

Enhancing High School Science Through Sensor-Based Lab Exercises

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Abstract – A participant’s experiences as part of the RAISE program (Revitalizing Achievement by using Instrumentation in Science Education). This program involved Polytechnic University professors, graduate and undergraduate students, high school teachers and their students. It seeks to facilitate the implementation of sensor-based labs in the curriculum of high schools in the NYC school system with a particular emphasis in science courses subject to state-wide Regents Exams.

The present article is based on the experience of a high school teacher in George Westinghouse High School. The program was perceived to have a positive effect on student performance and pedagogy.

INTRODUCTION

Mandated laboratory exercises are part of the curriculum in some New York State science courses. Laboratory participation is prescribed in all Regents science courses and must be documented by completed lab exercises that are kept on file for several years and are subject to review by the state. The need for effective, engaging lab exercises naturally feeds into the possible use of sensors to enhance the illustration of scientific principals and the scientific method.

The enhancement of laboratories was carried under the auspices of RAISE [1-4]. Project RAISE (Revitalizing Achievement by Using Instrumentation in Science Education) is a program in which graduate and undergraduate students (Fellows) from Polytechnic University of New York assist high school science teachers primarily through the introduction and use of sensor-based equipment to enhance laboratory content and methods. In addition, the Fellows provide other forms of assistance to the teachers. RAISE Fellows have been

employed in Living Environment, Active and Regents Physics, Marine Science, and Earth Science classes in four New York City inner-city high schools, three of which are located in Brooklyn and one in Manhattan [1]. RAISE is funded by the National Science Foundation (NSF)

RAISE THE PLANNING STAGE

During the spring of 2004, Dr. Vikram Kapila of Polytechnic University’s mechanical engineering department approached the Westinghouse Assistant Principal of science and math, with the prospect of participating in the RAISE program should the program be funded. Several Westinghouse science teachers agreed to take part and that summer, along with teachers from three other high schools, we had our initiation. During the initiation, we had a week of introduction to the program, the sensor based labs and the RAISE fellows. These were both undergraduate and graduate students, and we would be working with them to upgrade our lab procedures. The orientation was needed, not only for the teachers, but for the Fellows; many of them had expectations of the high school students that would not be borne out in practice. While not long out of high school themselves, most had no experience in instruction and they would need to perform in front of students as the given lab exercise would need introduction, explanation and elaboration. Some of the effort during that first summer session was devoted to robotics. This turned out not to be as valuable as the laboratory practice and familiarization with the software and established exercises. The week of orientation also allowed for the student-teacher teams to sort out their schedules. The requirement to create an original lab in each discipline during this week gave the teachers and Fellows space to establish a working relationship and eased the transition to the classroom where flexibility was needed. Because the Fellows represented novel participant, they could also be a distraction if not handled sensitively.

GEORGE WESTINGHOUSE HIGH SCHOOL

George Westinghouse is part of the NYC school system which contains some 1.1 million students and 80,000 teachers. The school, with an enrollment of 1200-1300 students, was being reoriented; from a vocational/technical school to an Information Technology (IT) technical school. Many of the incoming students had tested several years below grade level. At the same time, the IT emphasis ensured that the students gained significant computer skills, to the extent that they often demonstrated more expertise than their science teacher, in computers.

ABOUT THE AUTHOR

As a high school science teacher in his seventh year of teaching in the NYC school system and third year of involvement in the RAISE program, it seemed incumbent to revisit some aspects of evolution as an educator. Having come to this profession in his later working years, some reorientation of thinking was required. The author first career was as a metallurgical engineer for 7 years. Next he spent almost 20 years in health food retail. The acquisition of recent knowledge and techniques was necessary for to upgrade one's technical skills. The author's first experience as a teacher was three years as a lab instructor of undergraduates in an engineering college when he was pursuing his masters degree prior to working as a metallurgical engineer. That experience was positive and encouraged him to become a substitute teacher for two years. Substitute teaching helped to segue into full-time teaching. Ditto for B. S. and M. S. degrees in Material Science since this necessitated much experimental hands-on activity and thesis writing. Nevertheless, as the only physics teacher in a high school, the burden of providing meaningful state-mandated lab exercises was a solitary one. Given this situation, casting about for new modes and methods was necessary, if not sufficient.

PRIOR EXPERIENCE WITH SENSORS

My first exposure to computer based labs, equipment and software occurred, unintentionally, about five years ago (two years prior to RAISE) as part of a summer program under the auspices of STIR. STIR was organized at Lehman College to enhance the techniques of high school science teachers. A variety of science educators and vendors made presentations to a mix of high school and middle school science teachers from New York and New Jersey over the course of a week. As part of STIR, we were lead by a Vernier, Inc employee, using Vernier sensors and software and laptops supplied by the college for an entire day. As part of the same program, we also used Pasco, Inc. equipment for an entire day and the comparison was valuable. At the end of this program, each

participant had to develop a lab using the equipment and techniques acquired during the summer.

