A Ninth Grade Introduction to the Nanotech Biosensor Project

by

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CHAPTER 1: INTRODUCTION

Background

In 1989 the American Association for the Advancement of Science (AAAS) set the current trends in science education with the publication of Project 2061. The Project set long-term goals in science education to be accomplished by the year 2061. In the same year the National Science Teachers Association (NSTA) released a national set of science education standards. By 1994 Project 2061 had evolved and published Benchmarks for Scientific Literacy. Only two years later a third group, the National Research Council (NRC), published its National Standards. All three groups, AAAS, NSTA, and NRC, had the common language of gaining student scientific literacy through the use of inquiry to study our world and the problems we wish to solve, and through the ability to use and modify technology to meet population needs in our world today. This research project used inquiry with 9th grade students to look at the problem of water and food borne bacteria and viruses. The students will be discovering technology that is currently under design (The Nanotech Biosensor Project) to solve the problem of people becoming ill or dying from water and food borne bacteria and viruses.

I am a teacher in the Grand Rapids Public School District. Teachers in my district often wonder why the curriculum changes and why we must change our methods, when it seems what we are doing is working well. Often we get so busy in the day to day process of educating our students, developing relationships with them and their families, and taking care of administrative details, in addition to having a family life of our own with all the responsibilities
attached, that we don’t take the time to find out how the world is evolving and how our children need to be prepared for the future. However, all educators need to realize that change is a normal evolutionary process that will happen with or without us. The motivation for conducting this study came originally from the internship program on the Nanotechnology Biosensor Project led by Dr. Evangelyn C. Alocilja, Biosystems Engineer at Michigan State University in East Lansing, Michigan. The primary objective of the project is to decrease the time it takes to detect a pathogen (such as E.coli, salmonella, bovine viral diarrhea and lysteria) in water, fruits, vegetables, meat, and animal blood samples. The internship provided a unique opportunity to learn about the project from the scientists by assisting them in their work over the summer of 2006. From learning and working with scientists, my goal was to design and develop inquiry lesson plans for grades seven through twelve based upon the Nanotech Biosensor Project. Implementation and study of student response to the first three lesson plans began in May 2007.

The lesson plans were written in the 5E Instructional Model, an inquiry format originally developed in the late 1980’s by BSCS, a nonprofit corporation that conducts research and evaluation studies in science education (BSCS 2007). The 5E’s evolved out of the philosophy and work of Johann Herbart and John Dewey in the early 1900’s, Heiss, Obourn, and Hoffmann in 1950, and the Atkin-Karplis Model in the 1960’s (Bybee and others 2006). Embedded within the 5E format are the many facets of cognitive development and constructivism that emphasize the students’ active involvement in the process of science.
Grand Rapids Public Schools has adopted the 5E Framework for educators in the system to use across all curriculums, in all grades (GRPS 2004).

The 5E format stands for the five phases of the lesson. The first phase is the engage phase designed to draw the student’s attention to the topic, as often as possible with a real-world component. The second phase is exploration, designed to allow the student an opportunity to pose questions, make observations, examine raw data, build, draw, or “explore” the subject in a variety of ways. The third phase is explanation, which allows the teacher to build off the “explore” phase by answering some of the questions students have come up with during their exploration. The fourth stage is Elaboration, which brings students to the highest levels of thinking by taking their “explore” and “explain” phase experience and knowledge to practical “real world” applications. The final phase is the Evaluation phase where the student’s work is evaluated by the teacher. “Engage” is always done first and “evaluate” is usually done last. However, the middle three stages can be re-sequenced throughout the course of a lesson as often as needed to acquire the learning objectives.

**Literature Review**

The debate on teaching inquiry-oriented lessons has been going on for over forty years. Even though the purpose of this paper is not to debate teaching through inquiry, the lessons under scrutiny are written in the inquiry 5E format. Therefore it is important to reconfirm that inquiry-based instruction should engage students in the investigative nature of science (Haury, 1993). Inquiry is
multifaceted, rather than one approach to teaching. Inquiry involves the use of a variety of skills in a variety of activities. The focus of inquiry is on “the active search for knowledge to satisfy a curiosity” (Haury, 1993) gained from authentic questions generated through experiences of the student (NRC, 2001). As Haury shows through a variety of sources, teaching through inquiry is effective in “fostering scientific literacy and understanding of the science process, vocabulary knowledge and conceptual understanding, critical thinking, positive attitudes toward science, and higher achievement on tests of procedural knowledge” (1993). Because the evidence for an inquiry-based education is well documented, educators will slowly move toward this more effective and exciting approach to science education.

According to the National Science Foundation (NSF) and the National Center for Learning and Teaching Nanoscale Science and Engineering (NCLT), nanoscience is a discipline that is changing our entire marketplace and job force, causing the need for students today to be highly proficient in emerging technologies (NanoEd Resource Portal, 2007). The education community will bear the responsibility in educating our children in the field of nanoscience. One of the challenges in educating our students in the nanosciences is the interdisciplinary nature of the field. Nanoscience is not just physics, chemistry or biology. It’s all of these and other disciplines, on a nanoscale. As the NSF and the NCLT put a priority on funding and implementing nanoscience into all science courses, grades seven through twelve on a national level, the interdisciplinary nature of the field needs to be kept in mind (NanoEd resource Portal, 2007).
Enough has been happening in nanoscience that the education of students in this developing arena is getting to be as popular as a high school robotics competition. In New York there is even a “Nano Day” for students in New York City at Columbia University usually on a Saturday in March or April (Columbia Center for Science and Engineering 2004, 2007). The event takes place at Columbia University’s NanoCenter in cooperation with the City College of New York, Barnard College, and Rowan University. The list of speakers for 2007 included Bill Nye the Science Guy and a Nobel Laureate in Physics (Professor Horst Stormer, Columbia University). The program selected 500 10th and 11th grade students in New York City to attend with the hope of attracting these students to study the nanosciences after high school (The Columbia Center for Science and Engineering 2007).

Due to the priority placed on nanoscience education over the last several years, numerous institutions of higher education have developed nanotech programs similar to “Nano Day.” Some institutions of higher education now offer degrees in the Nanosciences. Michigan Technological University started a minor in nanotechnology in the fall of 2005, allowing “students in virtually all majors (to) explore one of the hottest fields in science and engineering” (Goodrich, 2005). The City University of New York (CUNY) offers a fully funded Ph.D. program entitled “Nanotechnology and Materials Chemistry” (Akins, 2003). Nanotechnology is a legitimate and valid part of science that’s producing endless opportunities not only for the scientist, but also for the open-minded and industrious entrepreneur.
Funded by the NSF, the Nanotech Biosensor Project utilizes a small branch of the huge nanotechnology field. “Biosensor” is a generic term that can be applied to any electronic instrument that detects anything in a biological system. I am only aware of one other group that is working on using a specific biosensor to detect pathogens in water or food: Intelligent Optical Systems, Inc., a small California based company, was awarded money from the Environmental Protection Agency to use nanotechnology to develop a method of detecting waterborne pathogens. “The proposed system will be used in water treatment facilities, food testing and medical applications and allow the detection of several different pathogens simultaneously” (Nieuwsbank 2007). It is important to realize that the type of biosensor we are working with in developing the lessons is rare and most people are unaware that the research, as important as it is to society, is taking place. There are many nanoscience lesson plans available, and there are even a few nanotech biosensor lessons, but the available lesson plans do not match our needs. The NSF made the development of lessons on the biosensor an integral component of the research grant because of the limited number of organizations developing nanotech, pathogen-detecting biosensors, and the lack of lesson plans to build upon.

Since part of the NSF grant for the Nanotech Biosensor Project was to have a secondary educator develop lesson plans for grades seven through twelve, I developed seven lessons that are specifically designed to continuously build within the students an understanding of the need for the biosensor in our society. The goal was for the students to have the biosensor always in the back of their
mind, even though the primary focus of a particular portion of a lesson is not the biosensor, but a component integral to the biosensor.

**Purpose of Study**

The effectiveness of the learning process within each of the three lessons written is what is under scrutiny in this study. The goal here is to not validate the many findings in science education, which we already know, such as whether inquiry is valid in the classroom or not. We need not investigate whether 5E inquiry lesson plans work better than older lesson plan formats. We need not debate the definition of scientific literacy, as all agree, that it is gained through the process of science.

The three lesson plans used in the ninth grade study are 5E inquiry lessons designed to increase scientific literacy through the use of a real world problem (bacteria/virus detection) and a real world developing technology (nanotech biosensor). Written within the design of the lessons is for students to understand the benefits of this technology. In this era of terrorist threats to our food and water supplies in addition to the threats we encounter daily from contamination of bacteria and viruses, detection time is vital. The biosensor is used to detect the contaminants in minutes, versus the days for which we now must wait. Students need to understand how this technology could save their life or the life of someone important to them. Students should understand that the development of this technology is ongoing. Through the process of inquiry we will be using in the classroom students can continue developing the biosensor beyond high
school. Through the inquiry process embedded in the lesson plans, students will know that they are capable of getting involved in the research process which can result in saving lives and, as in the movies, perhaps the human race. Students want to grow up and work in a field that is heroic and rewarding to society. The process of research and development can be just as heroic and rewarding as being a police officer or firefighter.

Throughout the process of writing lessons, implementing lessons, and building up students, many questions have arisen: some are critical and others are just an embedded part of the process. A questionnaire, used to gain data on the effectiveness of the learning process, was written to specifically answer the following questions:

- Will student attitudes toward the subject matter change in a positive way?
- Will students feel more knowledgeable in the subject matter after the lessons?
- Will students feel more confident in their ability to conduct research and develop answers on their own?
- Are there real world experiences the students have had that can impact the design of the lessons to better engage the students in the inquiry process?
- What will the students understand about the need for biosensors in our society after going through the three lessons?
There are many questions beyond the questionnaire that arise, some of which can be answered through the experience of teaching the lessons and observing the students:

- Are the students capable of handling the level of science that nanoscience demands?
- Can nanotech lessons engage the students enough to get them more interested in science and how it impacts their everyday lives?

