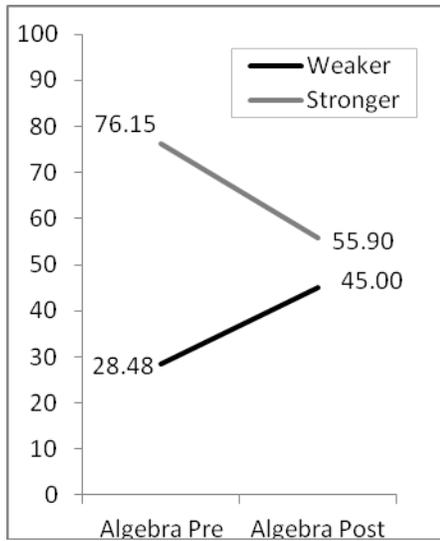
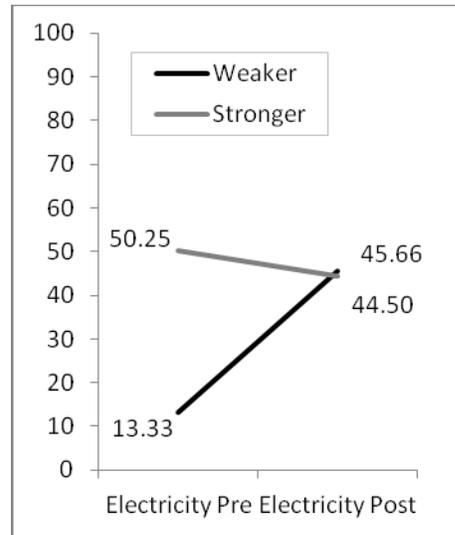


Figure 6

Year 2 (MS) Algebra results:
weaker/stronger



Year 2 (MS) Electricity results:
weaker/stronger



We can summarize these findings as follows:

For SES

- For high school algebra, the gap between high SES and low SES students *narrowed*.
- For high school electricity, the gap was not as great and *remained about the same*.

- For middle school algebra, low SES students scored higher than high SES students on the pre-test and the difference between them *did not change*.
- For middle school electricity, low SES students scored higher than high SES students on the pre-test but they also *increased more*.

For weaker compared to stronger students

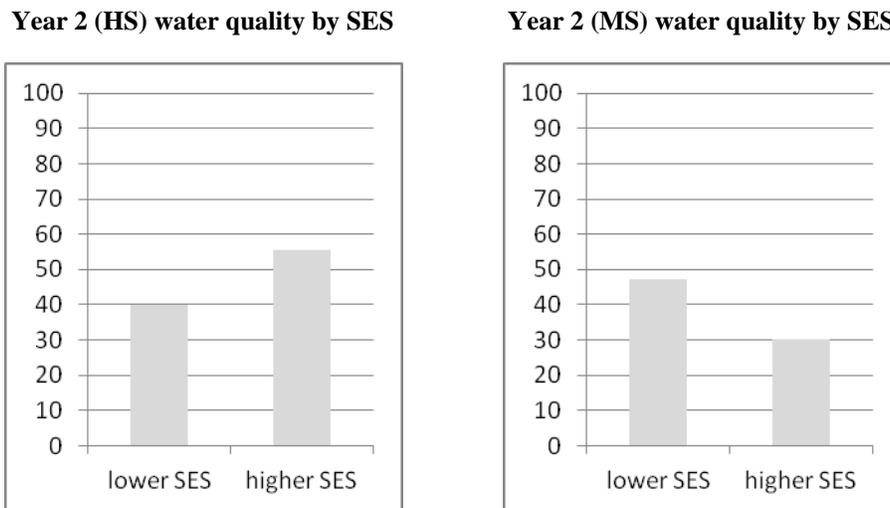
- For high school algebra, the gap between the weaker and stronger students *narrowed*.
- For high school electricity, the gap between the weaker and stronger students *narrowed*, and to a greater extent than for algebra.
- For middle school algebra, the gap between the weaker and stronger students *narrowed*.
- For middle school electricity, the gap between the weaker and stronger students *closed completely*.