Up till that time, almost all of my computer expertise (if use that word is accurate) was on Macintosh computer. This typically meant quickly getting lost when using Windows-based applications. However, it seemed apparent to this author that the Vernier equipment was more versatile and easier to use than the Pasco. At the end of the program, the grant under which the program was funded allowed for \$400 of equipment to be purchased by each participant. Vernier sensors were the option I chose, which were then contributed to the high school stockpile of lab supplies.

The following school year, a one-day Saturday workshop using Vernier equipment was organized by STIR for chemistry teachers at New York University Washington Square campus using their labs. Again, it was quite impressive but I struggled to keep up as every so often I would press the wrong key or click on the wrong tab and get lost. . Out of necessity I acquired a personal laptop that spring and a video-tape tutorial was employed to develop some proficiency with computers.

THE PROGRESSION – YEAR ONE

After the summer week of training for RAISE, Westinghouse teachers were teamed up with Polytechnic Fellows. Rapidly, in the author's case, we developed a series of labs for a course designated Active Physics, a non-Regents course offered to 9th grade students in the New York school system. While not as rigorous as Regents physics, there is a certain level of competence necessary to which students must accommodate. We had four laptops at our disposal and sufficient sensors to perform the same exercises on each machine simultaneously. It was relatively easy to instruct the classes in the concepts of velocity, acceleration, mass, inertia, etc. using modified handbook lab exercises as well as some specially developed, particularly as related to heat phenomena. Simultaneously, other teachers and their partner Fellows, developed biological labs for Living Environment, a Regents course, and the equipment was shared through suitable scheduling. The presence of the Polytechnic Fellows in the classroom proved crucial to the performance of the lab exercises because of their experience, competence and their sincere desire to enrich the student's experience.

One of the biggest challenges is illustrating concepts in abstraction. A typical example is inertia. A properly designed lab can show that more force is needed to achieve the same acceleration as the object's mass increases. The relative ease with which acceleration can be measured with sensors, rather than inferred through

tedious calculations, contributes to the student comprehension, especially when they lack the rigorous mathematical background.

At first the students were nervous and challenged by the need to absorb a great deal of new material. As a way to ease into the new vocabulary we were trying to inculcate, we made extensive, selective use of physics video tapes. They reinforced the classroom material and served better than the textbook in grabbing the student's attention. Thus, when we came to perform a lab activity, we shared a vocabulary and the students had at least a vicarious experience to relate to the execution of the lab. Needless to say, with a limited number of laptops, competition for position often became paramount within a group of lab partners. Each group had approximately 6-8 students, which is more than the optimal 3-4. Once the groups sorted themselves out, the exercises would proceed and most finished collecting their data and writing their labs in the time allotted. Most of our students possess some computer skills and were able to navigate the screens and data tables as needed.

In comparison to conventional, non-sensor based labs, much less time was spent in student set-up and data recording. More time is needed for the instructor to insure that the necessary equipment is available and working properly and then to secure the apparatus at the end of the exercise. Through measurement of parameters such as acceleration, rather than calculation, student interest remains focused on the outcome rather than the means of a given exercise.

YEAR TWO

The academic year was prefaced again with a week of orientation at the end of the summer. Earlier, during the previous spring, various high school teachers were tasked with interviewing and assessing new undergraduate and graduate students seeking to participate in the program, as Fellows. The experience of the previous year gave critical insight in terms of evaluating the college students likely to positively interact with the high school students. This new academic year saw Active Physics replaced with Marine Science, another non-Regents course in the New York State curriculum. Again we had a week during the summer to become acquainted with Sensors and to pair up with Polytechnic Fellows. Again a graduate student was assigned to assist our George Westinghouse students. An undergraduate, was also involved and responsibilities were shared. There is no Vernier Lab manual for Marine Science and it was necessary to modify Biology and Chemistry labs. Additionally, we had to develop other labs to illustrate important concepts that are not covered in Vernier material. Generally, the labs were well received by the students even though there is no lab requirement for

this course. In such a course, labs can provide a valuable diversion from the normal sequence of instruction as well as illustrating phenomena that would have to be taken on faith under other circumstances. An example is the diffusion of saline solution through animal membrane, in this case taken from a hard boiled egg. Such commonplace materials resonated with our students and clue them into complexities that occur in their everyday life that they would be unaware of, absent their science course.