Other questions are long-term questions about which science educators often spend their entire careers wondering:

- Will teaching nanoscience topics impact students as they choose careers?
- Will we, as educators, aide in the process of attracting students to careers in the sciences?

From the experiences of putting together and running the Ninth Grade Introduction to the Nanotech Biosensor Project, answers to these questions will be hypothesized. As educators we are always looking for ways to reveal conflicts or inconsistencies in our lessons and teaching practices. Evaluating the content of the lessons is additionally important because content affects many of the questions asked above. Through analysis of the data acquired from students on the pre and post questionnaire and the experience of teaching, recommendations will be made on future use of the first three Nanotech Biosensor Project lessons.
CHAPTER 2: METHODS

The study was based on the teaching of a set of three lessons on nanotechnology biosensors to 9th grade students at Union High School in Grand Rapids, Michigan. Students were surveyed before and at the conclusion of the instructional period.

Union High School is an urban school with a diverse population where 80% are on free or reduced lunches, about one third are Latino, one third are African American and on third are White. There are many problems that arise with students growing up in poverty, and some teachers tend to write off the students. The lessons were designed to expand students’ understanding of science. The study was conducted during the 2006-2007 school year. Of the 142 freshman that I taught, 104 students (mostly 14 and 15 year olds) participated in the study from 1st hour, 2nd hour, 5th hour, and 6th hour.

The Questionnaire

- Design and Focus

The questionnaire (Appendix A) was written to cover the objectives as listed in the Purpose of Study. The ultimate goal is to see how student attitudes, beliefs, and confidence change after doing the lessons. Is their attitude or belief in scientific research of the subject matter different? Will students feel they have new knowledge that benefits them? Will students gain confidence in any new skills they’ve acquired? Will student attitudes about science and the process of
doing science change? Will more students be inclined to desire to study science as they continue their educational process?

Because we’re looking for changes from “pre” lessons to “post” lessons, the same questionnaire had to be given prior to the lessons and again just after the lessons were finished. The questionnaire does have some items on it that pertain to a fourth lesson plan. Unfortunately, due to time constraints, there was not enough time to do the fourth lesson plan.

- **Implementation**

The pre and post questionnaire was optional for students to participate in depending upon their response to the Student and Parent Permission for Research Letter (See Appendix A). The pre-questionnaire was given to 1st hour on May 15th, and 2nd, 5th and 6th hours on May 17th. The difference in dates is only due to block scheduling and the school calendar. The students understood how the questionnaire was going to help with the project for Michigan Tech University and Michigan State University. There were a couple of students who noted that this was not for a grade, therefore they were not going to do it. Often comments like “You’re not going to help me out? It’s easy – just give me your opinions” will cause the students to want to help. Most students decided that if the questionnaire was going to help and all they had to do was tell me what they think, they went ahead and did the questionnaire. The students put their answers on Scantron sheets with the idea that one could get a tally on each question with a special Scantron sheet that is often used for analysis. However,
the Scantron sheets could not be found so all the data had to be entered into a spreadsheet manually.

The post questionnaire was given as soon as presentations were finished on Friday, June 1, 2007. Some students didn’t want to do it as it was the last Friday of school and they knew there were no points involved. The same tactics were used as in the pre questionnaire to get students to take it. As suspected, once the data got on the computer, fewer students took the post than the pre questionnaire.

**Lesson Plans and Instructional Methods**

Through the Biosensor Project I wrote a total of seven lesson plans for grades seven through twelve. The lesson plans are designed to build upon each other. Consequently, the introductory lesson plans for the earlier grades can easily be used in the upper grades to give the upper grades background information during the first few years of implementation. For my graduate research project I implemented and tested the following lesson plans:

- Lesson Plan 1: Bacteria and Viruses: a threat to the existence of the human species? (Appendix B)
- Lesson Plan 2: Intro to Nanotechnology and its current uses. (Appendix C)
- Lesson Plan 3: What are the 8 allotropes of carbon and how are they used in carbon nano tubes? (Appendix D)
The three lesson plans written for this graduate research project were designed to satisfy not only all of the national standards written by the AAAS, the NSTA, and the NRC, but also to satisfy the standards for the State of Michigan. State Benchmarks are listed in the right column as a part of each lesson plan. (Michigan Benchmarks were current at the time of this project; Michigan recently released new standards). Scientific Inquiry is a basic, integral component within the design of the lessons. As stated by Jones and Kaplanis (2003), we want to “produce students with a better grasp of how to look at and potentially solve issues that will confront them during the rest of their lives.” The lessons for this research project were designed to give the students real world issues to connect to their research and then give the students opportunities to resolve problems.

**Lesson Plan 1: “Bacteria and Viruses: a threat to the existence of the human species?”** was designed to build in students a desire to know more about bacteria and virus detection (Appendix B). I wanted to create a “gut” need in each student for an understanding of research and development in this area because it may save their life or someone they care about. This lesson plan was designed for implementation in any of the grades seven through twelve, recognizing the different levels of knowledge students would possess. I chose the movie “Understanding Bacteria” to provide basic information on a level that would appropriate for all ages. Teaching in an urban district where funds are limited, and in many years non-existent, I always kept in mind cost factors to the district or teacher while writing these lessons. From experience I’ve learned that students will not watch a movie, listen and behave without a concurrent
assignment. Consequently an inquiry analysis of the movie was created as an accompaniment. I used an “inquiry” approach on six questions that were short essays involving students’ opinions on various aspects of the movie. At the same time I consistently tried to relate the movie topics to the need for biosensor technology within the inquiry questions.

Lesson Plan 2: “Intro to Nanotechnology and its current uses” at first makes one feel as if we jumped topics (Appendix C). In fact the students do not even have a clue that this lesson is related to the previous lesson until we are in the powerpoint presentation discussing the many applications nanotechnology has today. At that point there is a purposeful connection voiced by the teacher to the students. An elaboration at the end of the powerpoint of what is currently happening in the Biosensor Project is important. In addition, the teacher needs to emphasize learning about this technology could have a positive impact upon their lives. This lesson plan was designed for implementation in any grade, seven through twelve.

One of the approaches I wanted to use in the development of these lesson plans was to give the students the freedom to research topics of their choice. In the case of Lesson Plan 2, the freedom came with choosing any nanotech product to research (of course, with no duplicates in each class). I wanted the students to have some ownership of their project and not just be looking for specifics and spitting out facts. As far back as 1961 (Suchman), it has been determined that self-directed inquiry needs “freedom and a responsive environment”. Lesson Plan 2 also took into account the “real-world” factor within
its design. The students had already heard of many products, such as the Nano iPod, and CNT Bats for baseball and softball. This provided a connection to the real world for the students and continued to allow students “ownership” of their project.

**Lesson Plan 3: “What are the 8 allotropes of carbon and how are they used?”** once again at first may make students feel as if they are skipping topics (Appendix D). This lesson plan was specifically designed for an 8th or 9th grade integrated science class where the students have already had an introduction to chemistry and the Periodic Table. The first phase of the lesson (Engage Phase) starts with interesting real world relationships that the students are already familiar with: “What are the most expensive, naturally found things on our planet?” As previously, there is not an immediate connection to Nanotech Biosensors, but the connection does come later in the powerpoint presentation of the lesson. The eight allotropes of carbon did provide a unique opportunity to allow the students to design and build. I wanted the building project to be one for which they did not have directions but one which they had researched and designed with a method for building themselves. Part of the fundamental goal in writing the lessons was to reconstruct “the curriculum to make science instruction look and feel like science as it is conducted in the real world (Gallagher, 1995).”

**Planning, Timing and Logistics**

As always, planning a research project takes time, patience and perseverance. Roadblocks along a well-planned route interfere with progress.
It’s not so much that there are roadblocks, but how one opens up one’s mind to deal with the roadblocks. Excellent planning should eliminate the most basic of roadblocks and certainly I’ve run into my fair share of them. I tend to over plan and have too much to accomplish with too little time, creating a roadblock that is stressful causing the need to shorten a lesson.

This research project proved to be no different. I intended to implement Lesson Plan 4 (CNT’s and Polyaniline: Conductivity, Temperature and pH are all related and intertwined), but we ran out of time in early June 2007. The other lesson plans (5, 6, and 7) could not be implemented because the terminology and concepts are beyond the freshmen level. If Grand Rapids Public Schools agrees to implement all of these lessons in grades seven through twelve, then I will continue working on the project which will be far beyond the scope of this research.

Lesson Plan 1 was timed for a speed day (55 minutes), but it was used on a block day (90 minutes) due to scheduling issues. Lesson Plan 2 was planned for a block day, but it took place on a speed day causing a rushed powerpoint presentation on nanotech products. In two classes two or three slides were left when the bell rang. Another change in the planning of Lesson Plan 2 was the amount of time the students needed to do their research. One day was not enough and students were just getting started. Consequently I added another day for research, which allowed the students to feel that they could complete the project on time. The day of the presentations for Lesson Plan 2 was a block day, and with my lack of experience teaching these plans, I was not sure how much of
Lesson Plan 3 we would complete. After 1st hour, I knew I could get through the powerpoint presentation of Lesson Plan 3. I also knew that in 2nd and 5th hour I would be rushed, and perhaps we wouldn’t quite finish due to the 35 student class sizes.

The Graduate Research for Michigan Technological University is only a portion of my involvement in the Nanotech Biosensor Project. This summer, 2007, the National Science Foundation Grant used to fund the Nanotech Biosensor Project was extended. This allows for more time to implement the lessons into Grand Rapids Public Schools and throughout the State of Michigan. In August I will begin work with Grand Rapids Public Schools on implementation of the lesson plans in science classrooms, grades seven through twelve. As designed into the NSF Grant for the Biosensor Project, the next step would be to present at the Michigan Science Teachers Association convention in March 2008 and possibly at the National Science Teachers Association convention. It is a project one gets involved with that seems to continue to have endless open doors. An even greater debate is how will we get the public involved enough to demand that they have access to biosensors for their own testing purposes on their own food supplies? As discussed with Dr. Alocilja, opportunities for the biosensor in the future are numerous. Above are just some of the goals and questions that are being pursued and researched.
CHAPTER 3: LESSON IMPLEMENTATION

Process

Lesson Plan 1: “Bacteria and Viruses: A threat to the human
species?” is found in Appendix B. Lesson Plan #1 was started on the same day
as the questionnaire was given. The Engage phase of the lesson plan, otherwise
known as the QOD (Question of the Day) went very well. All the students had to
do was make a list of bacteria or viruses that they had heard about, had, or been
exposed to. Every class had the typical “cold and flu” on their list. What was
surprising was how every class did eventually come up with “eColi and
Salmonella” on their list. The expression on student’s faces when they started
coming up with the list was gratifying.

