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When Educational Technology Meets New Pedagogical Methods

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The Science and Mathematic faculty at Salve Regina University have been working under the Eisenhower and RIBGHE Partnership Grant for the past 8 years. The RIBGHE (Rhode Island Board of Governors of Higher Education) Partnership Grant formally known as Eisenhower, works with high schools across the state to improve methods used in the science and math classrooms. (1) The cornerstones of the program consist of: 1) introducing technology in the high schools in R.I. 2) introducing new pedagogical methods in science education and 3) training teachers to develop inquiry-based curricular materials. Initially the grant was implemented to introduce technology into the schools. (2) Although with the addition of the "No Child Left Behind Act" signed by President Bush on January 8, 2002 and reviewing the goals of this grant, the focus has turned to underprivileged schools. However, even with this change, the main objective has always been the three cornerstones.

PACO Scientific, one of the new major manufactures of state-of-the art educational technology, linked the grant program to develop guided inquiry curriculum for high school science teachers. The following explains the purpose of the grant and the wonderful implications that it has offered along with Salve Regina University's important role with the grant. With Salve Regina's role, came my task as an advanced student to help in the revisions and success of the lab write activities both for the PASCO project and the training manual for the high school teachers.

The first corner stone was introducing new educational technology in high schools of Rhode Island. Computer technology has evolved now to the point where it can greatly facilitate the use of inquiry learning on many levels, and provide new tools for representing the nature of science in the classroom. This use of technology to support new teaching approaches and objectives holds great promise for improving science education in the classroom, as long as the inherent limitations are recognized and technology is used as a tool rather than as a foundation. (3)

Some of these technologies can actually help transform science "from canned labs and the passive memorization of content to a dynamic, hands-on, authentic process of investigation and discovery." (3) The interactive nature of computer technology allows students to carry out inquiry-based activities, using topics, questions, and even theories that they themselves define and develop. Through this new technology and being interactive, it does away with the passivity associated with the traditional learning model. The teacher is able to become more engaged with the students and act as a guide and facilitator instead of just standing in front of the class room and lecturing. (3) Students are able to take pride in their own work with instructors guiding them in the right direction instead of just telling them what to do. This also allows the student to be engaged in a more realistic scientific inquiry experience. "Computer-supported learning environments make it easier for students to propose their own research focus, produce their own data, and continue their inquiry as new questions arise, thus replicating scientific inquiry more realistically." (3)

Computer technology can also facilitate the manipulation of variables in experiments and models. Students can thus predict, observe, and explore the effects of experimental parameters on dependent variables in more complex experiments than could ordinarily be replicated in the classroom. (3) With the correct probes and software, students can see the effects of heating up a reaction, cooling it down, or even the effects of changing the pressure and volume. Through technology, students are able to see a direct response to the manipulation of parameters in front of them on the computer. Being able to see a direct response allows the students to make conclusions and draw correlations between the different parameters that they manipulated.

Even though simulations can be interactive, students cannot test alternative models or variables that are not programmed into the system. It should also be noted about simulations is their potential effect on the representation of reality. Computer simulations should not be used to replace real experiences, but rather to supplement them. The limitations of virtual representations should be pointed out by the teacher, and an appropriate context provided to students. "If technology is used in balance with real experience, though, and is placed in its proper context, it can enrich the classroom by providing new and contrasting contexts in which to understand experiences."(3)

Before software and equipment where cost prohibitive that this type of technology was not readily available; PASCO Scientific has been able to relieve that problem. PASCO has developed a new line of interface boxes, probes and computer software that is available to chemistry labs at both the high school and college level. PASCO has basically two configurations. The first one is the GLX interface box which can serve as a mobile computer yet only the size of a video game. The interface box can serve as a full computer. It's able to have four sensors connected at the same time and allow the experiment to be performed at the same time. The small "computer" screen allows variable and parameters to be set-up and display the results as well as data evaluation.

If mobility is not a vital issue, the interface box can also be connected to a computer. The connection to the computer coupled with the provided software of DataStudio, not only provides a bigger screen but also allows for further data analysis.

Data can be exported into Excel where transferable skills can be applied. Manipulations of equations and graphs can allow for further understanding of properties and laws in chemistry that might not normally be as obvious with just plotting data.