At this point it should be noted that, simultaneously, other Westinghouse students were studying AP Chemistry. This course entailed using the same equipment and software. However, the facilities employed were outside Westinghouse, at City Tech College. The lab portion of this course required about half of the labs to be computer based. This added exposure in Chemistry helped to lift competence and confidence in the use of Vernier equipment in Marine Science. City Tech personnel were available to set up Chemistry labs and resolve the glitches that inevitably occur when novel programs are being instituted.

YEAR THREE

After our summer exposure to sensors and some new fellows, found us teaching a two semester course of Earth Science in one semester. This necessitated a regimen of two labs per week. Fortunately, the same Polytechnic Fellows were again selected for Westinghouse. This reconnection saved the time needed for two or more people to get on the same page. Again, while many handbook earth science labs were used, it was also found expedient to develop our own labs for subjects not treated by Vernier..

With the termination of the RAISE program, next year, we will lose the use of many of the sensors. This will constrict our ability to perform many of the labs we have developed. Because George Westinghouse is an IT school, computers are widely distributed and don't pose a bottleneck. Funding for sensors may be available along with normal laboratory supplies.

EPILOG

As the RAISE program reaches the end of its funding, the question of continuity becomes paramount. While use of most of the sensors and peripherals will be lost, the high school has acquired a core of a few fundamental sensors, the necessary software and lab manuals. This should allow for some sensor based labs and demonstrations to be performed. Additions to our inventory of sensors and peripherals might be funded through grant applications.

This summer, the author participated in a new program, WISE, (Summer Workshop in Instrumentation, Sensors and Engineering) (Iskander et al, 2007). WISE provided training in sensors for 20 middle and high school math and science teachers in a two-week residential institute at Polytechnic University. While this program does provide teachers of science with sensors and relevant training, there is no involvement with graduate and undergraduate students in the high schools.

REFLECTIONS ON RAISE

It is difficult to be objective about a subject after an involvement of three years or more. From my perspective, it seems that sensor based labs are inevitable for the reasons given in this document. Data collection through charts, tape recorders and various counters has existed for many decades; the advent of affordable computers paired with sensors is simply an extension of this process. What is needed is more exposure of high school teachers and laboratory associates to these techniques and provision of adequate training as needed. In the author's experience, the teachers involved in the RAISE program remained in the program and implemented the computer based labs in their schools. Monthly meetings kept the group current with regard to developments generated by teachers and the Polytechnic Fellows helping them. Likewise, in our school, the teachers exposed to the RAISE program have adopted the sensor based labs as the standard of their classrooms. The other science teachers did not adopt sensors in their labs which is understandable, given (1) the extent of the learning curve, (2) the lack of help or training, and (3) the paucity of sensors in the high school. While new lab space has been created, at this time a wholesale department-scale commitment to these types of labs is absent.

In the author's opinion the use of sensors and computers to execute the required exercises yields a superior learning experience that can enhance the student's understanding and help meet the state mandated standards for a subject [5]. For example, one phenomenon that has proven difficult to transmit is the heating curve of water. Trying to illustrate the series of events with charts fails with most students. Using a temperature sensor, frozen into a cup of water like a Popsicle and then slowly heated in a beaker to the boiling point of water yields a textbook-type graph that the typical student can relate to the phase changes taking place.

The use of sensors is clearly beneficial in high school science education. However teachers need training in order to use sensors. Some sort of certification process should be considered for teachers who feel the need to adapt. This at a time when the use of sensors becomes easier as software and equipment design improves.

Additionally, more types of phenomena can be studied as different sensors are developed. This begs the question, what are we waiting for?

ASSESSMENT

Objective assessment of the effectiveness of sensor based labs is difficult to come by. An independent observer was employed and reported preliminary findings in [6]. There are serious difficulties in assessing an effort like RAISE including:

- 1) Comparing baseline to subsequent classes assumes equality of student ability between years, this equality can be questioned due to normal variability in incoming classes and the small sample size.
- 2) In comparing RAISE to non-RAISE classes there are no comparison groups for some courses, most notably Regents Physics.
- 3) There may be variability between teachers regarding their grading practices.
- 4) Comparing RAISE and non-RAISE classes for the same teacher is problematic because of transfer of information from RAISE class to non-RAISE class. Also, some classes are not created as equal to others—for example, "honors" classes."

Data is available for one comparison group of RAISE and Non-RAISE taking Living Environment in Year-1 of RAISE (Fig. 1). The Percentage of Students that took the Regents Test was higher for the RAISE group. Of those students that took the test, a higher percentage of RAISE students passed and the average grade of RAISE students was higher.

