Instructional Context

This introductory chemistry class meets each day during second block and is my largest class- 27 students total. Eleven students are sophomores- ages 15-16. Eleven students are juniors- ages 16-17. The remaining 5 students are seniors- ages 17-18. This set of 27 students is composed of 20 white students, 5 black students, and 2 Hispanic students. The class has no English Language Learners (ELL).

The true diversity of this classroom arises in the students' ability level. The state provides no progression of sciences for high school students. Consequently, this classroom can be divided into two groups- the students who will voluntarily enroll in several science courses after this course and the students using this course to complete their 4-credit science requirement. As an accomplished science teacher, I create specific instructional sequences for this class that foster scientific interest for my "credit-only" students and also challenge the curiosity of my other students. I designed this particular instructional sequence to employ an alternative method of assessment to monitor the progress of all of my students as well as to establish relevancy for the chemistry content in which we were already immersed.

Because this class illustrates great diversity in ability, students with exceptional ability and needs are present at both ends of the spectrum. As a result, my class is divided into 8 "focus groups" with 3 or 4 students of varying ability. This class set-up assists my 4 teacher support team (TST) students and challenges my 9 gifted students as they learn to explain concepts to those around them. My TST students tend to have poor literacy skills and a lack of motivation while 2 of my gifted students entered my classroom with a working knowledge of particle physics. However, not all of my gifted students display strengths in science, at least 2 students struggle in my class but excel in their English and history classes. With this in mind, I configured a unit that would provoke the scientific reasoning skills of each student regardless of ability and that would also encourage collaboration among all ability levels.

In an effort to create relevancy for the topic of chemical reactions, I chose to have my students design and create CO_2 cars while proceeding through the Engineering Design Method (EDM). I have my students each day for 90 minutes because our school district operates on the 4 x 4 block system. This provided me with ample time for students to engage in a group dialogue concerning EDM and then apply this method when constructing a CO_2 car in a five day period. Also, my district allows the science teachers to charge a small lab fee at the beginning of the course, so I was able to provide my students with vinegar, baking soda, and eggs for their design project. However, because I did not want to inhibit their design creativity, they could use any additional supplies to build their car. They were free to buy balsa wood from a local craft store, to buy legos from a local superstore, or to create their cars out of 100% recycled material. With a set of iPads as a technology resource, my students brainstormed ideas and recorded each step of their EDM process. To spark more interest in the project and to encourage the use of technology in the class, I also had them create a digital engineering design notebook on the iPads using the camera for photos and videos and a notebook app.

Planning

Accomplished science teachers design tasks and introduce issues that align with students' existing knowledge in order to move them forward **(Standard I)**. Consequently, as I created this lesson, including the whole class discussion, one of my first goals was to develop in my students a beginning understanding of EDM. This design method requires my students to employ their knowledgeable scientific method skills while pushing that knowledge forward through application into the specific discipline of engineering.

Skilled science teachers also spark student interest in science and promote active and sustained learning while their students constructively engage in building deep and profound knowledge of the natural and engineered worlds **(Standard IV)**. Because of my broad knowledge of science and science education, I recognized that after two difficult units concerning seven different reaction types and stoichiometry my students would need a unit to spark their interests and rejuvenate their minds. I also recognized that students also struggle with making the jump from chemical reactions to the study of gases and their properties **(Standard II)**. Consequently, I identified the best course of action would be to incorporate STEM pedagogy that would engage students in a deep knowledge of the engineered world, reawaken their interests in chemistry, and require my students to apply their newly acquired reaction knowledge while also investigating gas behavior. As a result, I challenged them to employ EDM to create a car that was fueled by the chemical reaction of vinegar and baking soda which produces CO_2 gas. Knowing that a student's first encounter with EDM can be overwhelming, my second goal for the whole class discussion was to create confident and curious attitudes towards EDM to help alleviate future stress.

My third and final goal of the whole class discussion was for my students to develop a clear understanding of how to implement the specific steps of EDM- 1.) Identify the problem. 2.) Brainstorm 3.) Design 4.) Build 5.) Test & Evaluate 6.) Redesign and 7.) Share. From past experience, students have the tendency to skip the first three steps and move directly into building. As a result, I conducted a group discourse that highlighted the significance of each step of EDM and then allowed us to practice techniques for each step together **(Standard X)**.

As a highly skilled science teacher who teaches chemistry to students of different abilities, my overarching goal for the course is to teach benchmarks using methods that help all students understand the importance and relevance of science **(Standard VI)**. By asking my students to apply knowledge of chemical reactions to build a car powered by one such reaction, I have illustrated the importance and relevancy of science as a key part of engineering. This activity also satisfies state benchmarks that focus on the scientific method, collecting data, reviewing and improving an experiment, and using technology to create formal presentations.