Taken together, these results suggest that participating in SENSE IT led to higher scores for all but higher SES and academically stronger high school students, and that this participation particularly benefited students in low SES schools and weaker students in all schools.

3) *Water quality*

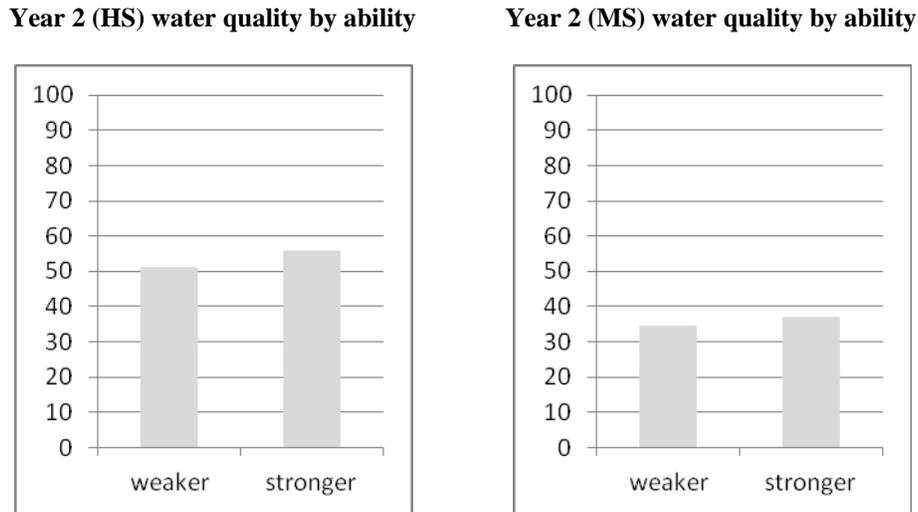
The students were given a post-only assessment in the use of sensor data in determining water quality. The results for middle school and high school showed that at the high school level, students in higher SES schools did significantly better on the water quality assessments, but at the middle school level, students in lower SES schools scored significantly higher (see Figure 7).

Figure 7



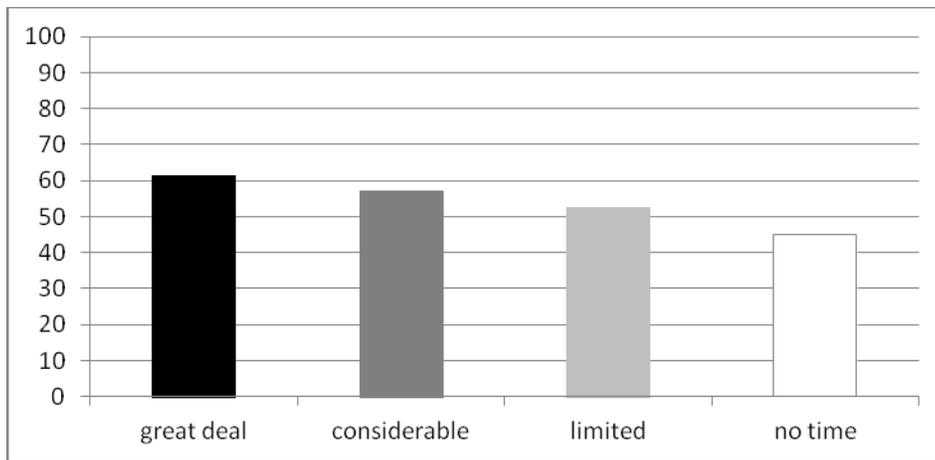
The same was not the case for the weaker compared to the stronger students at either the high school or middle school level. In this case, the stronger students did significantly better than the weaker students, whether the two groups were defined by their algebra pre-test scores. The differences using the electricity pre-test scores are shown in Figure 8.

Figure 8



Not all teachers focused on relating sensor use to water quality—many of the Physics and Engineering teachers, for example, did not feel that water quality fit well with their content. For water quality, therefore, time spent--rather than SES or student ability-- seems to have made the difference between lower and higher scores on the water quality assessments. Teachers reported if they had spent “a great deal of time,” “a considerable amount of time,” “a limited amount of time,” and “no time” on water quality issues. At the high school level, student performance on the water quality assessment differed significantly by time spent. In addition, those who spent a great deal of time scored significantly higher than those that spent limited or no time, but did not differ significantly from those who spent a considerable amount of time (see Figure 9).