The “eColi and Salmonella” discussion led nicely to the movie,
“Understanding Bacteria,” found on Unitedstreaming's website (Discovery
Education – Unitedstreaming 2007). In all the classes, students were engaged in
the movie until it was near the end of class. There were technical problems with
the internet service in 2nd, 5th and 6th hours. The movie kept cutting out and the
students would have to wait for it to re-download or “buffer” for the next segment
of the movie. It got very frustrating for everyone in attendance. The students
were given the Inquiry Analysis of the movie (Appendix B, Inquiry Analysis of
Movie) before the movie started. Once the students understood that they “did
not have to look for the answers in the movie” on the inquiry analysis, they did
fine completing the handout. There was plenty of class time, which, in this case,
made dealing with the technical difficulties easier.
Lesson Plan 2: Intro to Nanotechnology and its current uses is found in Appendix C. Friday, May 18th was the introduction to this lesson in all four classes. It was a speed day, so classes were only 55 minutes in length. The Engage and Explore phase of the lesson plan was effective as their Question of the Day. Students had to list all the prefixes they could remember for “meter”. On display in the front of the classroom were two meter sticks for students to see. In every class a student asked what the word “prefix” meant. Some students even figured out that we went over metric prefixes back in September and looked it up in their binder! Only one class actually came up with the prefix “nano”. The other three classes were prompted with the prefix “nano” by asking the students if they had ever heard of “nano” before. Most knew of iPod nano, which created an easy lead into the next segment of the lesson plan: to speculate on the meaning of nanoscience or nanotechnology.

All classes figured out that “nano” meant “small”. We then went to the Explain phase of the lesson plan: the powerpoint presentation (Appendix C). Students were happy that all they were asked to do during the presentation was to listen and be quiet, unless they had a question on the powerpoint. Because it was a speed day, we did not have time to elaborate on “nano.” “Nano” is in the presentation and finding out about all the products out there that “nano” has created within just the last few years continued to be engaging for the students. There were no disciplinary problems due to the students not having a “turned in” assignment along with the presentation. The students asked questions and shared knowledge that they had on nanotechnology. The presentation was
barely finished at the end of class. It was just like in the movies; the bell rang and students were still engaged in the lesson and had to suddenly jump up to hurry off to their next class.

Monday, May 21st was another speed day, so all four physical/earth science classes met. The QOD for the day was to assemble into teams for each of the different nanotech products. They were given information on the rubric for the project (Appendix C) in addition to any other details they may need to know. The students went to the Library where they could research their product and work on their poster. Students checked out markers and were given a team poster board. Parts of the team did research on the internet while other parts of the team worked on the poster.

The initial lesson plan called for this day, Monday, May 21st, to be the only research day. However, that was insufficient for the students. The students were just getting going when the bell rang, so another block day was scheduled to finalize their research and poster. The extra time would allow them time to decide on who was going to say what for their presentation the following day. Three of the four classes got to finalize their research and poster on Tuesday, May 22. The last class (6th Hour) finalized on Wednesday, May 23. The remainder of the students left class with posters still in hand, hoping to complete them at home. A risky situation for the students, as some will not come to school the next day with the project, leaving others in quite the precarious situation. By offering students the option of working on their project after school in the
classroom, I had hoped to avert the disaster of having an absent student at home with all the other students’ work.

On Wednesday, May 23, 1st hour was able to give presentations. Due to block scheduling, the other three classes gave presentations on Thursday. To encourage volunteers to start, extra points were offered. Presentations did not take too long and offered plenty of time to start the next lesson. Some classes were better at asking questions after each presentation than other classes.

**Lesson Plan 3: The Eight Allotropes of Carbon, May 23 – June 1, 2007,** is found in Appendix D. Since presentations for Lesson Plan #2 did not take long, the students were no longer a day behind. Having the presentations fresh in their in mind and having researched such terms as carbon nano tubes (CNT’s), Buckyballs, Fullerenes and such, the students were able to connect what had been done so far to the new lesson. The Engage phase or QOD for the lesson was to “list the most expensive, naturally found things on Earth.” Students came up with items such as coal, oil, diamonds, gold, silver and platinum, and discussed what those items are made of, how expensive they are, and what makes them so expensive. The first hour class quickly came up with coal and diamonds and then realized that they are both made of carbon. They were very interested in why diamonds are so expensive, in spite of all the synthetic diamonds that now can be made. Geologic conditions for temperature and pressure, and how rarely these conditions have occurred throughout geologic history were explained.
Concerned with time, I cut the Explore phase short so that the powerpoint presentation on the 8 allotropes of carbon could begin (Explain phase, see Appendix D). It starts out with Diamond and ends up with Carbon Nano Tubes. Students were told that they might want to take some notes because there would be a little project on one of the allotropes (Figure 1). As the presentation progressed, a little more project information was explained to the students. Even though the powerpoint presentation was rushed, students remained engaged in the topic. Teams were quickly formed after the presentation and then the bell rang. In spite of the rush and the push to finish these lessons before the end of the school year, the day went very well. The amount accomplished on this day kept the classes on schedule to complete all of the lessons on time.

On Tuesday, May 29th, the teams the students had created five days earlier were reassembled. The student's memory was refreshed on what they were doing on the Allotropes of Carbon Project. They received a sheet explaining the project they were to research (Appendix D). Because it was a short week, there were two block days and one speed day to complete the project. The students were allotted the first block day for research. The second block day was for building a model of their allotrope. On both days, some
students could work on their poster and presentation. Presentations were on the speed day, the last day of school before exams.

RESEARCH DAY: First block day. Interestingly, the students were in almost the same groups as they were in for lesson plan 2. Consequently, students quickly defined their roles and got started on research over the internet or on their poster. Students were engaged in the process and asked questions as I wandered around the media center, asking students questions to keep or even increase their engagement. As in the last project of Lesson Plan 2, some students who did not have a prayer of passing the semester were totally engaged in the project. One group of students in this category even made an impressive powerpoint presentation. Unfortunately, due to their lack of practice in following through, they never finished their presentation, but they did present what they had found.

MODEL BUILDING DAY: Second Block Day. This went very well with the morning classes. The students were called up to the supply table by teams, largest model size first (the C540 Team). In the meantime, the other teams could get their posters and start working on them, with discussion of how they would finish everything that day. As each team came up to the supply table questions were asked, such as, “do you know how many marshmallows you need?” “Do you have a photo off the internet of what your model will look like?” Most teams were organized and well prepared. I had to send a few teams back to regroup and amend their supply list before I would give them materials to build.
The easiest model to build was the Amorphous Carbon (Coal & Soot). Since amorphous carbon has no structure, the students only had to put a blob of marshmallows and toothpicks together. Since I had concerns that that they would get bored, I specifically chose for the amorphous carbon team students who had a respectable grade in the class in addition to showing positive behavior. The next most-simple model to build was the Diamond. All four groups (one from each class) had a photo of the structure, making it easy to build. Graphite and Lonsdaleite were the next most-simple models. Both of these groups in each class needed a little more direction and guidance, which usually only took a few questions. “How many sides are in this? How many hexagons should you hook together? How many layers up will you build this?” By the time the team finished answering each question, they either had questions of their own to ask, or knew what they were going to do next!

The three Buckminster Fullerines, otherwise known as the nanotech “Buckyballs”, were the most difficult to build. To encourage the students to come up with a method of building them, additional extra credit was offered. Extra time was spent assisting these teams and offering them some ideas to explore. The first class had the most challenges because there were no examples sitting around the room of what each allotrope would look like. Each class gained knowledge and experience from the previous class as they built their models.

PRESENTATION DAY: Friday, June 1st. Overall presentations went well. Everyone rushed as it was the last regular school day before final exams and there was much to accomplish. Some teams were not finished because of lack
of planning in arranging jobs. Because it was the end of the semester, these
teams were pushed to present, just so they would get their presentation points.
The students who cut and pasted information from the internet onto their poster
read what it said – but found they didn’t understand the information. At times
they were asking how to pronounce some words. Other teams did well and at
times even seemed excited about what they had learned (we all know how
teenagers can try to hide that!)

Outcomes

Implementation of Lesson Plans 1-3 was exciting and gave much
optimism of what Grand Rapids Public School students can accomplish. Overall,
a larger than usual number of students were engaged and active in the process
of science. I discovered some flaws in the lessons that are addressed within the
scope of this report. I discovered motivational techniques that had not been
written down until doing the lessons. Most students got all the points (30), on the
Inquiry Analysis of the movie “Understanding Bacteria”, unless they were feeling
lazy and did not complete the questions (Appendix B: Inquiry Analysis of Movie).

During and after the implementation of Lesson Plan 2 I found it interesting
to ponder if it was the real world component of the lesson plan or the 5E part of
the lesson plan, or a combination of both, that was working well for the students.
Students who finished research or project work before the end of class gave me
an opportunity to try to create other things they could do to add points to their
project. It was interesting and entertaining to see many of the usually
unmotivated students engaged into the project. For these students, the grade they get on the project will not change their semester grade, as they’ve already failed the semester. I felt as if I’d provided evidence that drug dealers and gang members can be engaged in the education process. To see these students engaged in a project, working and doing an excellent job, was very motivating. There were still a few students who were not involved in the project and caused behavioral issues. This is an issue for unmotivated students everywhere that educators all continue to struggle with.

During student presentations to the class of their projects, students raised the question as to whether a component of the student’s grade should be from gaining points for interesting questions for other team presentations. I felt this was a good idea and asked students to brainstorm how this component could be added without it becoming a bookkeeping nightmare for the teacher. Students came up with some good ideas. My favorite was to have another student be in charge of writing down names and points for good questions asked. Figure 2 shows examples of student posters created.