Before engaging in the nuts and bolts of an engineering design activity for the first time, a whole class discussion on the method, its importance, and how to implement it is necessary to establish the parameters within which the students need to work. A whole class discussion on EDM also provides an opportunity to demonstrate appropriate group interactions before expecting students to break off into their assigned lab groups. By modeling the method beforehand, I was able to influence how the students would interact with one another in their small groups and could illustrate a process that is criticism-free thereby supporting a learning environment that favors academic and personal growth and includes all learners.

Video Recording Analysis

This class discussion leads into a four day engineering design project centered on building cars fueled by a baking soda and vinegar reaction. Students applied their knowledge of acid-base reactions and limiting reactants to design a functioning car and to create an engineering design notebook for a formal test grade. This unit required students to not only apply and build on their developing knowledge of chemical reactions, it also served as an introductory inquiry investigation for the next unit on gases. As an accomplished science teacher who recognizes the varying learning types of students, I placed this unit in between two major ideas in chemistry to employ multiple, ongoing methods of assessment to monitor the progress of individual students.

Before the video recording begins, the students engaged in two meaningful activities that activated prior knowledge in science in order to move their knowledge forward. They began the class session by identifying, through the use of stoichiometry, which reactant- the baking soda or the vinegar- would stop the reaction and, as a result, stop the production of carbon dioxide gas (the fuel for their car). Then, as a lead into our discussion of the engineering design method, I asked them to verbally recall the steps of the scientific method.

With this prior knowledge at hand, the video comes in as I asked my students to compare the familiar scientific method with a newly introduced engineering design method. For the next twenty minutes, we discussed the significance of engineering on their life in the form of cell phones and cars and then moved into a mock design task as a class- take an item(s) that students or teachers throw away and design a useful item for the school or classroom. The video segment ends as we finish brainstorming items that are thrown away; however, the discussion continued as we moved through the design process and brainstormed items that are useful. Next, we connected the two categories- discarded items and useful items- and as a group we came up with eight possible useful designs made out of recycled items for our school. As the discussion progressed, students were introduced to the concept of a design matrix to choose the best design, to the concept of building and reworking prototypes, and finally to the concept of formally presenting those designs to a customer, boss, or, in our case, our principal. We concluded our class discussion with a small group challenge- construct a car fueled only by a reaction between vinegar and baking soda that would move forward 3 m and keep a passenger egg safe. Students were invited to use discarded materials as a part of their design.

As an accomplished science teacher, my overarching goal throughout my chemistry course is to spark student interest in science and to promote active and sustained learning **(Standard IV)**.

As a result, one of the three main goals for this whole class discussion was to introduce and develop a beginning understanding of the engineering design process. In the beginning of the video, my class engaged in a discussion of the similarities between the foundational knowledge of the scientific method (SM) with the new concept of engineering design method (EDM). Law demonstrated how his brain processed this new concept as he first began the conversation by connecting "Observation" and "Questioning" from SM with "Identify the Problem" in EDM and later asks the question "What about sharing?"- or (how is sharing from EDM connected to the SM). Because Law could initially connect these similarities and later had questions concerning the process, his contribution to the discussion revealed a developing understanding of the EDM.

Another goal of this classroom discussion was to develop confident and curious attitudes towards EDM in order to alleviate the introductory stress of building their own car. In the video itself, multiple examples exist of students developing interests and confidence. I fostered interest in the idea of engineering by first introducing a concept that I knew my students would relate to- the evolution of the cell phone. In the video, student curiosity is immediately displayed as we transition from the technical discussion of the steps of EDM and into this real world topic. The students' body language and facial expressions even indicate a transition from begrudging attentiveness to genuine interest in the conversation. This interest and curiosity is further displayed as we move the concept from the engineering of cell phones into the engineering of today's cars. When posed with the question, "What do engineers focus on when designing today's cars?" students from all around the classroom begin responding- biofuels, fuel efficiency, safety, etc. As a result, this shift from only a few key students engaged in class discussion to the majority of the class participating is a clear indication that this second goal of building curiosity was achieved.

The final goal of this class discussion was to begin developing in my students a clear understanding of the importance of the specific sequential steps in the EDM process. The video actually captures students embracing the first part of EDM- processing through identify the problem and building confidence in and learning how to brainstorm. During this entire discussion, I wanted to ensure fairness and equity for all my students by ensuring they each actively developed the skills and participated in the discussion- not just my few strong students. As a result, I used three methods to ensure this goal was achieved- iPads for individual students, focus group discussion before large group discussion and an individual brainstorming technique that led into large group contribution **(StandardVI)**.