Figure 9
Water quality scores by time spent



4) Understanding of sensors

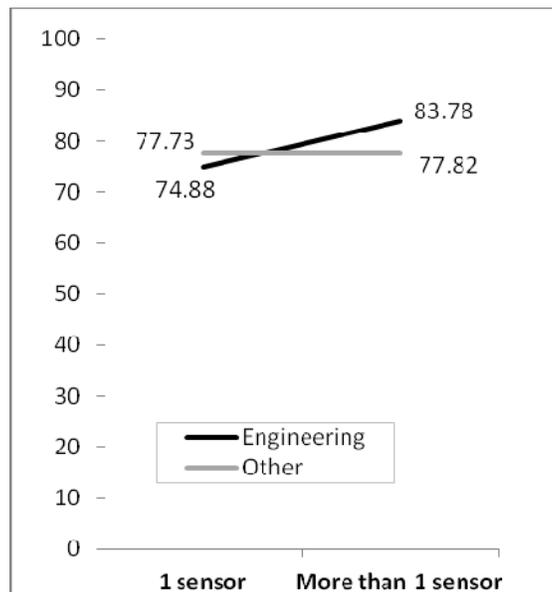
The teachers reported that SENSE IT helped students understand the role of sensors in monitoring the environment, but this appreciation did not translate immediately into the students' ability to define what a sensor does. After participating in SENSE IT, 50 percent of high school students and over 80 percent of middle school students were unable to answer a post-survey

question that asked them to describe what a sensor does--and most of those who could offer a description only included the sensor's ability to read or gather data, not to convert it. This finding is confirmed by a second assessment of student understanding of sensors. This was a pile sort, a Flash-based activity that asked the students to sort eighteen cards, twelve of which had pictures of items that have sensors and six of which had pictures of items that do not have sensors. Not all classes did the pile sort, primarily because of lack of access to computer labs.

Students had the most trouble with items that control for temperature but at first glance might not appear to, such as a pop-up toaster as opposed to an oven. In the non-sensor category, a majority of students believed that anything electronic or mechanical in appearance must have a sensor in it, for example, iPod ear buds. As we have found in previous projects^{16, 17}, students who can succeed in building and deploying complex artifacts do not necessarily learn the underlying principles. The students' inability to define what a sensor does suggest that the students needed more explicit instruction to understand the role that sensors play in everyday life.

It seemed possible that students in engineering-related courses (n=84) would have a better grasp of how sensors work than students in other science courses (earth science, biology, general science, etc., n=478) and also that students who build more than one sensor would improve more. The results showed that while there was a significant difference for those in engineering-related classes between those who built one sensor and those who built more than one, this was not the case for those in other types of classes. In other words, as the Figure 10 shows, students in engineering-related classes better understood what a sensor was when they built more than one sensor, but this did not make a difference for students in the other classes.

Figure 10
Year 2: Difference in pile-sort scores for engineering student, by number of sensors built

