INTRO TO NANOTECHNOLOGY AND BIOSENSORS
5E Inquiry Lesson Plans - Grade 10 or 11 (CHEMISTRY)
Lesson Plan #4: Conductivity, PH and temperature are all related and intertwined
2 block days and a speed day

ENGAGE: Show the students a bag of polyaniline. (Available from the Department of Biosystems Engineering, Michigan State University). Tell the students that PANI (polyaniline) is used in the biosensors used to detect bacteria/viruses in our food and water. It is a nanotech generated polymer. Ask each student to give a detailed description in writing of what they see: color, particle size, appearance of texture, etc…. If there is enough PANI, each table can have some to feel and add to their written description. Ask students to come up with other physical properties that perhaps we may be able to measure, especially if we put it into solution. They should come up with conductivity and PH. If not, the teacher may need to prompt these two ideas. (WO) (10 min)

EXPLORE: After getting this list on the board, the idea is to lead the students into how the conductivity and PH is related to what temperature the PANI solution is. Is this something we have the materials for in class? (Ask the students these Q’s). How do we put the PANI into solution? How do we measure PH? How do we measure Conductivity? Have students discuss these ideas in their individual groups. Why would we want to know how the conductivity and PH are affected as the temperature of the PANI is changes? What effect could conductivity and PH have on the biosensors as we try to detect bacteria and viruses? (These questions should be listed on the board or overhead). They need to understand that the hypothesis of this lab is embedded in these questions. Have each group discuss the questions and write down a group answer for each question. (WO) (20 min)

EXPLAIN: Have a student from each group explain what they figured out for each question. Fill in any missing points as the student teams give their explanations. Throughout the explanation, the students can begin their formal write-up for the PURPOSE (I), MATERIALS (II), and HYPOTHESIS (III) of the lab. Show the students the PH strips and the Conductivity meters and how to use them. Tell the students how much PANI they will get when they actually do this! (WO) (30 min)

EXPLORE: Each student now needs to write out a PROCEDURE. They can determine what the procedure is in their groups, but each student should write their own on their own piece of paper, as this will be part of what they turn in for their formal lab investigation. This should be added to what was written out in the EXPLAIN section above. The teacher should wander from group to group asking and checking to see if they have included things such as a time interval to check temps and measure PH & conductivity? What should their data table look like? Should any graphs be made from the data (I’d require at least 2 graphs)? The amount of teacher assistance here will be dependent upon how much experience the students have in writing their own procedure.

Michigan Benchmarks
I.1.1 Developing problems for investigation, understanding the need to build upon existing knowledge.
I.1.2 Suggesting tests of hypothesis, prediction, testing and conclusions
I.1.3 Designing and conducting scientific investigations.
Hypothesis, theory, observation, conclusion, law, data, generalization, aspects of field research.
I.1.6 Designing an experiment using quantitative data, recognizing and explaining the limitations of measuring devices.
I.1.8 Discuss topics in groups, restating or summarizing what others have said, elaboration, alternative perspectives.
I.1.9 Reconstruct previously learned knowledge (LP’s 1-3) in real world contexts.
II.1.1 Justify plans and explanations, aspects of logical argument including evidence, observations and conclusions in real world contexts.
II.1.3 Show how common themes of science, mathematics and technology apply in the real world
III.2.4 Explain what living things need for a stable internal environment as far as PH and temperature factors are.
for a lab. Have student groups share their best ideas with other student groups. Students need to see in action that genius often comes in the sharing of ideas. At the end of the hour, have each student turn in their procedure for teacher approval. (WO) (20 min)

**EVALUATE:** The teacher needs to evaluate each procedure before allowing the students to continue with the lab. I’ve used this process often and it is very effective. The students want to do the lab. If they do not turn in a good enough procedure, then they are not allowed to do the lab. It’s motivational! Students want to live up to teacher expectations.

Evaluation of the lab can be as simple as initializing each paper to giving them points on how much they’ve already done of the write up. Each teacher will need to choose how they want to do this depending on the time they have and the experience level of the students in writing up labs. In some cases, the students will need you to prompt them on their papers as to what to do to improve/fix their lab write up. Depending on how the teacher normally grades their labs, the teacher could give points for this part. I would give this part about 40% of the lab grade.

**EXPLORE:** Students do the procedure they’ve had approved, take down all data in their table and make graphs of temperature vs. pH, Temperature vs. conductivity, and pH vs. conductivity. (Data table and graphs should be a part of their procedure.) Emphasize that this is a formal lab and if they need to rewrite anything so that it is neat and legible, then they should do this for homework. (1 90-min class period plus finishing up details for homework)

**ELABORATE:** All of the following questions need to be answered either in the students conclusion paragraphs to the lab, or in a handout made by the teacher. 1. What is the relationship between temperature and PH? 2. What is the relationship between temperature and conductivity? 3. Could there also be a relationship between conductivity and pH? Does the PANI seem to be more conductive at different PH’s? 4. For the biosensors, do we need the PANI to be more conductive or not? Why? 4. For the biosensors, do we need the PANI to be more acidic or basic? Why? 5. What is some more information that we may need to know (like the PH & temperature that the bacteria/viruses grow in)? 6. Without knowing this information, at what temperature is the PANI most conductive and at what temperature is the PANI most neutral in PH? 7. What would be the next step needed in your investigation?

**EVALUATE:** Evaluation of this lab should be done as the teacher does all formal labs. Mine are worth 100 points. I find students take it more seriously if I weight it more than 4 points. Data tables and graphs are what should be graded from their data section (about 30% of their lab). Most importantly though is their conclusion where they’ve answered questions in the elaborate above. I’d make this worth about 30% of their lab. A well-written and communicated conclusion is vital to success not only in the sciences, but in all endeavors.