I noticed during previous large group discussions that some students shy away from participating. In the video, I achieved majority class participation in processing the problem presented by asking students to discuss the problem first in their focus groups. This moment is one of the first moments in the video that every student is actively engaged in the conversation (for example, the first two groups in the classroom). As a result, when I called the class back into whole group discussion, I received ideas from more students than just the prominent three students- Law, Macy, and Ben. In fact, almost the entire class initially responds that the problem is that "there's too much trash."

In addition to the focus group technique to encourage active participations, I still wanted to achieve engagement from the shy students, the quick thinkers, and the contemplators who sometimes are reluctant speakers. Consequently, I asked every student to take 30 seconds and jot down every idea that came to mind after I said a specific phrase. This provided time for all my students to think and solidify their ideas and led into a class discussion in which I called on students who had not yet been involved like Hallie, Wendy, and Devin. Because I had given time to formulate ideas, they demonstrated active participation and confidence in brainstorming when they answered immediately with ideas and therefore confirmed that my third learning goal for the discussion was achieved.

Before implementing the lesson, I gave a great deal of thought to the types of prompts that would propel the students toward the learning goals. Therefore, I was able to effectively accomplish two goals of this lesson at once. Students would develop introductory understanding of engineering design and the activity would foster confident and curious attitudes concerning EDM. As a highly-skilled science teacher, I seek to ask thought-provoking relevant questions that are integrally related to my students' concerns and interests of the moment. As a result, I chose to guide my students' consideration of engineering design by connecting it to the evolution of the cell phone **(Standard III)**.

In the video, we end our comparison of the scientific method to the engineering design method by discussing how and to whom engineers present their designs and prototypes. Law suggests that they present to patent offices, and I move his knowledge of ED further by asking the class to examine the evolution of the cell phone. By asking students to find their first phones and current phones on the timeline, I was successfully able to spark their curiosity. In the video, students reminisce about old phones, and I purposefully asked students about the "Saved by the Bell" telephone, the Razor phone, and the iPhone. They eagerly engaged in discussion about these topics; as a result, they were willing to answer my follow up questions- "Why was the first phone so large in comparison to the small Razor?" "What motivated designers to move from the small Razor to the slightly larger iPhone?" During this line of questioning, I required students to consider the motivation behind the changes in EDM and piqued the genuine curiosity in exploring the topic further.

I purposefully ended our class discussion on EDM by modeling the EDM process and involving the entire class because accomplished science teachers intentionally influence the quality of human associations to create a productive learning environment that favors both the academic and the personal growth of the students. Knowing my students' personalities and abilities as I do, I knew they would need subtle guidance in small group dynamics as opposed to leaving them alone to work through the EDM. As a result, in the video, I worked to engage all students- quiet and boisterous- in each step of the EDM process through whole class discussion before working in small groups. We processed through identifying the problem and developed brainstorming techniques together, and I stressed the idea that brainstorming is criticism-free. Consequently, the video reveals us as a class considering Law's idea of burning trash for energy and considering Macy's idea of the usefulness of gum. The video also features me reiterating the idea "Criticism-free" over and over.

Because the whole class discussion engaged my students in the consideration of engineering design while also piquing their curiosity, two specific instances on the video reveal different students learning to reason and think scientifically and also communicate that with others. During the comparison of the SM with the EDM, Law verbalizes his science reasoning. He connects that both observation and questioning are "collectively" the "Identify the problem" step of EDM. Later in this same discussion, he reveals that he has been actively considering the similarities when he blurts out "What about sharing?" Almost immediately, Ben answers his question by indicating that sharing is the conclusion step of the scientific method- or the papers that are published. This discourse exemplifies how both students are actively engaging in science reasoning (the comparison of two similar experimental methods) and in the communication thereof as Ben not only answers Law's question (the conclusion) but also explains why (the published paper).

As I moved the conversation from the theoretical design method and into actual applications of the method, Law and Colton engage in another discourse that reveals students' scientific thinking and communication. When I prompted the class to consider the reason behind moving from larger cell phones to the thinner and sleeker cell phones, the class as a consensus agreed that they were smaller for consumer convenience and satisfaction. I then posed the question, "What technology changed?" After a moment of consideration, Law volunteered the idea that the first phone had larger internal components. When asked which specific components were large, Colton considerately responded with the battery. Because we have never discussed how cell phones work in my classroom, both students are relying on prior knowledge and their own personal experiences with phones and technology to answer. As a result, this exchange is a perfect example of students engaging in scientific reasoning.

