Sparking Engagement in Science Education:

A Study on Implementing the Ambitious Science Teaching Framework

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Abstract

While student teaching at West Valley High (a pseudonym), I noticed that the teaching style my students were used to didn't seem to offer students many opportunities to engage with the content and come to deep understandings. Mainly, the class seemed centered around lecture on a topic and confirmatory activities. I wondered how effective the Ambitious Science Teaching (AST) framework would be at engaging students by offering more opportunities for engagement. To test the effectiveness of AST, I taught two units on biology - one with the traditional teaching style my students were used to and one using the AST framework. At the end of each unit, I conducted a quick survey of the class to measure their engagement in different ways. After comparing student engagement between a traditional style unit and an AST unit, it was obvious through student curiosity and thirst to learn that the later was much more effective at engaging students. In the future, I will try to implement AST practices as much as possible if it results in such engagement of my students.

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Introduction

On March 1st of 2016, I began student teaching at West Valley High. I knew that it would be a difficult experience with unique challenges to integrate myself into an already established classroom most of the way through the school year. The class I was set to completely take over was my cooperating teacher's (CT) integrated science class. My CT and I decided that the best way for me to transition into the classroom was to have me observe the class for a couple weeks before transitioning into teaching it full time. This would get me familiar with the dynamics and atmosphere of the classes that I'd be working with, as well as the style of teaching and routines that the students were accustomed to.

While I was observing her classes, I noted that my CT had a very traditional teaching style in the class I would be teaching. There was nothing inherently wrong with this approach, but it was just a shocking difference from the inquiry-based approach I had been introduced to in my teacher preparation program.

My CT commonly made PowerPoints on the content she was teaching and would use these PowerPoints while lecturing. Students were expected to copy down the content of the slides; a process she called "notetaking." However, lectures were never more than 10-12 minutes and after, she would stop and have the students do something with the notes they had taken like make a ven diagram, fill in a graphic organizer, or summarize their notes. If necessary, then she'd quickly finish her lecture. Afterward, they would commonly do an activity or lab related to the content of the notes for the rest of the period.

While I realize there is nothing wrong with this style of teaching, I had to wonder if it was ultimately effective at engaging students in a deep understanding of the content. That's when I knew that as I started teaching these students, my ultimate goal was going to be engaging as many students as I could in class and creating a deep understanding of the science content that I was to teach them. I decided that I'd try to reach this engagement and deep understanding by implementing the AST framework.

Background on West Valley High

West Valley High (WVH) is a high school in the Pacific Northwest that serves about 1200 students in grades 9-12. At WVH, students are required to take three years of science classes. The class I taught as part of my student teaching was the Inteagrated Science class, which covered basic biology, chemistry, and physics.

Research Question

How effectively can the Ambitious Science Teaching Framework spurr engagement among students compared to traditional teaching practices like lecturing, confirmatory labs, and memorization?

Literature Review

In a study by Turner et al. (2014), I found a simple definition of engagement and what it looks like in a classroom. This ultimately helped me frame my view on what engagement was and what it looked like in a classroom setting.

> Engagement is "The students' psychological investment in and effort directed toward learning, understanding, or mastering the knowledge, skills, and crafts that academic work is intended to promote. Engagement is manifested through activity and may be described as behavioral (eg., effort and persistence), cognitive (e.g., strategy use and self-regulation), emotional (eg., expressions of interest and positive affect), and agentic (e.g., making contributions to learning activities). (Turner et al., 2014)

This simple definition was helpful to my study because it provided me with examples of what engagement looked like in a classroom, which told me what to look for when measuring engagement. This definition suggested that emotional engagement manifests as expressions of interest. As will be discussed later, I measured students' interest in class through a survey question asking them how interesting they found a unit. I determined that agentic and behavioral engagement were too difficult to measure accurately in the classroom, but that cognitive engagement might be a possibility to measure. I just didn't know how at this point.

The National Research Council and the Institute of Medicine offered this measurement of cognitive engagement and another connection to the AST framework in their 2004 book titled "Engaging Schools."

> Research on learning shows that students become cognitively engaged when they are

> asked to wrestle with new concepts, when they are pushed to understand – for example, by being required to explain their reasoning, defend their conclusions, or explore alternative strategies and solutions. (National Research Council et al., 2004)

This idea of asking students to struggle a bit with new concepts and explain their reasoning was very similar to the fourth AST core practice of "Pressing for evidence-based explanations." This practice involves students using evidence from class activities to back up their claims about how a complex event happens. Since explaining complex events and using evidence are part of an AST unit, I can expect to see students more engaged in such a unit than in a lecture based unit, which doesn't afford students these opportunities. If I see students wrestling with ideas or thinking deeply about the content, this quote tells me that I have found proof of cognitive engagement.