**FIGURE 2:** Student Created Nano Tech Posters for Lesson Plan #2
During both Lesson Plan 2 and 3, on the research day, going from group to group, giving encouragement or offering direction and advice, as in the last lesson plan, I had many thoughts on re-examining the directions given to students. Many groups tended to only try to find a specific answer to questions posed in the directions, whereas the goal was to see what information the students could find and then share that with the class. Some students misunderstood this explanation too. A few printed
information from the internet and then only cut and pasted it on their poster. A larger realization was that students were printing, then cutting and pasting information they didn’t understand. Unfortunately, the groups who did a lot of cutting and pasting without taking the time to understand, probably didn’t get much out of the project. Otherwise, all the other presentations were informative and well done. Most completed presentations received A’s.

I enjoyed seeing the creativity and problem solving as the students came up with models of the Carbon Allotrope in Lesson Plan 3. The first class had the most challenges because there were no readily available examples of what each allotrope would look like. Each class gained knowledge and experience from the previous class, as they built their models. Because Buckyballs are in the shape of a ball, several teams used a ball of some type to help hold their structure together (See Figure 3 for photos). The C70 and C60 had their own unique challenges, as they are both are combination of hexagons and pentagons all hooked together to create a ball. Some students used a soccer ball to hold the C70 and C60 Buckyballs. Other teams tried to create a cardboard ball of the correct mix of polygons to attach the marshmallows to. One team used a pop bottle to hold up their C60. The C540 was obviously the largest, but completely composed of hexagons. One C540 team used an exercise ball to wrap their structure around. Another C540 team made a paper-mache ball to attach their marshmallows to. It was entertaining watching them use their creativity to come up with solutions to their individual dilemmas. It was excellent problem-solving in
action. Most of the students enjoyed the process while a few got extremely frustrated and needed encouragement.

**FIGURE 3:** Photos of Carbon Allotrope Models and Poster

*(Below Left)* A Carbon Nanotube (CNT). In the back left is the Lonsdaleite Allotrope.

*(Above)* A C70 Allotrope held together with a cola bottle

*(Right)* Amorphous Coal and Soot is in the back left. Back right is another CNT, and in front is a C60 Buckyball in progress.
(Below) C540 Buckyball made with a paper mache interior.

(Above) A C70 Buckyball made with a soccer ball interior.

(Right) A C60 Buckyball project in progress. Students cut out a combination of pentagons and hexagons to fit together to create the interior of the C60. In the background is a CNT model and several posters.
(Below) C540 Allotrope: Students used an exercise ball to hold their model together.
CHAPTER 4: RESULTS

Introduction

Each spreadsheet covered one of the twenty-one questions on the questionnaire. Next to each student’s name or code name was their pre-questionnaire response. Responses for each possible answer were totaled. The percent of responses for each answer was calculated. In another column the post-questionnaire responses were totaled and percentages calculated. Graphs for pre and post answers were made. What follows is only an interpretation of the pre and post questionnaire responses. An overall analysis of the interpretation will follow in the Implications and Conclusions chapter.

Analysis of Student Responses by Questionnaire Number

Question 1: I know enough about bacteria and viruses to have a healthy life in this world.

<table>
<thead>
<tr>
<th>Figure 1A:</th>
<th>Pre Results – Question 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Strongly Agree</td>
<td>8.5%</td>
</tr>
<tr>
<td>B. Agree</td>
<td>37.2%</td>
</tr>
<tr>
<td>C. Undecided</td>
<td>31.9%</td>
</tr>
<tr>
<td>D. Disagree</td>
<td>16.0%</td>
</tr>
<tr>
<td>E. Strongly Disagree</td>
<td>6.4%</td>
</tr>
</tbody>
</table>

Pre questionnaire results show that most students either agreed (37.2%) with the statement, or were undecided (31.9%) about the statement. Some
students disagreed (16%) and a few were on the extreme ends (strongly agree 8.5%, strongly disagree 6.4%).

There was a significant shift on the post questionnaire results. I expected more students to end up disagreeing or strongly disagreeing with the statement, however, after the lessons more students agreed or strongly agreed that they knew enough about bacteria and viruses to live a healthy life. The intention of the lesson plans is to get students to understand how we need to research and learn more about bacteria and viruses as their threat to our existence is extreme. However, the full scope of lesson plans will not be realized until the students have completed chemistry and physics. Consequently, the students’ change in answers has more to do with them having a little more knowledge about bacteria and viruses than before they experienced the lesson plans.

**Question 2: Nanotechnology has changed the way I live today.**

Prior to the lessons being taught, 51.1% of the students were undecided as to whether nanotechnology has
changed the way they live. After the lesson plans only 21.7% were undecided. Before the lessons, 31.9% agreed or strongly agreed with the statement. This number more than doubled after the lessons with 68.7% agreeing or strongly agreeing that nanotechnology has changed they way we live. The results of the posttest provide evidence that the lesson plans were effective in educating the students on the impact nanotechnology has had on our culture.

**Question 3: I could explain what “nanotechnology” is.**

Before the lessons were taught more than 60% reported no knowledge of nanotechnology. About 20% (strongly agree plus agree) were aware of nanotechnology. However, I highly suspect that 20% had just heard of nanotech and perhaps knew that “nano” only refers to the “small” components within a Nano iPod. I hypothesize that the “undecided” group (17%) had heard of
nanotechnology, but had no idea what it was. Almost 55% of the students felt they could explain nanotechnology after the lessons. This is a gain of almost 25%. Almost half (48%) of the students who originally disagreed or strongly disagreed moved to a higher category (undecided, agree, or strongly agree) after the lessons. I noticed that the 12% that disagree or strongly disagree on the post questionnaire had absentee issues or answered, "strongly disagree" on every question asked.

**Figure 3B:**

**POST Results – Question 3**

- A. Strongly Agree 19.3%
- B. Agree 35.0%
- C. Undecided 32.5%
- D. Disagree 6.0%
- E. Strongly Disagree 6.2%

**Question 4: Biosensors could change my life or someone I know.**

The results from Question 4 are not nearly as dramatic as the previous questions. Over 58% of the students before the lessons were “undecided” on whether biosensors could change their life or someone they know. The

**Figure 4A:**

**PRE Results – Question 4**

- A. Strongly Agree 5.3%
- B. Agree 16.0%
- C. Undecided 58.5%
- D. Disagree 8.5%
- E. Strongly Disagree 11.7%

"undecided" group only dropped by 1.9% after the lessons. Those who agreed or strongly agreed that biosensors could change lives increased by 11.3%, giving notice that some students remembered the discussion in the first
lesson plan. The first lesson plan was the only lesson in which biosensors were discussed and introduced in the Explore, Explain and Elaborate stages. There was an attempt to connect biosensors to lesson plan 2. The powerpoint presentation in lesson plan 2 in the Explain stage reconnects students with biosensors in one of the final slides. The data indicate that this connection needs to be strengthened in some way. I would like to look at strengthening this connection in both lesson plan 2 and lesson plan 3. Biosensors are not even mentioned in lesson plan 3. In lesson plan 2 the connection needs to be made much earlier, perhaps as early as the Engage or Explore phase, if not earlier in the powerpoint presentation.

**Question 5: I could explain using my logic what a biosensor is.**

The ability to explain a biosensor using one’s logic was a question asked because teachers are always trying to get students to think, learn new vocabulary and make connections. During the first lesson when
biosensors were brought up, I asked the students this question and broke down
the word into two words: bio and sensor. We as a class came to a logic
conclusion through discussion as to what a biosensor is. However, this was only
a five-minute discussion as part of the first lesson plan.

Before the lessons only 8.5% of the students felt they could possibly
explain what a biosensor is (agree). None of the students strongly agreed that
they could explain what a

| Figure 5B: |  
|-------------|---|
| POST Results – Question 5 |  
| A. Strongly Agree | 4.9% |
| B. Agree | 15.6% |
| C. Undecided | 45.7% |
| D. Disagree | 23.0% |
| E. Strongly Disagree | 10.8% |

biosensor is. The lesson more
than doubled the percent of students who either “agreed” or “strongly agreed” in
the post results, an improvement of approximately 12%.

Before the lessons, almost 63% of the students either “disagreed” or
“strongly disagreed” with their ability to explain what a biosensor is. This number
of students decreased by almost half after the lessons (34%). The majority of the
movement went into the “undecided” category. “Undecided” students jumped
17% from pre to post questioning (Pre = 28.7%, Post = 45.7%).

**Question 6: I can explain the difference between diamond, graphite, and coal.**

Lesson plan three focused on the six allotropes of carbon. Consequently,
I expected the results of this question to be good, even though we finished this
lesson the same day the post questionnaire was completed. By adding the “disagree” and “strongly disagree” together, nearly 39% of the students knew that before the lessons they would not be able to explain the difference between diamond, graphite and coal. I suspect that the “undecided” group of 24.5% had heard of all three things (diamond, graphite, and coal), but were not totally sure of the difference between them. Almost as many students (36%) believed they could explain the differences as the students who knew they could not explain the differences (39%).

After the lessons were taught almost 60% either “strongly agreed” or “agreed” that they could explain the difference between diamond, graphite and coal. With only 23% of the students being “undecided” and less than 17% percent “disagreeing” or “strongly disagreeing”, the indication is that the lessons were very successful in students learning the difference between diamond, graphite and coal.
**Question 7: I know what it means if an object is “conductive” or has “conductivity.”**

Question seven is covered in lesson plan four, which was not implemented. Consequently, the results on this question are negligible, yet interesting. Those students who felt they knew what the word meant rose from 39% to 55% (agree + strongly agree). This is a significant jump. There are no data to indicate why this jump occurred. I can only hypothesize that the students heard the word “conductivity” mentioned during the course of lesson plans 1, 2, and 3 either as part of a presentation, classroom discussion, or came across it in their research done for lesson plans 2 and 3. Before the lessons, 33% felt they did not understand “conductivity”. After the lessons, only 19% felt they did not understand “conductivity”. Even though this question was designed to answer the effectiveness of lesson plan 4, the word “conductivity” was used enough for students to gain new confidence in their vocabulary.