Either setup allows for experiments to be brought into the lab that might not normally able to be performed. Probes and sensors range from temperature, pH, pressure, drop counter, and colorimeter to name a few. The probes can be used separately or in combination. For instance, the drop counter can be used with the pH probe to demonstrate a titration mimicking an automatic titrator that might not normally be available in a high school or college lab. Another example would be coupling the temperature and pressure probes to monitor the change in a closed system to demonstrate a variety of gas laws.

The second cornerstone under the RIBGHE grant was introducing new pedagogical methods in science education. Through the years, there has been continuous discussion among science educators that there needs to be a change in the classrooms of physics, chemistry, biology and Earth/space science in the way that these subjects are taught to the students. The National Science Teachers Association, the National Research Council, and science education leaders have encouraged teaching in ways that actively engage students in inquiry learning experiences. (4) Inquiry learning should be based on conducting a scientific investigation and should provide the opportunity for reflection and closure in an effort to understand how scientific research works. The effective use of inquiry-based learning engages students in self-directed inquiry, in learning to think critically and scientifically, and in understanding the relationship between evidence and theory. (5) There is an inquiry continuum that distinguishes between four specific forms of learning: direct instruction, structured inquiry, guided inquiry, and open inquiry. The adaptation of any inquiry model has to be done very carefully balancing between ability of the students, lab time, learning objectives, and standards to be met.

"Direct instruction" is a teacher-directed approach to learning. Direct instruction supports a static knowledge base where students are told what to think and do. This model usually includes: state objectives clearly, teach and then model desired goal, use guided practice, and then allow independent practices. (4) If the sole purpose of the class is covering certain amount of material, this is a plausible way to go. Hence, direct instruction often gets the label "inch deep – mile wide." Students usually are limited to memorization thus students become passive recipients of knowledge. (5) The primary goal of education is to make content/skills transferable to future and past learning which in turn can then be hopefully connected to world experience; it is questionable if directed instruction allows this correlation to exist.

On the opposite end of the inquiry continuum is the "Open Inquiry." Open inquiry is where students form their own questions and work through a logical devised method in order to solve their own problem. (4) A primary example of this would be the science fair at the high school level or undergraduate research at the college, however even these examples are usually under the guidance of a supervising professor. Furthermore, this technique relies on skills that perhaps only the most enthusiastic students possess making it not appropriate for most students. (5)

In between the two approaches of directed inquiry and open inquiry is the other two approaches "Structured Inquiry" and "Guided Inquiry." Since directed inquiry typically involves talking about science instead of doing science, and since open inquiry makes it challenging for teachers to focus the curriculum toward specific standards, structured inquiry and guided inquiry fall in the middle making it more feasible to develop a lab curricula. Structured inquiry is probably the most familiar form to both teachers and students in the chemistry labs. This form of inquiry is most often referred to the "cookbook" method since it informs its students with step-by-step instructions. Teachers usually provide students with all the details at the beginning of the investigation: the problem, the procedure, the data table, various questions to consider, then models exactly what students will do during the lab. Generally these labs seek identical or very similar responses from all the students. This may be a good way to introduce a difficult concept; however, it requires very little thought on the student's part. While it might allow students to *engage* in the activity, it lacks the *discovery* process by just covering everything on the surface.

"Guided Inquiry" provides an excellent balance. There is some direction given, yet students are then able to explore through answering questions. By answering questions they are guided to the objectives and concepts in a ways that make sense to them and in ways that interest them still under the supervision of a professor. Teachers are still able to meet certain curricular goals, while students are able to engage in a meaningful and exciting hands-on learning. Through this process, students are able to develop critical thinking skills that can be carried with them and prepare them for real-world scientific problems. (5)

One argument against guided inquiry is that students' minds struggle to learn effectively in an independent manner; therefore they need guidance every step of the way. When students enter the lab for the first time, this is definitely true. However, if the professor provides guidance every step the way for each lab, the students will hit a plateau and will not continue to grow or learn. By designing the curriculum so that it starts out with structured inquiry labs then increases the independence of the students by slowly removing the scaffolding, the students will become more familiar and comfortable with the guided inquiry labs overtime. How much scaffolding can be safely removed is not an easy question and depends on several factors: the abilities of students, curricular objectives, departmental atmosphere, just to name a few. (6)

By using gauging techniques the challenge of knowing how much "scaffolding" to be removed is relieved. The guided inquiry rating (GI-rating) provides a qualitative "measure" of the level of inquiry to be used through out the curricula of the labs. The instructor increases the inquiry component throughout the curriculum which in turns increases the independence of the students, but is still able to preserve the structure of the activities. (6)

Since instructors are trained in the traditional way and have been teaching that way for years; it represents a real challenge for most of them to go from lecturing to be only the facilitator of the learning process in the lab. It can be extremely tempting to simply give answers to students when they ask, or just tell them what to do instead of intriguing them with more questions to guide them to the answer.