This book also states that "Over the long term, [students] are more likely to engage when they are asked to ... create a model and complete projects rather than answer questions about how a process works" (National Research Council et al., 2004). Again, this is another solid link to the AST framework. The AST practices of "Eliciting Students' Initial Ideas" and "Pressing for Evidence Based Explanations" both are centered around helping students organize their thoughts into coherent models. It could also be argued that creating the final explanation of the anchoring event might be considered a large project. Thus, AST offers students chances to make models and complete projects, which were both here identified as possible ways of fostering engagement.

Turner et al. offered another description of how engagement can be created in a classroom by saying "Engagement develops as teachers and students participate in classroom activity and work toward a joint objective" (Turner et al., 2014). This idea of a joint objective tied in well with the AST core practice of explaining an anchoring event. In my AST unit, the "joint objective" was the teacher and students working together to come up with an explanation for an anchoring event. In this way, I expected to see some evidence of engagement being created in a unit framed through AST as the class worked toward the joint objective or anchoring event. Conversely, I did not expect to see this engagement happen as much in my traditional lecture based unit.

Chapter 11 of "A Framework for K-12 Science Education," by Quinn et al. (2012) included a quote from McDermott & Weber, which described the major goal of science education as "To provide all students with the background to systematically investigate issues related to their personal and community priorities" (Quinn et al., 2012). This quote stood out to me, because it didn't seem to match at all with the traditional lecture style of teaching.

In traditional lecture-style teaching, students listen to a lecture, memorize the information, and repeat it back on an exam. However, it doesn't necessarily provide students with the opportunity to see how the material relates to their personal lives or communities. This is where the anchoring events in AST come into play. By using an anchoring event, students can see how the instruction relates to their lives, which idealy helps to get them more interested and engaged in the content.

Appendix D of the NGSS outlined some effective strategies for teachers, which would, if used properly, help ensure that students were being allowed better opportunities for learning and engagement. The main strategies that related to implementing the AST framework in a classroom were:

1. Value and respect the experiences that all students bring from their backgrounds.
2. Articulate students' background knowledge with disciplinary knowledge (NGSS, 2013)

The second step of the AST framework is called "Eliciting Students' Ideas," and connects well with the first suggested practice. In this step, students' initial ideas about a phenomena are elicited and made public. Eliciting student ideas can take many forms, but frequently consists of students filling in a graphic organizer and making drawings to help organize their ideas into a coherent explanatory model before having them share ideas with each other on a large poster of hypotheses explaining an interesting event. By having students share their ideas publicly, AST effectively tries to "value and respect the experiences that all students bring." Each students' voice is heard and each student made a contribution.

In AST, the second suggested practice from the NGSS is also implemented. By pressing students to come up with an idea of how an interesting event happened before discussing it as a class or learning anything about it, students are forced to rely on their background knowledge. When they rely on their background knowledge, they have to apply it in the context of science and the event being studied. Along the way, students usually find that some of their initial ideas were somewhat linked to explaining the anchoring event, but just in an incorrect or roundabout way. This effectively articulates their background knowledge with disciplinary knowledge by drawing a bridge between the two.

Methods

To investigate the impact of AST on student tengagement, I taught one unit following a traditional lecture and activity style, and then taught a second unit following the AST framework. I could then measure student engagement between the two units and compare them. I selected two bilogy units for my study: one on cell organelles and oneon photosynthesis and respiration in an an attempt to avoid student disciplinary preferences; if I mixed scientific disciplines, results on student engagement may be biased since some students may like physics more than biology, for example.

The Traditional Cell Organelles Unit

When designing my unit on cell organelles, the main NGSS standard I tried to target was MS-LS1-2: "Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function." Though this was a middle school standard, many of my students indicated that they hadn't studied cell organelles too much in the past. This was likely because the NGSS had just recently been adopted in the state and schools were still transitioning to the new set of standards. I targeted this standard by devising a lengthy slideshow about cell organelles and their functions to serve as the basis for a series of brief lectures.

In addition to targeting the standard through lecture, the whole unit on cell organelles was centered around the essential question of "What are the different parts of a cell and what do they do for us?" This essential question was posted on the front whiteboard every day and helped students know that they should understand the names and functions of the different cell organelles.

Each day of this unit started with a simple warm-up question related to the previous lesson, and then went into 10-12 minutes of notetaking from a powerpoint I had created. I lectured about the parts of the cell from information from my slides and then had students do a relevant activity from their lab manuals for the rest of the period. This was usually an online simulation or worksheet.