<table>
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<tbody>
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<td>13.8%</td>
</tr>
<tr>
<td>B. Agree</td>
<td>25.5%</td>
</tr>
<tr>
<td>C. Undecided</td>
<td>26.6%</td>
</tr>
<tr>
<td>D. Disagree</td>
<td>21.4%</td>
</tr>
<tr>
<td>E. Strongly Disagree</td>
<td>12.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 7B:</th>
<th>POST Results – Question 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Strongly Agree</td>
<td>22.9%</td>
</tr>
<tr>
<td>B. Agree</td>
<td>32.5%</td>
</tr>
<tr>
<td>C. Undecided</td>
<td>25.3%</td>
</tr>
<tr>
<td>D. Disagree</td>
<td>14.5%</td>
</tr>
<tr>
<td>E. Strongly Disagree</td>
<td>4.8%</td>
</tr>
</tbody>
</table>
Question 8: If asked to find the pH of a liquid, given the right supplies, I know how to do it.

Once again, this question was designed to test the effectiveness of lesson plan four. In the pre questionnaire results, the answers are almost evenly divided. The post results show that those who either agree or strongly agree increased from 36.2% to 44.6%. Students who disagreed or strongly disagreed dropped from 41.5% to 21.7%. The decrease in students feeling they don’t understand pH and how to test for it is significant, in spite of the fact that pH was not taught in the first three lesson plans. I hypothesize that the students picked up much knowledge in their research of nanotechnology products in lesson plan two and of carbon allotropes in lesson plan three. I believe that in their research the students found that pH was a vital component to the function of the product.
**Question 9:** We spend enough money on the research and development of bacteria/virus detection and healing.

It’s apparent that most students before the lessons were taught were “undecided” (39.4%) as to whether we spend enough money on research and development of bacteria/virus detection. Both those who “strongly agree” and “agree” combined (30.8%) and “strongly disagree” and “disagree” combined (29.8%) were fairly evenly split with close to 30% for each group. The post results show a slight realignment of the numbers. The “undecided” students still were the largest group. Those students that “agree” or “strongly agree” rose from 29.8% to 36.1%. And those students the “disagree” or “strongly disagree” dropped from 29.8% to 22.9%. Even though the shift is slight, about 7% of the students shifted their attitude and decided that perhaps we do not spend enough research and development dollars on bacteria and virus detection.
**Question 10: I’m usually very interested in science subjects and labs.**

Before the lessons 57% of the students said that they were interested in science subjects and labs. Almost 29% did not have interest in science and labs.

In the post questionnaire results, those who are interested in science and labs changed by less than 3%. The three lessons taught between the pre questionnaire and the post questionnaire took only three weeks. To change a persons attitude takes much longer than three weeks. In retrospect, question 10 would only be a good question to ask at the beginning of a school year and then at the end of the same school year.
**Question 11: I really like doing research and solving problems through research.**

The purpose of question eleven was to see if the amount of research done on the problems in the lessons had an effect on the students “desire” to do research to solve problems. Prior to the lessons, about 47% of the students liked doing research to solve problems and 33% did not.

There was a notable positive change in attitude about doing research to solve problems. With more experience doing the lessons, the change should be more positive. After the lessons were taught, 51.8% of the students (strongly agree + agree) liked doing research, an increase of 5%. The students who did not like doing research decreased, dropping to about 29%, a decrease of 4%.
Question 12: I’m good at research and can find the answer to most
questions asked.

When studying the charts below on question 12, most data show positive changes
as a result of the experience students gain in research during the lessons. Those who
“strongly agree” rose from 14.9% to 18.1%. Those students who “agree” that they are good
at research rose from 35.1% to 38.6%. Those who were “undecided” dropped from 25.6% to
19.3%. I conclude that the experience gained in research and problem solving in both lesson plans two and three were successful in changing student attitudes toward doing research and having control over their project.
Question 13: Given a “question”, I can design my own experiment to test hypothetical answers to the question.

This question was also designed to work with lesson plan four, which helps the students design their own experiment to test conductivity. However, even though lesson plans two and three did not have the students design their own experiment, the students did have to design their own research project.

Before the three lessons were taught, most of the students (44.7%) felt “undecided” as to whether they were capable of such an endeavor. After the lessons, this number of students dropped by almost 15%. While the students who did not feel confident designing their own experiment changed by less than 2%, the students who gained confidence jumped from 24.4% to 42.2% (strongly agree + agree). By designing their own research projects in lesson plans two and three, the students seemed to have gained a tremendous amount of confidence in their ability to design experiments and test hypotheses. I hope to have these students again when they are juniors or seniors in my physics class!
**Question 14: Have you or someone you know ever had food poisoning?**

Question fourteen and the remaining questions are designed to find out what life experiences the students may have had that would relate to the lessons. The idea is to find out how much potential the “real world” component of these lessons may affect their engagement in the lesson. If the student or someone the student knows has had food poisoning, they will have a greater need to avoid food poisoning the rest of their lives. Consequently, the need to have more effective methods of detecting food poisoning before it reaches them is increased. This should increase their engagement in the lessons, or should increase their need for more knowledge in this subject. Over 60% of the students have either experienced food poisoning or known someone who has had food poisoning. In retrospect, I would change the post questionnaire to ask students to rank how engaged they were in each lesson. It would be interesting then to correlate those who were engaged in each lesson to those who have experienced food poisoning in one way or another.

![Figure 14: Percent of students who've known someone who has had food poisoning](image-url)
**Question 15: Have you ever had the flu?**

One in five students said they had never had the flu. When inputting and correlating the data, I concluded that there were two types of students who answered “no” on this question. Some wanted to invalidate my research and others wanted to be funny.

Others may actually be ignorant as to what the flu is. Part of my purpose in asking this question was to get the students to think about their own life experiences (such as having the flu) before the lessons. They need to realize that with research, perhaps we can keep them from having this miserable experience again. This is an effective question prior to the lessons. In retrospect, the question was not necessary after the lessons.

**Question 16: Have you or someone you know ever not been able to go swimming due to unsafe water in the river, stream, lake or pond?** Since we live in the city, I suspect that most have not experienced this. I am surprised however, at how many students have experienced unsafe water in the river, stream, lake or pond (45.7%). There is less than a 10% differential between those who have experienced unsafe water and those who have not. On the west
side of Grand Rapids, there are some little lakes that students may go swimming in. There is also a county park on a lake with lifeguards. We also have the Grand River and many streams that run into the river that students may use as summer swimming holes or for fishing.

**Question 17: Have you ever heard of people dying from food poisoning?**

The purpose of question seventeen was one of curiosity. I thought that if this number is high enough – I will use this statistic to help sell the lesson plans to the students. I have found that most freshman do not listen or watch the news, so I’m surprised that 46.7% of the students have heard that people have died from food poisoning. This high number could be useful in motivating students to be interested in the lessons.
**Question 18:** Have you or someone you know ever been hospitalized due to having the flu?

![Figure 18: Students who've known someone hospitalized due to having the flu]

Questions eighteen and nineteen regarding the flu have the same purpose as question seventeen did. Nearly half of the students have known someone who has been hospitalized due to the flu. This will be a good statement to use when engaging students in the lessons.

**Question 19:** Have you ever heard of anyone dying due to having the flu?

The data show that approximately 63% of the students had never heard of anyone dying from having the flu. But more than one third of the students have heard of this happening. I conclude that this is also a good statement to use when engaging students in the lessons.

![Figure 19: Students who've heard of people dying due to having the flu]
**Question 20: Have you ever heard of NanoTechnology before today?**

Question twenty is only valid before the lessons were taught. I only asked this question out of curiosity. I wanted to know what percent of the students were familiar with the term. Surprisingly, 41.1% of the students were familiar with Nanotechnology. In retrospect it would have been good to find out if the students knew at all what Nanotechnology is. This question only tells us that 41.1% have heard of it before.

**Question 21: Have you ever heard of CNT’s (Carbon Nano Tubes) before?**

Carbon Nano Tubes were presented in Lesson Plan Two and extensively worked on in Lesson Plan Three. Before the lessons, only 10% of the students had heard of CNTs. The results of this question are what I expected; about half of the 10% who said they had heard of CNTs before actually had done so. I noticed that some of the students who had answered YES to this
question were the last ones you’d ever expect to, as they are students who did not even pass 9th grade. Now all of the students have had exposure to this amazing material in lessons they’ll remember – hopefully forever.
CHAPTER 5: IMPLICATIONS and CONCLUSIONS

The data from the questionnaire can be broken down into four areas: how students attitudes have changed, how students confidence has changed, how students self reported knowledge and skills have changed and what real world experiences the students had prior to these lessons that could impact the design of the lessons.

Changing Attitudes

The effect of student attitude in learning science was somewhat ignored until recently. With the realization that western countries were losing students in the sciences, the study of student attitude has been rejuvenated. Contemporary educational theorists readily admit that attitudes, values, beliefs, opinions, interest and motivation all affect learning (Koballa, 2007). Six questions on the questionnaire had to do with the affective dimensions (#1, 2, 4, 9, 10, 11, see Appendix A). Of the six questions only two showed a significant change in attitude in the desired direction (#2 and 4: Nanotechnology has changed the way I live today, and Biosensors could change my life or someone I know). One question raised in the study was whether students would more fully understand the need for biosensors in our society. While there was a positive shift in attitude on question 2 (gain of 37%) and question 4 (a gain of 9%), I think this shift will increase with continued refinement of the lesson plans and with students completing lesson plans four through seven.
The lack in the change of attitude for the other four questions (#1, 9, 10, 11) is likely related to having less than three weeks to spend on the lessons. It takes longer than three weeks to change a person’s opinion on public policy, interest in science, and attitude about doing research. Furthermore, changes in the lessons could increase student response. In the first lesson plan a new emphasis on how much more there is to learn about bacteria and viruses, their detection, and the treatment of those infected needs to be formulated. Perhaps a different movie, or more prompting from the teacher would cause a larger change in attitude. Even better would be simple research into the news on bacteria and virus contaminations in food and water over the past year. Then students could write a paragraph or two on defining the problem, what society should be doing about the problem, and what knowledge still needs to be learned.