Designing guided inquiry labs can be even more challenge. When developing inquiry based activities, there are several key issues that the students should go through: (6)

- asking question(s)
- designing and conducting investigations

- using appropriate tools, techniques, and experimental setup to gather data
- thinking critically and logically about relationships between evidence and possible explanations
- constructing and analyzing alternative explanations, and communicating scientific arguments
- apply conclusions to other, relevant phenomena

There should be a clearly articulated scientific question to which students are expected to find the answer too which helps them to stay on track. The balance among the steps is critical, but most importantly there should always be sufficient time for discussion and closure.

To ensure the success of guided inquiry, high quality questioning is essential for such labs. The question must engage students in the beginning, in the middle be able to guide their thinking and help clarify, and in the end help them to articulate their findings. The problem is that when developing the labs, the professors have to assume the mindset of the students which is far from trivial. If the questions are not designed carefully, the process breaks down and the students are left frustrated and unsatisfied. (6)

The S-C-I-E-N-C-E Framework coupled with the GI-rating helps to address these issues. It provides a roadmap in a "worksheet" format when trying to develop an inquiry based lab. The best way to approach this is to make two columns. On the left side, address each component with a bulleted list of the concepts to review (chemistry or math), and expectations from the students at that step. Based on the list, design the right column with the desired level of inquiry (see Table 1). (6) Based on the inquiry level of each segment the overall GI-rating can be determined on a scale between 0 and 9. Scale 0 would be strictly descriptive ranging to the opposite end of the spectrum where scale 9 would be entirely guided (except for the collecting of data).

GI Rating:	0	1	2	3	4	5	6	7	8	9
Scientific question to be answered										
Concepts students should know to be able to develop a strategy to answer the question.	D	D/G(1)	D/G(2)	D/G(3)	G	G	G	G	G	G
Indicate a hypothesis/prediction	D	D/G(1)	D/G(1)	D/G(2)	D/G(3)	D/G(3)	G	G	G	G
Engage in constructing of a strategy to collect relevant data	D	D	D	D	D	D/G(1)	D/G(2)	D/G(3)	G	G
Negotiation of an experimental setup by each team (configuration, calibration, etc.)	D	D	D	D/G(1)	D/G(1)	D/G(2)	D/G(2)	D/G(3)	D/G(3)	G
Collecting the data	D	D	D	D	D	D	D	D	D	D
Evaluation/Conclusion/Application	D	D	D	D/G(1)	D/G(2)	D/G(3)	D/G(3)	G	G	G

D = Descriptive
D/G(1) = Mostly descriptive with few guiding questions
D/G(2) = Descriptive and guided nature equally balanced
D/G(3) = Mostly quided with questions with little description
G = Written up entirely with guiding questions

(Table 1)

Once the rating is determined, The S-C-I-E-N-C-E Framework is then implemented for constructing the activity: (6)

Scientific question to be answered

A scientific question should be clearly articulated, to which students are expected to find an answer to during the discovery process. A clear wording of the question helps students to remain focused. This component naturally is always descriptive.

Concepts students should know beforehand (science and math concepts)

There should be questions to review science and math concepts that students already know.

Indicate a hypothesis/prediction

Based on the reviewed concepts students are expected to provide a reasonable prediction as to what they expect the answer to the question would be.

Engage in constructing a strategy to collect relevant data

Based on the reviewed concepts and the nature of the scientific question, students are expected to provide a strategy, and a technique to find the answer to the question.

Negotiating an experimental setup by each team

Based on the strategy and the technique, students identify, and they are to propose a possible experimental configuration. At this point the professor has to make sure that students are still on the right track.

Collecting data

The experimental setup greatly varies from implementation to implementation of an activity. It may also involve configuration, calibration etc. This part of the activity usually is not a key component of the inquiry process and students simply have to follow the provided instructions. This segment is always descriptive.