My unit on cell organelles culminated with two summative assessments. The first was a colored, labeled, and described drawing of a plant and animal cell. On this assignment, students labeled a drawing of each cell with the different parts and described what each part did for the cell. On the plant cell image, they only had to label and describe the organelles specific to plants. The second summative assessment was the unit test, which was a multiple choice test that all teachers in the school used for their cell organelles unit.

The Ambitious Science Teaching Unit

The Ambitious Science Teaching unit, in comparison, involved much more thought and preparation to plan properly. The AST Framework is constructed of four parts: Planning for engagement with important science ideas, eliciting students' ideas, supporting on-going changes in student thinking, and pressing for evidence-based explanations. Steps in "planning for engagement with important science ideas" include selecting standards and essential ideas that will be taught, and developing an anchoring event - an interesting and complex event or phenomena that students will attempt to explain using the ideas they learn in their unit.

My essential ideas that I wanted students to learn in the unit were how photosynthesis works and how cellular respiration work. Specifically, what the two processes consume and produce. These foci are encapsulated in the Next Generation Science Standards under the following performance expectations:

HS-LS1-5: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-L21-7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

The connected anchoring event I decided on is to have students investigate formation of oceanic dead zones. I gave the unit the essential question of "How do dead zones form and what makes them so deadly?"

Dead zones are areas of water with low dissolved oxygen. I wanted my students to realize that dead zones formed when phytoplankton or algae "bloom" in the ocean using photosynthesis to make their own food, grow, and produce oxygen. Then, I wanted my students to realize that if photosynthesis produced oxygen, there must have been some other process that depleted the oxygen in the water - cellular respiration.

I wanted students to show that cellular respiration broke down the products of photosynthesis (the algae bloom) and removed the oxygen from the water, causing the dead zone to form. In order to have a firm anchoring event, I selected a quick 4 minute public service announcement video clip about a dead zone that formed off the coast of the Pacific Northwest recently. Having this video meant that I had something to refer to when discussing the anchoring event. (Meyer, 2009)

The second step in the AST framework was “Eliciting Students’ Ideas.” In order to see what students initial ideas were about dead zones, I had them discuss the following two questions in a “Think, Pair, Share” style:

1. Why do we care about dead zones?
2. What does a dead zone look like? What are some characteristics of one?

After the initial discussion, I asked students to make a model of what they thought was possibly happening to form the dead zone using past knowledge and observations from the video clip. I created a graphic organizer for students to organize their initial thoughts on that had three sections corresponding to the ocean before a dead zone formed, the event that sparked the formation of a dead zone, and the ocean with a fully created dead zone. Students were given space in each section to draw pictures or diagrams, choose descriptions, and to write a summary for each drawing.

The third step in Ambitious Science Teaching was “Supporting on-going changes in thinking.” This means that the instructor takes students existing ideas and misconceptions and designs activities or lessons to help resolve misconceptions and lead students toward an appropriate explanation for the anchoring event. From my students’ models, I determined that they did not know what made the oxygen in the water so low, and that many of them thought it stemmed directly from pollution or photosynthesis. To fill these gaps in understanding, I selected interactive activities and lab experiments from the students’ lab book. I will not go in depth on the content of these lessons, as I’m focusing on the effect of the AST framework as a whole, not individual lessons.

The final step of the AST framework was “Pressing for evidence-based explanations.” Before beginning this step, I created a graphic organizer to help students organize what they already knew about photosynthesis, respiration, and what each process consumed and produced. In addition to this, I created a series of what I called “bridging questions” to help students reason through how photosynthesis and respiration might work together to form a dead zone. Each question should have been answerable from something we did in class.

The questions started simple with things like “What small organisms do we commonly see associated with dead zones” and ended with questions like “What process did we learn about that consumes oxygen” and “why might that process happen in a dead zone?” Students were allowed to collaborate in their table groups and look back at past assignments and notes when completing this step of the process. I made sure to check students’ work along the way and guide students’ thinking so that nobody was too far off track or misinforming others.

Finally, I pressed the students for explanations when I asked them to fill out a flowchart on how a dead zone formed and draw me some pictures to help explain the differences between life before and after a dead zone. Students earned credit for showing certain key terms properly in their flowchart and pictures. The checklist I used to grade this assignment is shown in Figure 1. Students were given this checklist in advance so they knew what was expected of them.