**Self-Reported Knowledge and Skills**

In spite of the lack in the change of attitude, students did feel far more knowledgeable in the subject matter after the lessons (questionnaire #’s 3, 5, 6, 7). The greatest change in knowledge came with questions 3 and 6, a 35% and 25% increase respectively. This increase was expected, since their ability to explain nanotechnology and the differences between diamond, graphite and coal constitutes the majority of the lessons. With an average increase of 22% in self-reported knowledge, most changes from pre to post responses either doubled or almost doubled the number of students who felt knowledgeable. Interestingly enough, the neutral category (undecided or response “C”) had a positive shift
from students who originally did not know anything about the content matter. With almost double the gains in all four questions, clearly the lessons were successful in helping students feel knowledgeable about biosensors and nanotechnology. The question still arises, however, how much of the technical details of nanotechnology will the students retain? Are the lessons too rigorous, or not rigorous enough? The students do feel confidence in the knowledge learned, but to how much higher a level can I push them? An entirely different type of pre and post-test would be needed in order to answer these questions. The students had no trouble handling the level of science that nanotechnology demands.

In some cases students felt that they gained confidence in scientific skills throughout the lessons (questionnaire #’s 8, 12, 13). The smallest gain was in question 12 (6%), “I’m good at research and can find the answer to most questions asked.” Somehow I need to communicate to students that they should use the questions asked only as guidelines in their research. In the process of research, the answer one is looking for is not always found, however the additional knowledge gained usually leads to an answer to other questions. Finding the answers to the particular question posed by the teacher may not necessarily be the point. Through the process of research the student may come upon some other discovery of information or insight that is far more profound than the answer to the original question. Students have trouble moving beyond finding the correct answer to the questions posed.
Real World Experiences

Questions 14 - 21 on the questionnaire were written specifically to assess in the lesson plans’ ability to engage the students. With the knowledge from these questions, how can the lessons be modified to maximize the previous set of experiences of the students? Can I use the students’ previous experiences to engage them more in the lessons? These questions were only answered in the pre-questionnaire. Questions 14-19 were specifically designed to help improve the “Engage” phase of the lessons. Through experience I have learned that poor, urban students must have some interest in the lesson in order to get anything out of it. How educators get the students interested in the topic is what the engage phase is all about. Because Lesson Plan 1 sets up the students for the next six lessons, which are designed to be given in each science class as they go through high school, the Engage phase of Lesson Plan 1 is vital to the success of the other lessons. I designed Lesson Plan 1 be repeated or re-vamped for use again in the later grades for the sole purpose of re-engaging the students in the topic of biosensors. The results of questions 14-19 on the questionnaire suggest cause to entirely redesign Lesson Plan 1.

Over 80% of the students have had the flu, over 50% have known someone hospitalized due to having the flu, and over 63% of the students have heard of people dying from the flu. Experience with the flu is high, and as debated in the Results Chapter, probably higher than reported by the students. Consequently, there would be great benefit to connect the flu with the study of viruses. A good question to pose to the students in Lesson Plan 1 would be:
“How can we kill viruses or detect them before they make someone ill?” Once the students get into the high school biology lessons, this question can easily be expanded further.

Question 20 is directly written to help with the Engage phase of Lesson Plan 2 (Have you ever heard of nanotechnology before today?). Only 41% had heard of nanotechnology prior to the lessons. If the student had heard of “nano” and of “technology” before, they often can associate the words together to come up with a meaning. This was the purpose of the Engage phase of Lesson Plan 2. Sometimes educators assume students are always “word associating,” however teenagers are often so absorbed into their own reality that they are not. Since over 55% of the students felt they could explain what nanotechnology is after the lessons (Question 3), I currently feel the Engage phase of Lesson Plan 2 is sufficient.

Only 10% of the students had heard of CNTs (Carbon Nano Tubes) prior to the lessons (Question 21). This question was asked more out of curiosity than for the purpose of using the data to help guide the Engage phase of Lesson Plan 3. A better question would have been one that referred to diamonds, graphite or coal. Question 3 did ask whether the student could explain the difference between diamond, graphite and coal, which showed a significant difference of 25% from pre to post administration. I would like to add a component to Lesson Plan 3 in the Evaluate phase of the lesson because it felt incomplete. I could see the need for another way for students to express the knowledge learned. My current thoughts for the additional component to the Evaluate phase would be to
assign an essay describing the differences in at least three of the eight allotropes of carbon.

**Insights**

Each experience of teaching and revising the lessons will cause additional student growth over the previous group taught. Through observing, prodding, sometimes pushing, and building up students during the implementation of the three lessons, I have learned that the students have no problem handling new technical information such as nanotechnology. Nanotechnology is high-level knowledge, but it is also real world knowledge. Students appreciated researching book knowledge for the purpose of understanding their real world. Nanotech lessons are an ideal topic for the classroom to engage students in the process of scientific inquiry due to the real world component of nanotechnology. As an educator who is passionate about engaging my students in science, I can only hope and dream that many of them will remember and will choose science as their career.

**Further Research and Work**

The introductory research of the first three Nanotech Biosensor Lessons shows much potential for use in Grand Rapids Public Schools (GRPS), grades seven through twelve, and perhaps even on a State or National level. Since the direction of the National Science Foundation and the National Center for Learning and Teaching Nanoscale Science and Engineering is to put a little
nanoscience into the curriculum in each grade, seven through twelve, implementation in GRPS is a vital step. Recommendations for the Nanotech Biosensor Lessons are to edit the first three lessons as outlined in this research report. It will be important to make the lessons “teacher friendly” so it will be easy for teachers to implement them within their current curriculum. A meeting with the head of curriculum for GRPS will be scheduled with the idea of planning a process for integrating the lessons into the curriculum. Lesson Plans and the outcomes of this research project will be given to Dr. Evangelyn C. Alocilja for submission to the NSF to complete the parameters of the Biosensor Research Grant. From that point, Dr. Alocilja and I can make plans as to what will happen next.
APPENDIX A: PRE or POST QUESTIONNAIRE  Lovell’s Freshman Classes, May 2007

Directions: On your scantron sheet, use the following scale to answer each question:

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
</tbody>
</table>

1. I know enough about bacteria and viruses to have a healthy life in this world.

2. Nanotechnology has changed the way I live today.

3. I could explain what “nanotechnology” is.

4. Biosensors could change my life or someone I know.

5. I could explain using my logic what a biosensor is.

6. I can explain the difference between carbon, graphite and coal.

7. I know what it means if an object is “conductive” or has “conductivity”.

8. If asked to test the pH of a liquid, given the right supplies, I know how to do it.

9. We spend enough money on the research and development of bacteria/virus detection and healing.

10. I’m usually very interested in science subjects and labs.

11. I really like doing research and solving problems through research.

12. I’m good at research and can find the answer to most questions asked.

13. Given a “question”, I can design my own experiment to test hypothetical answers to the question.

**Bubble in A for YES, and B for NO.**

14. Have you or someone you know ever had food poisoning?  YES  NO
15. Have you ever had the flu?  YES  NO

16. Have you or someone you know ever not been able to go swimming due to unsafe water in the river, stream, lake or pond?  YES  NO

17. Have you ever heard of people dying from food poisoning?  YES  NO

18. Have you or someone you know ever been hospitalized due to having the flu?  YES  NO

19. Have you ever heard of anyone dying due to having the flu?  YES  NO

20. Have you ever heard of NanoTechnology before today?  YES  NO

21. Have you ever heard of Carbon Nano Tubes (CNT’s) before?  YES  NO
May 1, 2007

Dear Parent or Guardian:

I am a student in the Education Department at Michigan Technological University. I am conducting a research project on lesson plans I’ve written on biosensors and nano technology. This research is part of gaining a Master’s in Applied Science Education Degree at Michigan Technological University. The objective of this project is to increase student knowledge and societal need for biosensors and nano technologies. Through your student’s participation, I eventually hope to understand how best to educate grades seven through twelve on how nano and biosensor technology can improve the lives of all of us. This letter for you is to request permission for your child to participate.

The study consists of a series of four lesson plans that are within the normal range of regular education in a freshman science classroom. The project will be explained in terms that your child can understand, and your child will participate only if he or she is willing to do so. Only I will have access to information from your child. At the conclusion of the study, student responses will be reported as group results only.

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect the services normally provided to your child by Union High School. Your child’s participation in this study will not lead to the loss of any benefits to which he or she is otherwise entitled. Even if you give your permission for your child to participate, your child is free to refuse to participate. If your child agrees to participate, he or she is free to end participation at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child’s participation in this research study.

Should you have any questions or desire further information, please call me or email me at 819-3408 or at lovellj@grps.k12.mi.us. Keep this letter after tearing off and completing the bottom portion and have your child return it to me during class.

If you have any questions about your rights as a research subject, you may contact the Michigan Technological University Institutional Review Board (IRB) by mail at 1400 Townsend Drive, Houghton, MI 49931, by phone at (908) 487-2902, or by e-mail at ipolzien@mtu.edu. This study (IRB #M000) was approved by the IRB on May 1, 2007.

Sincerely,

Jennifer Lovell/Science Educator/Union High School/Grand Rapids Public Schools
Graduate Education Candidate/Michigan Technological University

Please indicate whether or not you wish to allow your child to participate in this project by checking one of the statements below, signing your name and having your child return the letter. Sign both copies and keep one for your records.

_____ I grant permission for my child to participate in Jennifer Lovell’s study on nano and biosensor technology.

_____ I do not grant permission for my child to participate in Jennifer Lovell’s study on nano and biosensor technology.

________________________________________________________________________

Child’s name

________________________________________________________________________

Parent signature

Date: ___________________
ASSENT TO PARTICIPATE IN RESEARCH

“How will Nano and Biosensor Technologies benefit my life?”

1. As your science teacher this year, I would like to invite you to participate in a research study because we are trying to learn more about educational practices which allow you to learn about the real world and how science can improve life with the greatest efficiency.