Evaluation/analysis/application

This step is done collaboratively. It is imperative to have enough time for this step. If the hypothesis and prediction are not aligned with the obtained data, revision and potentially further experiments are necessary. Students need time for discussion, reflection and to place their findings in context, also they need to apply it to a different situation and possibly to a real life example.

The other most common argument against guided inquiry is that one cannot cover all the expected areas in the curriculum due to its time consuming nature. Granted, guided inquiry based activities do take more time, some of the time related issues are alleviated by utilizing technology in the lab.

Through the design of the equipment put out by PASCO Scientific, it was soon realized that by pairing the easily available equipment with guided inquiry lab activities, a vast difference could be made in the learning of science in the school systems. Dr. Sandor Kadar from Salve Regina University was approached to make a sample of lab reports using the technology of PASCO along with the S-C-I-E-N-C-E framework and guided inquiry rating. As mentioned before, the problem is that when developing the labs, the professors have to assume the mindset of the students which is far from trivial. Therefore it is vital to enlist the help of motivated and talented students to help with the write-ups. Dr. Kadar put together a team with Amy Beltramini and myself to review the lab write-ups after they were completed.

Before a lab activity can be written, first the scientific question must be identified and the GI rate determined. The GI rating will determine if the write up should be more descriptive and what level the questioning should be. Next the concepts that want to be reviewed and introduced must be laid out. Once the concepts are known, then the S-C-I-E-N-C-E framework is used to map out the lab activity. After the lab activities are written, Amy and I would perform the labs based on the write-up and provide feedback. Since we are still students, we still have the mindset of what the average student would understand and be able to answer, but also have the advance understanding of what is to be expected from the lab and what should be taken away after the completion of the experiment.

Through this team setup about 20 lab reports have been able to be written up and tested. First there is the paper handout lab report written up and provided to us to be performed. Based on our feedback, questions maybe added or reworded to ensure the fluidity of the write-up and a gauged understanding if the students would understand the material. A solution manual is then written up to provide what the students should have answered. The handouts are then converted to DataStudio workbooks so that students can answer the question and perform the experiment all on the computer. The final step to the design of the lab report is the recording of the lab setup. Every lab is descriptive for the collection of data no matter the GI rating.

The third cornerstone of the RIBGHE grant is training teachers to develop inquiry-based curricular materials. The lab write activities developed under the PASCO project serve as a prime example for the training of high school teachers. Through the project teachers learn and are eventually able to create guided inquiry based activities in science curricula, with integrated math concepts coupled with the latest computer-based educational technology. This has been funded by Department of Education for several years. (2) The grant addresses the need for a program to assist teachers in developing expertise in the use of the activity-based approach to teaching science concepts and the underlying mathematics within the Rhode Island science and mathematics standards. Therefore, workshops are performed to introduce and educate teachers to the guided inquiry method of teaching and lab design. The teachers are assisted in the use of the activity-based approach to teaching science and introduced to the technology of PASCO. The program provides teachers with the opportunity to draw on the experience of their peers who have either been through the program before or familiar with the guided inquiry setup. Once teachers are able to develop an activity-based lesson, they are then able to bring it to the class room and present it to students. Through this interaction, teachers are able to witness the conceptual understanding that the students develop. (2)

The program also provides the participants with useful methods, materials, lessons and activities that they can use in their own classroom. The Project activities will help teachers to achieve state/national standards in mathematics and science. Majors Rhode Island goals of communication, problem solving, body knowledge, and responsibility for education are implemented in the program. In this environment, teachers act as facilitators so that students are required to take “responsibility” for their learning, Students acquire a “body of knowledge” as it is needed and use this knowledge to formulate new “problem solving” approaches. Peer collaboration naturally leads to “communication” of what had been learned through effective reading, writing, speaking, listening and conversing. (2)

The first phase was to introduce the science teaches from the high schools across the State to the concepts of guided inquiry. Another crucial part of this phase was to integrate mathematical concepts, where they are essential, into the activities. The addition of mathematical concepts into the guided inquiry write-ups helps students to create links between abstract mathematical concepts and phenomena in the sciences which they might never have linked before.