Dead Zones Final Model		
In Drawings (½ pt. each, use 10)	In Flowchart (½ pt. each, use 10)	Other Requirements
❑ Bloom ❑ Cloudy Water ❑ Consumes Oxygen ❑ Dead Life ❑ Decomposes ❑ Nutrients ❑ Low Oxygen ❑ Neurotoxins ❑ Photosynth. ❑ Phyto. and/or Algae ❑ Pollution ❑ Respiration ❑ Runoff	❑ Bloom ❑ Cloudy Water ❑ Consumes Oxygen ❑ Dead Life ❑ Decomposes ❑ Nutrients ❑ Low Oxygen ❑ Neurotoxins ❑ Photosynth. ❑ Phyto. and/or Algae ❑ Pollution ❑ Respiration ❑ Runoff	Flowchart: ❑ Logical path to formation of a dead zone (only minor errors) ❑ Clear, easy to read ❑ Ends with a dead zone Drawings: ❑ Follows mostly logical path to formation of a dead zone (only minor errors) ❑ Understandable
/5	/5	/5
Total:		/15

Figure 1: Grading Checklist for Dead Zones Final Model

When I implemented this step in the framework, I wound up differing from the prescribed method because I mostly left out the "evidence-based" part. The only evidence students had to back up their explanations were their activities and notes from class, and I didn't require students to say where they had gotten their ideas from. I did this because students in my class weren't used to the practice of backing up conclusions with evidence and dropping an intense practice like that on students in the middle of the year would likely cause an uproar.

Finally, I figured the students deserved a bit of a break from writing and allowed them to do a creative project that I called "Dead Zones Story Time" instead of writing captions or summaries for their pictures. I told students their project could be anything from a comic to a short story or song, as long as it addressed 10 of the important terms from the unit and provided a narrative explaining certain key features about how a dead zone formed. The checklist that I used to grade this assignment is shown in Figure 2. Again, students were given this checklist in advance so they knew what was expected of them.

Story Time Project	
Story Time (Use 10)	Other Requirements
❑ Bloom ❑ Cloudy Water ❑ Consumes Oxygen ❑ Dead Life ❑ Decomposes ❑ Nutrients ❑ Low Oxygen ❑ Neurotoxins ❑ Photosynth. ❑ Phyto. and/or Algae ❑ Pollution ❑ Respiration ❑ Runoff	❑ Life before dead zone ❑ Change to start dead zone forming ❑ How the oxygen in the water lowered ❑ Underline, highlight, or bold ten terms ❑ Name on project
/10	/5
Total:	/15

Figure 2: Grading Checklist for Creative Project

Data Collected

The data that I collected was feedback from what I called an "exit poll." After the traditional and AST units, I asked students to fill out a simple survey on a Google Form during class. I gave this same exit poll to both periods that I taught. The exit poll administered after the traditional unit on cell organelles consisted of the following two short answer questions:

1. How interesting did you find the unit on cells? What was your favorite part?
2. What do you think could have made the unit on cells better or more interesting?

After administering the poll, data were compiled into a spreadsheet (Appendix A). Since the first question had two parts, I had to go through and separate the responses to the first and second part of question one and pull out the relevant text in the answers to question two. This was done by color coding. After that, I pulled out the words that directly answered each individual question and compiled it into its own spreadsheet**.** On yet another spreadsheet, I grouped similar results together into categories and counted up the amounts for each. This lended itself well to quick graphing of the results through pie charts**.**

After teaching my AST unit on dead zones, I again administered a digital exit poll to my students, but this time I changed the wording of the questions to make them simpler to analyze later. The questions were as follows:

1. What was your favorite part of the unit? (short answer response)
2. How interesting did you find the unit on a scale of 1-5? (multiple choice)
    a. 1 - not interesting at all
    b. 2 - somewhat interesting
    c. 3 - interesting

    d. 4 - very interesting
    e. 5 - my mind was blown
3. How could the unit be made better? (short answer)

Since the scale of 1 to 5 created extra categories of interest, I combined the "not interesting" and "somewhat interesting" categories into a "less than interesting" category so that students' interest in the AST unit could be directly compared to students' interest in the traditional cell organelles unit.

Findings

During the exit poll from the traditional cell organelles unit, I experienced some technical difficulties in one period, so I only wound up getting half the data that I wanted. However, I was able to properly administer the exit poll for the AST unit to both periods, which gave me a much larger sample of data. Since I had varying data sample sizes between the two exit polls, I decided that the best way to analyze the data was with pie graphs and relative percentages - not direct comparisons of the number of responses for each type of answer.