2. This research study will be a direct application to my work at Michigan Technological University in a Master’s in Applied Science Education.

3. If you agree to be in this study you will be taking a pre questionnaire and a post questionnaire to the lesson plans that I’ve written.

4. The course work during the implementation of these lesson plans is not beyond what is normally done in the classroom.

5. You may directly benefit from this project through the knowledge gained on how you can save lives from food and water borne bacteria and viruses such as e-Coli and Salmonella.

6. If you don’t want to be in this study, you don’t have to participate. Remember, being in this study is up to you and no one will be upset if you don’t want to participate or even if you change your mind later and do not want to participate in the post-questionnaire.

7. You can ask any questions that you have about the study. If you have a question later that you didn’t think of now, you can call me at 819-34087, email me at lovellj@grps.k12.mi.us, or ask me next time.

8. Signing your name at the bottom means that you agree to be in this study. You and your parents/guardian will be given a copy of this form after you have signed it.

________________________________________  ____________________
Printed Name of Subject      Date
Appendix B
INTRO TO NANOTECHNOLOGY AND BIOSENSORS
5E Inquiry Lesson Plans - Grades 7-12
Lesson Plan #1: Bacteria & Viruses: a threat to the existence of the human species?
one 45-55 minute class period

Even though there is not any information here on how we detect bacteria and viruses, the video adequately shows the
problems there are with bacteria and viruses. It is important to stop the video where they are shown collecting samples and explain
what it currently takes to detect bacteria and viruses. The idea is to lead the students into the project of bacteria/virus detection and
detection time. This is the definition of our problem! This is the basis and purpose of the entire program.

ENGAGE: Have students generate a list on the board of all the bacteria and viruses they’ve ever heard about or experienced.
What types of problems with bacteria/viruses have they heard about on the news or experienced in their lives? The teacher can have
the list as detailed as the level of the students (i.e.: a high school biology class will differentiate between bacteria and viruses,
whereas a 7th grade science class would just list them all together).

EXPLORE: Show the first half of “Understanding Bacteria” movie (about 25 minutes long). Stop at appropriate times to have
students comment on the following: Depending on the level of the students, you could have them answer these questions on paper
for more accountability.
1. Could understanding more about bacteria and viruses be vital to the survival of the human species?
2. What do they do with the samples they’ve collected? Why?
3. How do we currently detect bacteria and viruses?
4. Since it takes 2 to 7 days to detect bacteria or viruses in your food, water or blood stream, what problems are there
   with this lengthy wait time?
5. Why is it important to learn how to detect bacteria and viruses in less than 2 to 7 days? Why would it be beneficial to
   you, your family & friends, your community and even your country?

EXPLAIN: Either during the movie or after the movie (teacher judgment here), direct or explain the correct answers to the
questions above in the explore stage. Students will have questions that need to be answered also.

ELABORATE: After the movie and discussions have the students write a paragraph explaining what they think we should be
doing about bacteria/virus detection and why we should be doing it. What are the consequences if we don’t? What ideas do you
have on how to get detection time down? WQ

EVALUATE: Evaluation is on any notes you may have had the students take for the questions in the explore phase
and on the Elaborate paragraph they have written.
Appendix B: Inquiry Analysis on Movie

NAME ________________________ Hour ____

Understanding Bacteria
From www.unitedstreaming.com

1. Could understanding more about bacteria and viruses be vital to the survival of the human species? Why? ________________

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

2. What do they do with the samples they’ve collected? Why? ________________

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

3. How do we currently detect bacteria and viruses? ________________

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

4. Since it takes 2 to 7 days to detect bacteria or viruses in your food, water or blood stream, what problems are there with this lengthy wait time? ________________

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

5. Why is it important to learn how to detect bacteria and viruses in less than 2 to 7 days? Why would it be beneficial to you, your family & friends, your community and even your country? ________________

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
6. Write a paragraph explaining what you think we should be doing about bacteria/virus detection and why we should be doing it. What are the consequences if we don’t? What ideas do you have on how to get detection time down?
APPENDIX C

INTRO TO NANO TECHNOLOGY AND BIOSENSORS

5E Inquiry Lesson Plans - Grades 7-12
Lesson Plan #2: Intro to Nanotechnology & its current uses!

ENGAGE: Get out a meter stick. Have students volunteer all the prefixes for the unit of measure – “meter.”
You may have to fill in some of the blanks, depending on which level of students you are working with. The complete list is in the PowerPoint under the explain phase.

EXPLORE: Ask students to speculate on the meaning of the word “nanoscience” and “nanotechnology.” Speculate on ways in which it is likely to affect scientific research. Does anyone know of a product that has come from this research? List student responses on one side of the board or overhead.

EXPLAIN: Give the slide show on PowerPoint showing how small “nano” is and the products created using nanotechnology. Tell the students to be thinking about which product they are most interested in so they’ll be prepared for the next step of the lesson plan.

EXPLORE: Have students pick one product to work on. The teacher could facilitate this by using several different methods. One method would be to have a sign for each of the 10 products taped to the wall at different locations around the room. Have the students get up and go to the sign which they are most interested in. The teacher may need to reassign some students to equalize the teams. For example, if there are 30 students in the classroom and we have 10 products, then they will need to group into teams of three. Explain that if there are already 3 people at a location, they need to find another location.

Give each group a poster board and make markers available for them to create a poster on their product. Take them to the computer lab to do internet research. Their goal is to make a poster telling us more about their product, the company that makes it, and where the company’s current research is heading. What did the company do on a nano-scale to create the product? All work on computer will need to be done today, as tomorrow students will present their findings and poster to the class.

EXPLAIN: Student presentations. Each group should get no more than 3-5 minutes. Be sure students are aware of presentation protocol, such as: introducing each member of the team, the product they’ve researched and the company that creates the product. Calculate out the time needed for presentations and put presentations at the end of the class period. Then at the beginning of the class period students can refine their poster and their presentation.

EVALUATE: Present the rubric you want to use prior to student’s working on their poster. A sample rubric could be: Aesthetics – 5pts, Presentation protocol – 5 pts, Use of graphics – 5pts, Detail & preciseness of explanation – 5pts, participation of each member – 10 pts. Total points possible for this sample rubric is 30 points! Attached is a sample evaluation sheet you could use.

Michigan Benchmarks

SCIENCE
I.1.1 Understanding the need to build upon existing knowledge in real world contexts.
I.1.7 Gather and synthesize information from books and other sources of information.
I.1.8 Discuss topics in groups by being able to elaborate and take alternative perspectives.
I.1.9 Reconstruct previously learned knowledge.
II.1.2 Understand the general limits of science and scientific knowledge as constantly developing human enterprises.
II.1.3 Show how common themes of science, mathematics, and technology apply in real world contexts.
II.1.6 Describe the historical, political, and social factors affecting developments in science. Other benchmarks will be hit, but will be dependent upon which product the student researches.

Task Objective Key
WO: writing objective
ReadO: reading
MO: math objective
ResO: research
NANO TECH POSTER PROJECT

Your goal is to make a poster and do a presentation to the class on your nano tech product. Most of your research will be done on the internet. The following is a list of things you will want to research.

- Explain more about the product
- Tell about the company that makes the product
- Where is the company’s current research heading?
- What on the nano scale did the company do to make the product?
- Use photos and/or graphics on your poster.
- Each person should say something during your 3-5 minute presentation

PRESENTATION PROTOCOL

- Introduce your product
- Each person will then introduce themselves
- Each person takes their turn talking about your product
- Ask the class for “questions”

NANOTECHNOLOGY PRESENTATION POINTS Earned

<table>
<thead>
<tr>
<th>Points Earned</th>
<th>Team Member 1 Participation (10)</th>
<th>Team Member 2 Participation (10)</th>
<th>Team Member 3 Participation (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics of Poster</td>
<td>(5)</td>
<td>(5)</td>
<td>(5)</td>
</tr>
<tr>
<td>Use of graphics on Poster</td>
<td>(5)</td>
<td>(5)</td>
<td>(5)</td>
</tr>
<tr>
<td>Presentation Protocol</td>
<td>(5)</td>
<td>(5)</td>
<td>(5)</td>
</tr>
<tr>
<td>Detail &amp; preciseness of explanation</td>
<td>(5)</td>
<td>(5)</td>
<td>(5)</td>
</tr>
</tbody>
</table>

Name:

Points:

TOTAL POINTS AWARDED
Slide 1

NanoTech 101

What is NanoTechnology and where is it taking us???

Slide 2

Go through each one working students to say if they recognize it. Try making connections between the power of ten, the word, and the prefix.

Slide 3

See if you can get the kids to define it before you click on the explanations.

CONSEQUENTLY... Nano Tech is......

✦ The Science of Small Things: How Small?
✦ An examination of the world at one billionth of a meter (10⁻⁹)
✦ The placement, measurement, and manipulation of atoms and molecules with extreme precision
Slide 4

Almost every industry will be affected by nanotechnology.

It has a lot of support:
1. In 1999 President Bill Clinton started the NNI (National Nanotechnology Initiative) to accelerate & fund R&D
3. Japan, Korea, Israel, Taiwan, China & Singapore have similar stuff going on.
4. It could make you a lot of money!

This slide is important so as to get the kids to realize how the world sees nano technology.

---

Slide 5

What has Nanotechnology brought to our world so far?........

The pencil-thin iPod nano - It's 4 GB NAND flash memory is created using Nanotechnology.

The product that all the kids know about!

---

Slide 6

Fat-Busting Canola Oil

Made from an Israeli company called NutraLease.
Because of their size (30 nm), they can seep through tissues for a better delivery of nutrients.
Has shown to reduce LDL cholesterol by 14%.

Remind students that they will be choosing one of these many products to research with a group after the presentation.
Ever had chocolate chewing gum?

No? That's because the fat's in chocolate causes chewing gum to fall apart and lose it's elasticity.

They were able to get past this problem by modifying the crystal surfaces at a nano – scale. You can find it either on their website or at specialty chocolate stores in Chicago. $1.25 for 12 pieces. Great Price!

It turns out that the material has remarkable antioxidant properties.

$260 per jar.