A group of a bout 30 teachers attended the workshops as Salve Regina University. Both chemistry labs were equipped with equipment for Science Workshop and computer based hardware for Physics. First teachers had the opportunity to become familiar with the hardware and software. Next, teachers were presented with traditional "cook-book" activities then with guided inquiry activities similar to those developed by Dr. Kadar. Teachers were encouraged to then return to their schools and transform traditional method activities into the new method that they just were introduced. The teachers were even able to return to their respective school with one of the new hardware so they could share and demonstrate their experience.

In the second phase, teachers met through out the year to share their experience of the new guided inquiry method. Teachers were introduced to more hardware and software. Through the program some of the latest technology was returned to the schools. Based on school needs, 12-14 computer-based student stations with the latest hardware where installed at the schools. Next, teachers got more practice writing inquiry based activities by either based on new lab assignments they had or converting old traditional labs into the new method. Teachers then performed each other's labs to provide feedback on the writing process; ensuring that their questions are able to guide students through the different concepts. Those who have been involved in the program longer discussed their experience of implementing the guided inquiry in the classroom. These teachers discussed the change and the improvement student's performance and understanding of the material that was introduced to them.

Through peer communication, practice and workshops held at Salve Regina University through the implementation of the GIBIS Center, teachers are soon on their way to develop their own guided inquiry activities. The activities developed by Dr. Kadar through the PASCO project serve as a road map for the teachers who are newly involved. Soon teachers will have the ability to create their own activities using the S-I-E-N-C-E framework and set the labs at different GI ratings.

The progress of the program is going to be over the next three years before the teachers are able to produce their own inquiry based labs and introduce them in their own class room. However, Dr. Sandor Kadar and I wanted to first hand see how the students would react to such activities and if there really is a difference between guided inquiry based labs and traditional based labs. Dr. Kadar and I traveled to Woonsocket High School in Woonsocket, Rhode Island were we introduced two general chemistry classes to two lab experiments. The two labs that were completed by the two general chemistry classes where the same, except Mrs. Janet Miele's class performed the experiments with guided inquiry based lab write-ups, while Mr. Tim Brown's class performed the experiments with traditional "cook-book" based lab write-ups. All experiments were completed the in DataStudio using PASCO equipment.

The first experiment that was introduced was Boyle's Law experiment, examining the inverse relationship between volume and pressure. The setup included using a syringe, a pressure probe connected to the GLX interface box, PASCO chemistry probe and a computer with DataStudio software. The object of the experiment was to push in the syringe 5ml and record the volume while the pressure probe monitored the change is pressure. As the volume continues to decrease, the pressure continues to increase, hence an inverse relationship. Both classes were given the same introduction of the concepts of Boyle's Law. The difference being, Mrs. Miele's class (performing the guided inquiry lab) answered a series of questions before completing the experiment, while Mr. Brown's class (performing the traditional lab) read some back ground information answering no questions before completing the experiment. After completing the experiment, both classes took the same assessment test to see which class better understood the concepts of the lab. Back at Salve, the assessments were graded and following graph was generated based on the two classes' performance.