The following is a comparison of the findings for each exit poll question - first from the traditional cell organelles unit, and then from the AST dead zones unit. From looking at the graph of results for students' favorite part of the traditional cell organelles unit, it was easy to tell the favorite activity was using microscopes - almost 90% of the responses to the question mentioned using microscopes. The other 10% of the responses were a mixed bag of demos, lecture, and powerpoints. See Figure 3. In comparison, the students' favorite part of the AST dead zones unit was very mixed. The most popular parts of the unit seemed to be split between the creative project, labs, the use of an anchoring event, making final models, and a Bill Nye video that we played one day as a backup plan when a simulation wasn't working properly. Each of these five results accounted for 12.5% to 18.8% of the total responses to this question. See figure 4. On these figures, the faded portions represent data groups that didn't contribute significantly to interpretations of the results.

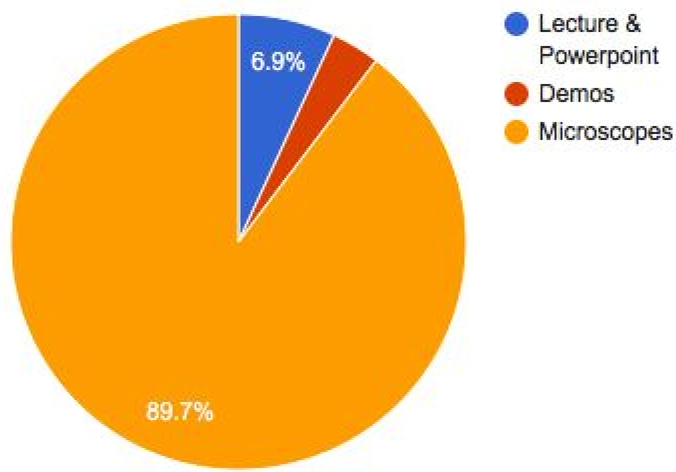

Figure 3: Students' Favorite Part of the Traditional Organelles Unit

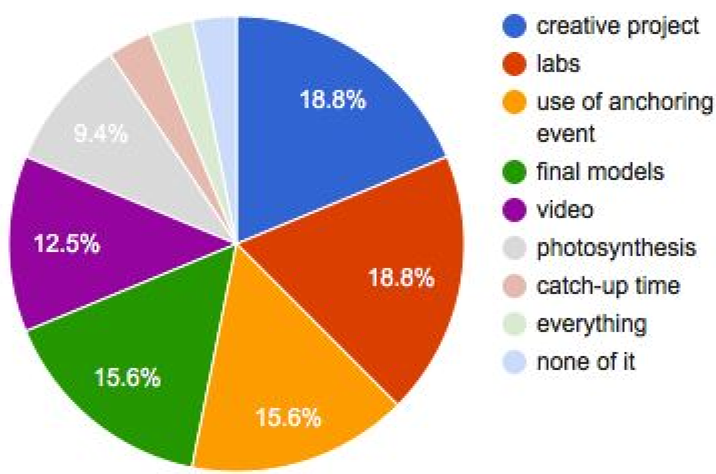

Figure 4: Students' Favorite Part of the AST Dead Zones Unit

When students were asked how interesting they found the unit on cell organelles, the results were fairly split. In Figure 5, approximately 30% of the class said they found the unit interesting, 30% found it less than interesting, and 30% found it more than interesting. After the AST unit on dead zones, figure 6 shows that about thirty percent of the class still said they found the unit less than interesting, but about 45% of the class found it interesting and 20% found it more than interesting.