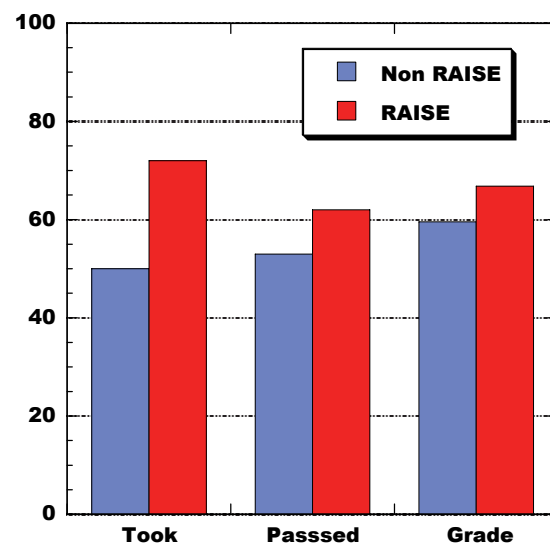


Fig. 1 – Effect of Participation in RAISE on Student Performance in Living Environment

CONCLUSIONS

Why go through the trouble of introducing computer labs when many tried and true procedures exist, developed by generations of science teachers? Why write new labs and have to proof them and obtain new materials and probes? Some possible answers to these questions are listed next.

Perhaps a school such as George Westinghouse, lacking in adequate lab space, electric service, water supply, gas supply, lab benches, operational hoods and safety equipment is still required to perform 30 exercises per year per student in Earth Science, Chemistry and Living Environment. In this event, computer based labs provide the ability to perform other than traditional experiments that illustrate the important aspects of the subject without more of an investment than for a few laptops and some probes and still meet state-mandated requirements. If computers are unavailable, exercises and hardware are available that adapt TI-83 calculators to collect and display data.

Perhaps it is crucial to demonstrate transient phenomena such as sound transmission through various materials or the progress of a chemical reaction. Absent specialized equipment such as oscilloscopes and colorimeters, it is virtually impossible to perform such procedures unless computer based labs are employed. Thus, the lab teacher and students can boldly go where no high school labs have gone before.

Rather than having to tediously plot data of dependent and independent variables, the software allows for data massage and makes printing of data and graphs very simple. It also enables the export of data into Excel documents. The various curve-fitting options take the student out of the realm of liner relationships.

Perhaps most importantly, computer based labs prepare and familiarize high school students with techniques applicable to advanced courses where such labs are requisite.

The availability of Sensors and the support of Polytechnic Fellows enabled several student groups to develop independent projects for the annual science fair and to compete on a city-wide basis with other students.

Because the labs are computer based, it is easy to save data when a lab can't be completed in the allotted time. It is also easy for groups to share data through using a computer connected to a DLP projector display.

To inject computer based labs into a curriculum need not be traumatic. The transition from what might be called analog labs can be gradual. Workshops are available for

teacher training at reasonable cost and customer support is good. The acquisition of hardware can also be gradual. The laptops and desktops we employ are mostly castoffs of the technology department and the demands of data acquisition software are modest. Grants may be available from non-profit or governmental agencies. The key is to start. What is needed is a geometric increase where teachers and college students train other teachers in a given school until computer based labs become the standard. Recent science graduates are sure to have had prior exposure to such labs and often are well versed in sensors. They would be the logical choices to include in RAISE type programs.

It should be noted that teachers not exposed to the RAISE program have not exhibited much curiosity or enthusiasm for computer based labs. In fairness, established teachers may lack the skills outlined above. Certainly, most curriculums can be satisfied without the use of computers and sensors. Another factor is the training needed for lab associates. They need to become familiar with the equipment so that they can set up and tear down apparatus and determine when an item is not performing or broken. Some probes need special storage. Some need calibration some time before the actual performance of an exercise. Three years is not enough to establish an new culture, which is what the introduction of sensor-based labs represents. It is regrettable that RAISE was not further funded and the established base will not be available to other teachers in the NYC school system.

ACKNOWLEDGEMENTS

Revitalizing Achievement by using Instrumentation in Science Education (RAISE) is supported by the GK-12 Fellows Program of the National Science Foundation under grant DGE-0337668. Thanks are due to Drs. Vikram Kapila, Magued Iskander and Noel Kriftcher who are the project PI The author would like to thank Polytechnic University Fellows William Kok, Arsen Zavlayanov, and Edwin Yu, for their cooperation. Thanks are also due to the New York City Department of Education and to Dr. Raju Philip Assistant Principal of Science and math at George Westinghouse High School.

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