It uses Nano-scale Fullerene Carbon 60

This is where 60 Carbon Atoms are arranged in the shape of a soccer ball.

CNT stands for “Carbon NanoTube Technology”

your ordinary, run-of-the-mill carbon fiber bat contain only resin, which weakens the bat's power

So they put Carbon NanoTubes in the bat's resin

It gives more responsiveness and “kick” through the hitting zone for maximum performance

will cost you $175 and up.
They incorporate 19nm size silver particles within their fibers. It has permanent resistance to odor and fungus.

The incorporation of silver nanoparticles in the fabric has a permanent antibacterial and antifungal effect, preventing the growth of bacteria and fungi that cause unpleasant odors. This technology is particularly useful for athletes who need to maintain hygiene and freshness during physical activities.

Tyneside Minimann & Co. has integrated Silver Nano Technology into their sock's fibers, creating a product that is not only functional but also environmentally friendly. By using silver nanoparticles, the socks provide a level of comfort and performance that is unmatched by traditional socks.

Buffer, N.Y.-based Nanodynamics, is leading the way with sustainable and technologically advanced products. Their Nano Soxs, which incorporate 19nm silver nanoparticles, provide superior odor control and prevent the growth of bacteria and fungi, ensuring that the wearer's feet stay fresh and dry throughout the day.

Incorporating silver nanoparticles into the fabric is a cutting-edge technology that offers a range of benefits, from enhanced durability to improved comfort. The incorporation of these nanoparticles makes the socks not only effective but also sustainable, as they reduce the need for frequent washing and replacement.

The combination of silver nanoparticles and advanced textile technology is revolutionizing the sock industry. By using these innovative materials, manufacturers are able to create products that are not only functional but also environmentally friendly, setting a new standard for sustainable fashion.
Military Grade Disinfectants

... in one step. In the year 2003, Boeing recommended ExecuVe for use on airplanes, and in 2004, the company attracted 30 airlines as customers. Currently, CoCHe is the only EPA-regulated Tox Category IV disinfectant product in the U.S. This means there are no harmful dermal (skin), ocular (eye), inhalation (breathing) or ingestion (swallowing) effects.

Footwarmers

Northampton, Mass.-based Aspen Aerogels launched a nanotechnology-based footwarmer in March of 2004, which is now used by the U.S. Army, U.S. Navy, and the Canadian Ski Team and the U.S. Military’s Elite Special Forces. Aspen’s Pyrogel ARMOR utilizes highly-innovative nanosporous-aerogel technology, providing 10 to 20 times more thermal performance at a given thickness when compared to existing materials. Pyrogel ARMOR is a product called Hotbeds, which is being used in military boots for improving the level of comfort in cold weather operations. Since the Pyrogel ARMOR is so efficient, the Hotbeds are only 2 mm thick.

What will 2008 bring us? ......

- CHEMICALS:
  - Creation of custom materials with specific electronic, optical & chemical properties desired for the given application.
  - New combinations and compounds will add strength, reduce weight, improve resistance or electrical conductivity.
Greater than 40x improvements in data storage/retrieval, allowing for the storage of up to 1 terabit of data per square inch.
A new frontier of computing where matter is as readily programmable and manipulated as software and lines of code.
Non-volatile Flash Memory, eliminating the need to “boot-up” computers.

Currently, NanoTechnology is allowing for the cost of chip fabrication facilities to be decreased by tens of billions of dollars.
WHAT DOES THIS MEAN???
Everything that uses semiconductors will become cheaper for us to purchase!

Nano-Filters to take the lead out of gasoline could be a cost savings of 80 to 90% of the refining oil costs.
Over the next decade Nano-structured catalysts will have a $100 billion impact on the petroleum and chemical processing industries.
NanoTech will advance our ability to store hydrogen in Hydrogen Fuel Cells. Automobiles are now being made to use liquid hydrogen rather than gasoline.

This is a long presentation - & the kids start to get tired by the time you get here…… Let them know the presentation is almost over & then they’ll get to choose their product.
This slide reconnects the kids to the biosensor we discussed in the previous lesson plan – very important that the attention of all the kids are gained here!

This is just an additional slide I liked

Forbes/Wolfe Nanotech Report 2002
www.forbasnanotech.com
Appendix D
INTRO TO NANOTECHNOLOGY AND BIOSENSORS
5E Inquiry Lesson Plans - Grades 9 - 12
Lesson Plan #3: What are the 8 allotropes of Carbon & how are they used in CNT’s?
One speed day, 2 block days (approx 180 min)

**ENGAGE:** Propose the question to the class on the board or overhead: What are the most expensive, naturally found things on Earth? How expensive are they? What are they made of? What makes it expensive? (the idea is for them to eventually come up with the diamond & that it’s made out of carbon). This could be a homework question given the day before!

**EXPLORE:** Give each group (of 3) about 10 minutes to explore and prepare their answers and thoughts. Go through each group and present all their ideas on the board as one.

**EXPLAIN:** How carbon is covalently bonded together in the diamond (see powerpoint slide #1) Go on to explain that carbon can actually combine together 8 different ways. These are called the 8 allotropes of carbon. By going through the power point, the students will learn about the 8 allotropes of carbon.

**EXPLORE:** Have the students break up into 8 teams. Each team will use K'Nex or marshmallows and toothpicks to build one of the 8 allotropes of carbon. When they present their allotrope they need to also give some history on that particular allotrope. If it’s used for anything, they need to give that information too. Consequently, a little bit of research is required – or notes will need to be taken during the power point. ResO

**EXPLAIN:** Student presentations.

**ELABORATE:** What is polyaniline? Show some pictures from the lab of polyaniline, what it’s made of, and perhaps even let them see a bag of it. Show the short powerpoint titled “polyaniline.” Have a short discussion of how PANI-CNT development can help with the development of a biosensor for bacteria and viruses. Have the students write a paragraph of how they see PANI and CNT used for bacteria and virus detection. WQ

**EVALUATE:** Give the students the rubric when breaking them up into teams. A good sample rubric would be: 10 points presentation protocol, 10 points for preciseness of the building of their allotrope, 10 points for information given about their allotrope, 10 points for participation.

---

**MICHIGAN BENCHMARKS**

I.1.3, 9 Students will construct knowledge and conduct investigations using appropriate technology; they will learn from other sources of information; communicate their findings; and reconstruct previously learned knowledge.

IV.1.2 Students will measure and describe the things around us; explain what the world around us is made of; the properties of elements which make them useful in technological systems.

IV.2.5, .6 Students will investigate, describe and analyze ways in which matter changes; and how human technology changes matter and transforms energy. They will explain the changes in carbon in terms of the arrangement of the atoms; explain how visible changes in matter are related to atoms and molecules and related to energy.

**Task Objective Key**

WO: writing objective ReadO: reading objective
MO: math objective ResO: research objective
**Allotropes of Carbon PROJECT**

Your goal is to make a poster and do a presentation to the class on your allotrope of carbon. Most of your research will be done on the internet. There will be a few copies of the powerpoint presentation you can check out for the hour to help with your research. The following is a list of things you will want to research.

- Explain more about the crystal structure of your allotrope
- IF NATURAL:
  - Where on earth is it found?
  - How did it form and get there?
  - What is it used for?
- IF SYNTHETIC (man made):
  - Who first created this allotrope?
  - What motivated them to create it?
  - What are they using it for?
- Build a model of your allotrope using marshmallows and toothpicks
- Use photos and/or graphics on your poster.
- Each person should say something during your 3-5 minute presentation

**PRESENTATION PROTOCOL:**

- Introduce your product
- Each person will then introduce themselves
- Each person takes their turn talking about your product
- Ask the class for “questions”

**CARBON ALLOTROPE PRESENTATION POINTS EARNED**

Aesthetics & use of graphics on Poster (10) ________

Presentation Protocol (10) ________

Detail & preciseness of explanation/information (10) ________

Model of your atom (10) ________

<table>
<thead>
<tr>
<th></th>
<th>Team Member 1 Participation (10)</th>
<th>Team Member 2 Participation (10)</th>
<th>Team Member 3 Participation (10)</th>
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<td></td>
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</tbody>
</table>
Slide 1

Slide 2

Slide 3

The Engage phase leads nicely into the first slide – be sure to use this opportunity to your fullest.

Carbon doesn’t always form into the shape of a cubic lattice.

- In fact, there are 8 different allotropes of carbon.
These are the 8 different allotropes. Ask the students to tell you which one is the diamond.
Slide 7

Lonsdaleite

- Identified in 1967 in a meteorite found in an Arizonan crater
- Believed to be originally graphite
- Due to the heat and pressure upon impact, it turned to diamond but kept the crystal structure of graphite

Slide 8

Slide 9

FULLERENES

- Discovered in 1985 by a team of scientists from the US and England
- Shape of a hollow sphere
- Referred to as "buckyballs"
- Also known as C60. Why?
- Use nano-technology to combine the atoms in this way
- Hopeful for use in tackling melanoma and other tough cancers

Discovered “in” 1985
Like all fullerenes, C540 is a hollow spherical shape created using nanotechnology.

- How many atoms of carbon are in it?
Slide 16

Slide 17

Slide 18

ONT's (Carbon NanoTubes) are now used for or being researched for……

- Clothes - water proof, tear resistant cloth fibers
- Military combat bulletproof - the ultra strong CNF fibers will monitor the condition of the soldier
- Concrete - increases tensile strength and eliminates cracks
- Polyethylene plastics
- Sports equipment - lighter & stronger equipment as seen presently
- Space Elevator - possible! It's in the planning stages
- Artificial muscles
- Paper
- LCD screens
- Nanocomp
- Computer circuits
- Air and water filters

Stronger than diamonds
Conduct heat well
Can be made as either a conductor or semiconductor
This is an extra slide of interest. The students found this chart interesting and several used it in their presentations.
REFERENCES

- http://www.answers.com/topic/fullerene

Assignment

- Divide into 8 groups as listed on the lab tables
- You will be then assigned an allotrope of carbon to make with the kinex or marshmallows (ck funding)
- You will be given the appropriate number of pieces to make your allotrope
- Present your allotrope with some information on a poster board about it which you’ve researched on the internet!
REFERENCES:


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