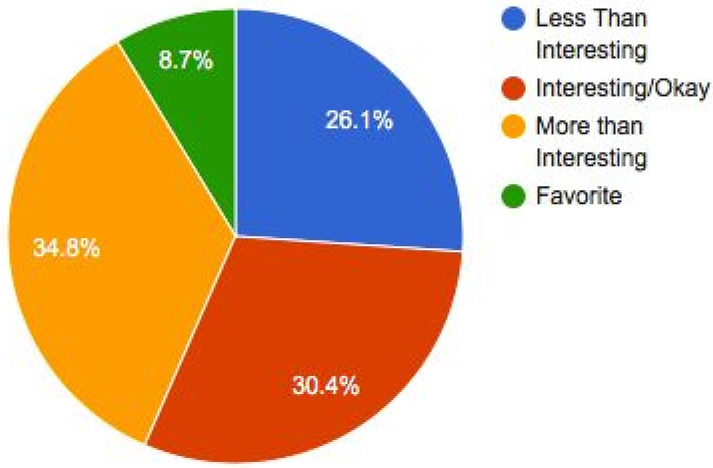

Figure 5: Students' Rating of the Traditional Organelles Unit

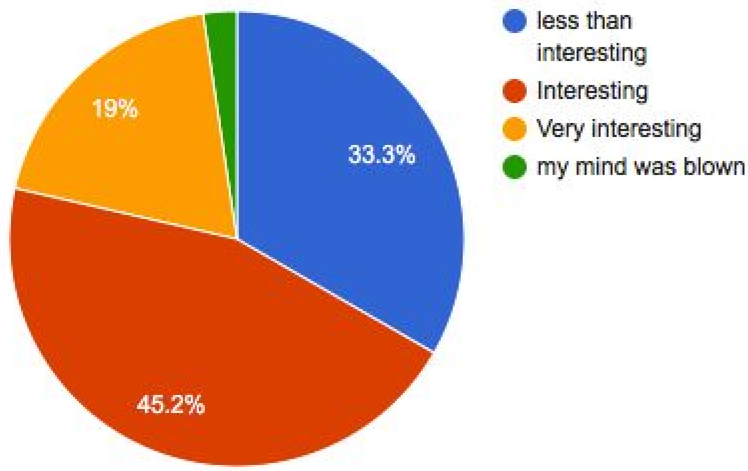

Figure 6: Students' Rating of the AST Dead Zones Unit

The feedback on suggestions for improving each unit turned out to be the most interesting yet the most difficult to analyze due to the wide variety of responses. However, despite the variety, there were some definite patterns. Figure 7 shows how during the traditional organelles unit, over half the class wanted more hands-on or interactive activities. The next most popular change that students requested was alternative methods of disseminating information, which was about 20% of the results. These were the only two major suggestions for the organelles unit.

In comparison, the AST unit had four major suggestions and numerous other minor suggestions only made by a few students each. These suggestions are shown in Figure 8. A large percentage of the class still wanted more hands-on or interactive activities, but no significant percentages of the class wanted more detail and notes from lectures (previously, these suggestions had only been voiced by a few students in the organelles unit). In addition, there was a new suggestion on the table - explicit direct instruction about the anchoring event. This made up about 12% of the responses.

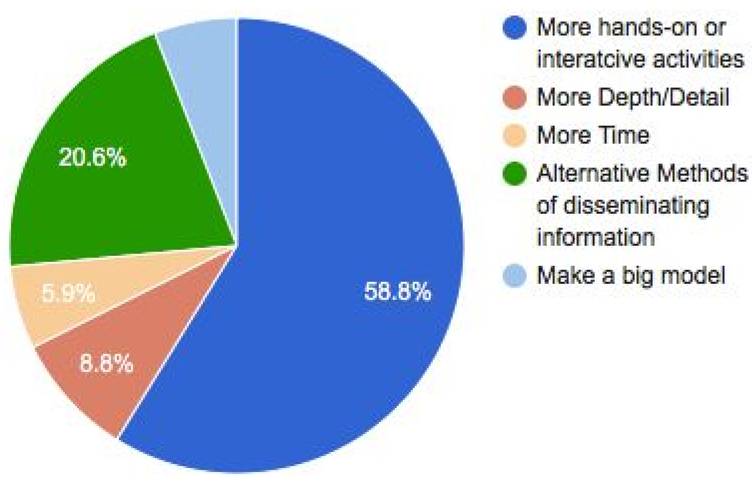

Figure 7: Suggestions for Improving the Traditional Organelles Unit

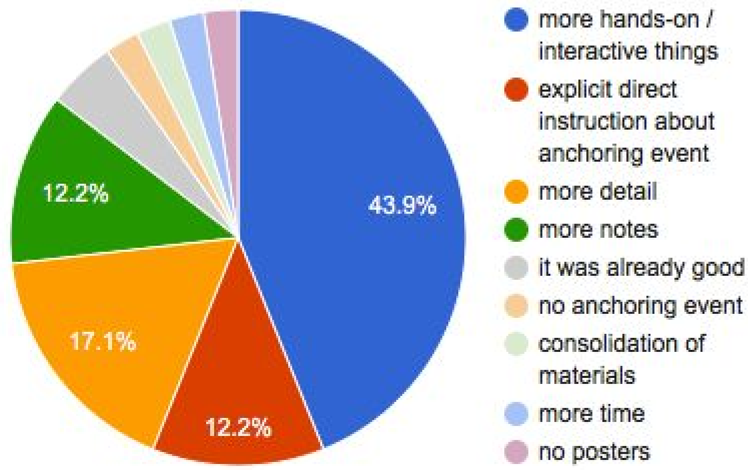

Figure 8: Suggestions for Improving the AST Dead Zones Unit

Discussion and Implications

In my results for my students' favorite part of the AST unit, I found it interesting that there was such a variety of favorite parts. It was also interesting that some of the favorite parts were things like the final models and the creative project, which were summative assessments. However, I believe that this indicates students enjoyed reasoning through some of the material on their own and explaining a process as opposed to answering questions on a test. This made me think back to the quote from the "Engaging Schools" book in my literature review, which stated that students were "more likely to engage when asked to ... create models and complete projects rather than answer questions" (National Research Council et al., 2004). Obviously, this preference for creating models and doing projects was evidence that I had created engagement through AST.