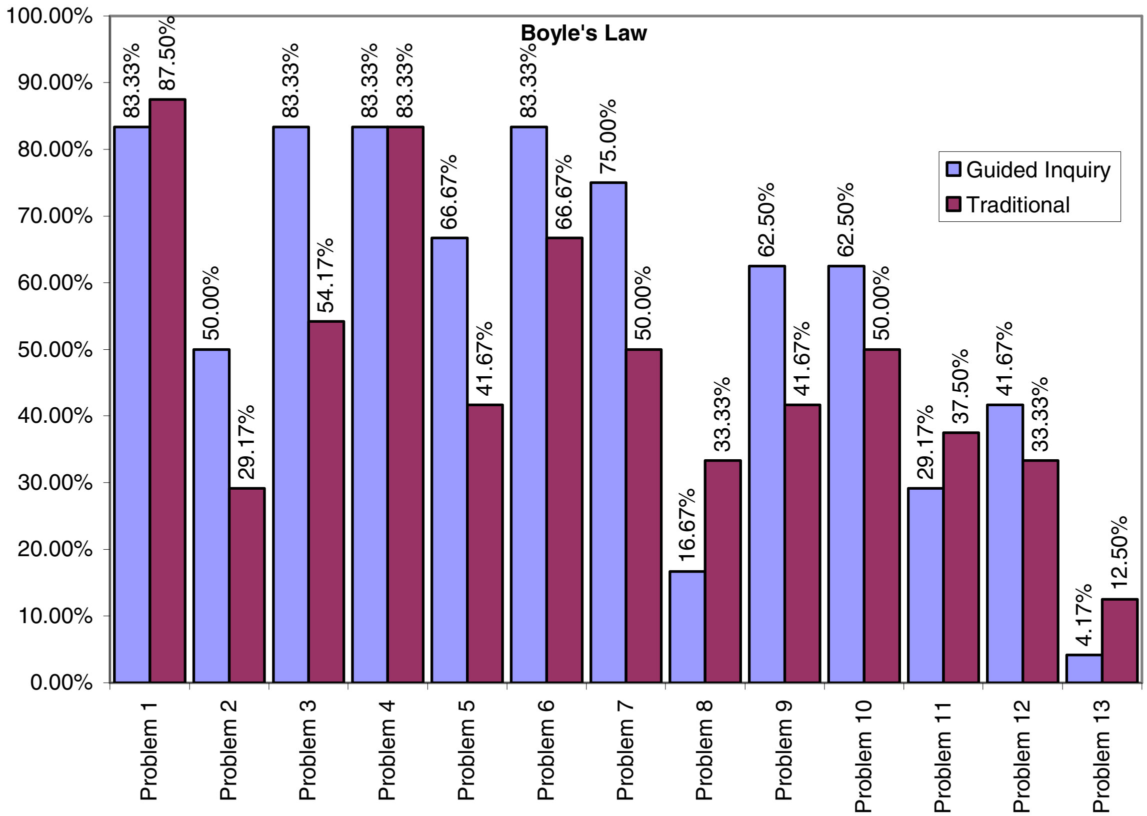

Figure 1 Performance results for Boyle's Law

As shown above, for 8 out of 13 of the problems, the class using the guided inquiry labs had a higher percent of students who answered the question correct compared to the class using the traditional lab, tying on problem four. It is evident, that overall the class using the guided inquiry labs had a better understanding of the concepts presented.

The second lab that presented to the students was the Guy-Lussac's Law, examining the direct relationship between pressure and temperature. The setup for the experiment was a beaker filled with water and a stirring bar, a hot plate, lab stand, a Zero Temperature Apparatus, GLX interface, PASCO chemistry probe, and a computer with DataStudio software. The object of the experiment was to place the Zero Temperature Apparatus into a heating beaker of water. The Zero Temperature Apparatus has a pressure and temperature probe inside a closed system which can be monitored when connected to the interface box and computer. When the water is heated, the temperature is increased along with the pressure, hence a direct relationship. Just like with the first experiment, both classes were given the same introduction of the concepts of Guy-Lussac's Law. The difference being, Mrs. Miele's class (performing the guided inquiry lab) answered a series of questions before completing the experiment, while Mr. Brown's class (performing the traditional lab) read some back ground information answering no questions before completing the experiment. After completing the experiment, both classes took the same assessment test to see which class better understood the concepts of the lab. Back at Salve, the assessments were graded and a graph (figure 2) was generated based on the two classes' performance.

It is more evident with this experiment that the concept of the Guy-Lussac's Law was better understood by the class that performed the lab with guided inquiry labs; for every question the guided inquiry class out performed the traditional class.

It is interesting to compare the average performance between the two experiments. For Boyle's Law the average is around the 60% while for Guy-Lussac's Law the average is in the 80%. The difference in the average performance can be due to the fact that Boyle's Law demonstrates an inverse relationship which can be a difficult math concept to understand especially at a high school level. This reiterates the concern that math concepts are not usually linked in the science field which causes students to have a difficult time drawing a connection.