As an established science teacher, I seek to ensure that all students succeed in the study of science and understand the importance and relevance of science **(Standard VIII)**. Consequently, in the video, two specific techniques are displayed that I use to aid students in the exploration of the engineering design method and its application for our CO_2 cars. Both techniques employed were designed to establish relevancy for the topic-both scientifically and personally. The video begins with me challenging my students to "compare the EDM handout to the scientific method." By asking my students to relate this new process to a process in science with which they are already familiar, I provided legitimacy to the topic and established a reason for them to engage in a discussion about the method. Using the familiar SM as a scaffold provided them with a foundation on which to build their new EDM knowledge.

Then, as a class, we move from a comparison of the two methods and into how EDM is applied today- specifically to cell phone and automobiles two topics which students are always concerned. Both of these topics not only provided relevance for the subject but also succeeded in actively engaging the majority of my students in discussion. By giving them an avenue to reminisce about old phones and brag about new phones, I was able to easily lead my students to explore the more intellectual design-related topic of why the cell phones changed as they did. Then later, when we discussed what engineers are concerned about as they design cars today, students voluntarily provided suggestions of biofuel, fuel efficiency, safety, and aesthetics. In fact, when a student provided the smart car as a solution to fuel efficiency, Macy yelled out, “But they’re ugly,” and Colton contributed “if you get in a wreck in one of those. . . you’re dead.” From here, the discussion easily moved into the design matrix and how engineers have to consider more than just the customer’s one criteria when designing a product. Therefore, by establishing relevant topics in which to explore EDM, students easily and readily engaged in discussion.

Reflection

As a professional who teaches students with great interest in science alongside students who are merely seeking a Carnegie unit, I designed this whole class discussion to spark student interest in science and to promote active and sustained learning through the world of engineering for all present. As I watched the video and reflected on the effectiveness of this discussion, I identified moments in the video that successfully met the three goals I had set for the discussion. Throughout the video, multiple parts of the discussion supported my first goal- develop a beginning understanding of the engineering design method (EDM). For instance, the video opens with a comparison of the scientific method and EDM. This comparison proved to be effective because it naturally led into a discussion of engineers and how they share their designs. This discussion later supported my project requirements when the students learned that they would have to also formally present their CO_2 car designs to the class.

The discussion of the evolution of the cell phone dually supported my first goal as well as my second goal- creating confident and curious attitudes towards EDM. The discussion easily led into what/who fuels engineering's purpose- the consumer- as we discussed how the cell phone morphed from the first long and box-y phone to the small razor to the slightly larger smart phones. The cell phone discussion also brought more students into the discussion supporting greater curiosity and confidence- students like Hunter, Macy, Kirby, Devin, Hallie and Kathy who had not yet engaged in class discussion (and usually do not participate in class discussions). As a result, bringing in a relevant and fun topic allowed us to easily discuss engineering's purpose as well as to naturally begin developing curious and confident attitudes towards EDM.

Consequently, as the class discussion moved into today's cars and the purpose behind designing new cars more students were engaged in conversation, and I was able to easily connect this discussion to the purpose of their car design project. This final discussion satisfied my goal of creating confident, curiosity in all my students- from sophomores to seniors. This topic also supported my initial goal of introducing engineering design when students started arguing the benefits and disadvantages of the smart car. This argument allowed me to naturally introduce the idea of the design matrix.

Finally, in the last segment of the video the brainstorming techniques in which all my students participated effectively supported my third goal of developing clear understandings of how to implement the specific steps of EDM. This technique required the participation of all my students and allowed each student the time to consider possibilities before entering into a whole class discussion. As a result, I was able to confirm that each student had the opportunity to practice implementing EDM. The video also reveals evidence of the third goal being met as my students moved from ideas like burning trash as a fuel source before the brainstorming exercise and into connecting trash items like cardboard and plastic bottles to useful items that can be made.

If I could implement this discussion with another class in the future, I would use the CO_2 Car design challenge as a whole class project to model EDM with the students. I discovered as I broke the students into their small groups to begin using the EDM to create their CO_2 cars that the concept was slightly too complicated for students to jump into because EDM was too new to them. I actually had to reiterate the design method a second time for students to step into their project independently. Consequently, when I guide this discussion in the future, I will use the CO_2 Car design challenge to model the EDM with my students as an entire class. We will hash out the challenge together and develop brainstorming techniques while considering the car design. This would better support confident attitudes and approaches to the project and would make better use of class time. I would work on transitioning their enthusiasm for cars and phones into the CO_2 car challenge.

I also discovered later in the unit that using a design matrix significantly improved my students' critical thinking while helping them choose a design. Consequently, in the future, as the discussion begins to lead into the direction of comparing differing designs- like our discussion of smart cars did- I would engage the class in a formal use of the design matrix. Taking them through the many aspects of design that have to be considered and then demonstrating the need for compromise would not only prompt further student discussion but also would encourage positive group behavior.