Another interesting piece of data from my AST unit was that some of my students indicated they enjoyed having an anchoring event to explain. In my AST unit, I framed the goal of the unit as working together to explain how dead zones form. Turner, et al. (2014) would argue that this was evidence for students engaging by having a “joint objective” that the teacher and students are working together to tackle.

Unfortunately, the data on students’ interest in each unit didn’t seem to yield quite as much insight about engagement. Even though the AST unit increased the amount of students that found the unit “interesting,” the “very interesting” category seemed to shrink and the “less than interesting” category seemed to grow. Overall, this data seemed inconclusive on whether or not the AST unit increased interest. If both the “interesting” and “very interesting” categories had grown after the AST unit, Turner et al. would have said that the expression of interest was evidence of emotional engagement. However, since some interest seemed to be gained and some seemed to be lost, I can’t tell if the AST unit increased overall emotional engagement or not.

In comparison, my students’ suggestions for improvement on each unit were much more fruitful at measuring engagement. As the National Research Council et al. described, “... students become cognitively engaged when they are asked to wrestle with concepts, when they are pushed to understand…” (National Research Council et al., 2004). I determined that my students were indeed wrestling with ideas because they suddenly wanted much more detail and explicit instruction about dead zones as soon as we started trying to explain them as an anchoring event. There was definitely a drop in the amount of students wanting hands-on or interactive activities, and an increase in wanting to know more about the content - a sure sign that students were thinking about what they had learned and were wanting to know more. That shows cognitive engagement after applying the AST framework.

Overall, I believe that the Ambitious Science Teaching framework definitely increased student engagement in my class across the board. I proved that the AST framework created engagement through giving students opportunities for model making and project based learning and am backed up in this connection by the National Research Council et al. (2004). I also proved that the AST framework created cognitive engagement by making students think critically about content and wrestle with concepts. I'm again backed up in this connection by the National Research Council et al. (2004). Since some of my students indicated that they enjoyed having an anchoring event, Turner et al. (2014) would argue that they were engaged because the teacher and students had the same "joint objective" of explaining the anchoring event. The only inconclusive evidence I had was that students' ratings of interest in the AST unit when compared to the traditional style unit were too similar to tell any difference. I had hoped students would rate the AST unit as more interesting, thus showing engagement (per Turner et al.)

In retrospect, my traditional style unit on organelles did not afford my students as many opportunities for engagement because I didn't press them to struggle with new concepts and I didn't have them make as many models or big projects. By not giving my students enough of these opportunities for engagement, I was doing them a disservice because they couldn't delve into the material and come to the deeper understanding I wanted them to achieve.

In the future, I will definitely take the AST framework with me and implement it in as many of my science units as I can. By implementing this framework, I can promote higher engagement and deeper understandings among more of my students - not just those who are already academically strong and interested in science. While it may be impractical to do this with every single unit I teach my first year out of college, I will definitely try my hardest if these are the results.

When I next implement the AST framework, I will definitely make sure to create another exit poll for students with similar questions so I could measure how engaged they were with the content. I would also like to just sit and chat with students about what kinds of things they would like to see in the classroom. This could function as a sort of “entry poll” at the beginning of the unit, in addition to the exit poll at the end of the unit.

Another thing I would like to do in the future is find more ways that I can differentiate my instruction for various learners in my class. While implementing the AST framework definitely helped engage the majority of my class, there were still some students who struggled for various reasons. For example, when students were asked to fill in their graphic organizer for their initial ideas on dead zones, some ELLs struggled with the writing section. However, many of them were able to express their ideas in pictures. Another time I noticed the definite need for differentiation was during the microscope activity. Some of my students had fine motor skill issues, so they couldn’t adjust the microscope properly.

Overall, my main message is this: The Ambitious Science Teaching framework was a great tool for increasing engagement in my classroom, but it’s not a silver bullet - it takes time and practice to engage every student.