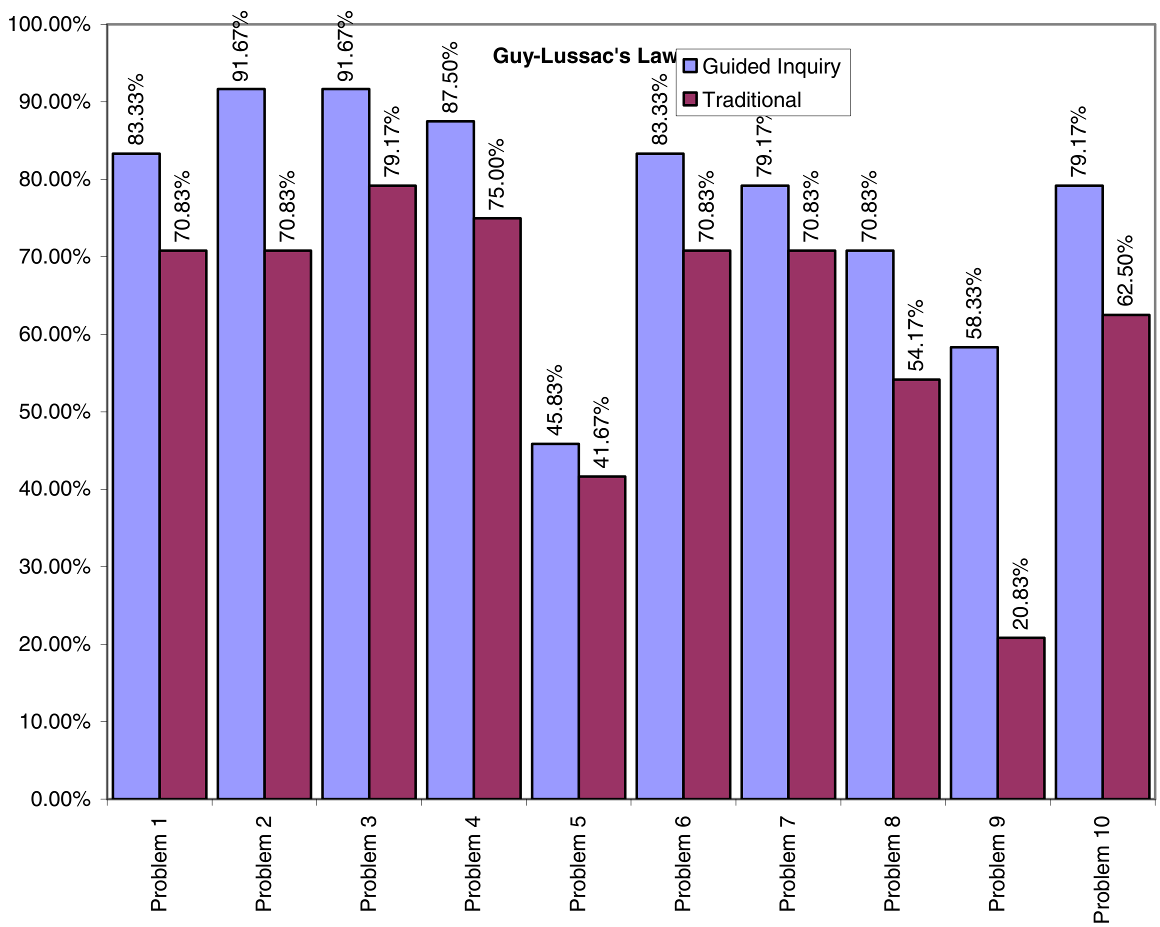

Figure 2 Performance results for Guy-Lussac's Law

The experiments in Woonsocket had multiple benefits. It was the first time that the students used the PASCO equipment and thoroughly enjoyed it. Of course any student enjoys a day of from taking notes, but the students dove right into the experiment and were eager to do more. It certainly makes all the hard work feel rewarding.

It was through the RIBGHE formally known as Eisenhower Grant, that the three cornerstones just explained held as the driving force behind my senior thesis; 1) introducing technology in the high schools in R.I. 2) introducing new pedagogical methods in science education and 3) training teachers to develop inquiry-based curricular materials. Working with Dr. Sandor Kadar on the PASCO served as an excellent tool for the training of the high school teachers. But it was also through this experiment that it was realized how much the grant did for the local community. The RIBGHE grant provide a service to the local high schools. It introduced new teaching methods to Rhode Island schools that need improvements with its curricular standards. The grant also helped professional development and certification of high school science teachers that might not normally be able to do so on their own. But probably most importantly for the students, the grant delivered the latest technology to high schools that might normally be able to afford such lab equipment. However overall, the grant allowed the expertise of the joined faculty- student team help bring high school science education to the 21st century in the local community.

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Thank-you to Woonsocket High School, Mrs. Janet Miele and Mr. Tim Brown's General Chemistry Class

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