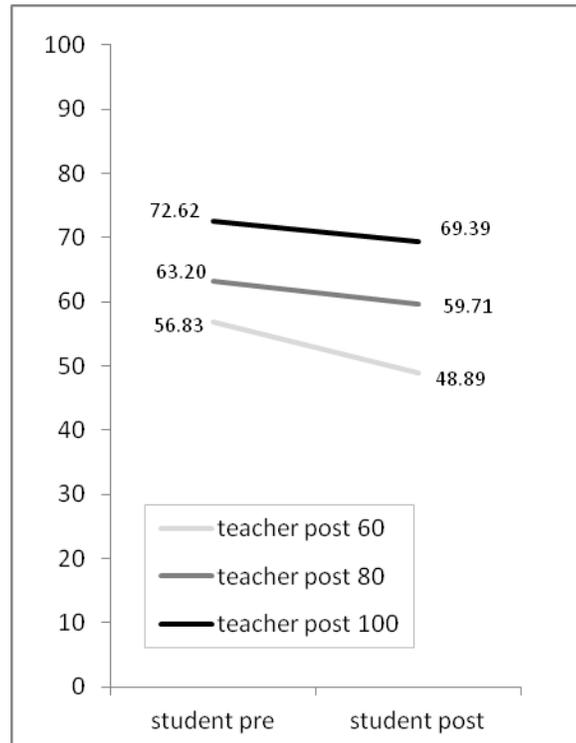


5) *The link between teacher performance and student results*

Teachers took the algebra pre-tests and the electricity pre- and post-tests, partly to familiarize them with the process and partly so the SENSE IT staff could assess their background knowledge. Since it seemed likely, based on findings from other projects^{18, 19}, that teachers who

knew the material well would be better able to teach it, we used these results to explore the relationship between teacher and student performance. In summary, in all cases, teachers' scores were significant predictors of student scores. In addition, weaker students were more likely to better if their teachers' scores were high and to do poorly if their teachers' scores were low.

Figure 11
Year 2: Relationship between teacher and student algebra scores



V. Next Steps

In an attempt to formulate a plan to scale-up the SENSE IT program and reach more students and teachers across the country, a no-cost extension was requested for the project. The pilot extension plan involved reaching out to new teachers through regional science centers for face-to-face workshops focused on a single sensor, followed up with online webinars and instruction--for a total of ten hours of professional development associated with each sensor. The recruited teachers were able to decide which sensor they would like to build and implement in their classroom. The teachers were provided with the necessary equipment and were required to report data to the project evaluator. In addition, the classroom materials were condensed to potentially increase the number of teachers willing to use the materials, compress the professional development experiences to increase the likelihood of teacher interest, and provide more explicit instruction for students as to the role that sensors play in everyday life.

VI. Conclusion

SENSE IT offers fully integrated STEM education modules, requiring students to learn and apply principles within science, technology, pre-engineering, and mathematics to construct and deploy water quality sensors. Tracked implementation of SENSE IT in classrooms demonstrates that it is possible, although additional time and effort is required, to have students carry out complex problem-based, hands-on projects within the scope of existing standard curricula and tied to state and national education standards. The applied themes of environmental stewardship and sensor networks provide: 1) a motivating and meaningful scenario for learning a wide range of core math, science, and technology topics and workforce readiness skills, 2) an awareness of the ubiquity of sensors in our world while demonstrating the link between biological, physical and social sciences, 3) a means to encourage learners to look at local water quality and environmental issues and data from a global perspective, and 4) an opportunity to engage students in the use of sensors for environmental monitoring and to learn about potential careers involved with environmental monitoring and management.

Research results indicate that the participating teachers were positive about the benefits of the SENSE IT curriculum for their students, both in terms of how it engaged them and in terms of what they had learned. Teacher responses indicate that this success was in part because they were able to adapt the curriculum to fit into their existing courses and to meet their students' academic levels. In other words, a strength of the curriculum was its flexibility—as shown by the integration of SENSE IT into a wide range of courses with a wide range of students—from upper level high school students to middle school students, from academically advanced students to academically challenged students, from Advanced Placement courses to courses for those students who could not qualify for higher level science. The research results suggest that participating in SENSE IT led to higher scores for all but higher SES and academically stronger high school students, and that SENSE IT participation particularly benefited students in low SES schools and weaker students in all schools. Although SENSE IT can be taught by teachers in many subject areas, the strong correlation between teacher and student results indicates that teacher preparation is necessary if strong student results are desired.

Based on research results, we hope to grow the SENSE IT program. However, we are also aware that there are too many activities and lessons for the average teacher to use in the classroom and that the two-week summer workshop model requires a time commitment that many teachers cannot make. In order to reach more teachers, it will be necessary to condense and compress both the professional development experiences and the classroom materials. As we grow the program and network of SENSE IT teachers, we also plan to administer similar evaluation tools to continue understanding the impact of SENSE IT materials on students and teachers. The refined SENSE IT materials will continue to ease classroom implementation issues and increase the numbers of teachers and students exposed to hands-on learning experiences that revolve around the world of sensors, as well as help them prepare students to handle the complex, multidisciplinary challenges awaiting them in the 21st century, technology-focused workplace.

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