References

Meyer, K. (2009, December 02). Hypoxia: Dead Zone. Retrieved April 0, 2016, from https://www.youtube.com/watch?v=yh5Ev8VEbZ0

National Research Council and the Institute of Medicine. (2004). *Engaging schools: Fostering high school students' motivation to learn*. Washington, D.C.: National Academies Press.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Retrieved April 24, 2016, from http://nextgenscience.org/

Quinn, H., Schweingruber, H., & Keller, T. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. doi:10.17226/13165

Turner, J. C., Christensen, A., Kackar-Cam, H. Z., Trucano, M., & Fulmer, S. (2014, December). Enhancing Students' Engagement: Report of a 3-Year Intervention With Middle School Teachers. *American Educational Research Journal, 51*(6). doi:10.3102/0002831214532515

Appendix A

Raw Data from Exit Polls

Table A1: Raw Data from Traditional Cell Organelles Unit Exit Poll

How interesting did you find the unit on cells? What was your favorite part?	What do you think could have made the unit on cells better or more interesting?
not very interesting but my favorite part was using the microscopes	much more labs with them instead of verbal learning
i found it very interesting and i really enjoyed learning about the plant and animal cells	if we had done big posters of the cells and label them and put that the parts of the cell do
yes the cell unit is my favorite	more looking at cells and do activities
use the microscope was intersting	make a cell model, maybe
it was somewhat interesting and the microscopes was my favorite	more labs
The parts of the cell.	The animal and plant cells.
when we use the microscopes to look at cells that was my favorite part	nothing it was fine
Getting to use and learn how to use the microscopes.	
The cell unit was interesting. My favorite part was looking at things under the microscope	I think the unit on cells could have been better if we went into depth about the insides of the cell and the functions of each part. Needed more time to talk about it.
looking in the microscope	i don'i know
Interesting. 6/10	A tad bit more time to study.
It was very interesting and my favorite part was using microscopes.	Nothing, it was very good.
i found it hard to understand and honestly did not find it that interesting. but i did enjoy looking through the microscope	if we learned about them on hands or through a text book reading instead of learning everything on a screen.
it was alright. the microscope part	i have no idea
it was my favorite part f the whole year	i dont know
i found it very interesting, biology is my favorite science subject... my favorite part was looking at cells under a microscope	i have no idea :D
it was okay but i dont really care about cells	im not sure
The fact that it was multiple choice so I don't make myself look too idiotic	More pictures, we're pretty much just sitting here reading and thinking
it was very interesting, my most favored part of this unit was using the microscopes to observe cells	to make it more interesting, do more activities with microscopes and observing and describing cells

I found this unit quiet interesting, and my favorite part was definitely looking through the microscope.	A little bit more of using the microscopes.
I like knowing about cells and their functions and my favorite part was getting to see them under the microscope.	If we could see live cells and if we had stronger microscopes to be able to see each of the organelles closely and name them that way.
My favorite part was learning about the organelles, and I found the unit fairly interesting.	We could've gone into more detail about how the organelles work together.
microscope lab	more labs
It was very helpful to learn, and I could easily pick it up.	The unit could've had more labs there wasn't many in class.
comparing plant and animal cells	nothing, it all covered it pretty well in my opinion
the unit was interesting at times. my favorite part was the microscopes.	more group interactions
It was interesting when we used the microscopes and looked at the cells.	More experiments with microscopes. No to the next question
The cell unit was a review for me, since we have done this unit in other school years, so it wasn't super interesting, my favorite part was the note taking, surprisingly.	A more in depth look at the way mitochondria and chloroplasts work
I m very interesting in animal cell	I think could do more review and practice
Not very interesting, I didn't have a favorite part.	
The microscope was my favorite	I don't know
It was really interesting finding out what the parts of a cell, how ever i did not enjoy this unit as much as i enjoyed the digestive unit. My favorite part of this unit was the plant and animal cells.	More interaction and less taking notes. And if we got to see more examples of cells.
It was moderately interesting. It didn't blow me away or anything. My favorite part was looking at cells under a microscope.	Doing more microscope activities. Note: I didn't mean to pick the Option 1 below.
It was alright. My favourite part was looking through the microscope at cells.	Food.
My favorite part was using the microscope in the lab.	I think that more interactive activity would have made the unit more fun such as another lab maybe. Or more videos, those are interesting and make sense (for the most part)
i am not really interested in cells but my favorite parts were when we watched demos	maybe more hands on work
not that interesting and i honestly found it hard to understand but i did enjoy the microscope lab. it was interesting.	less screens. i would probably found it more interesting and enjoyable if their was more hands on experience. i also think if we used text books to read about the cells and microscope uses i would if been able to focus more.

Table A2: Raw Data from AST Dead Zones Unit

What was your favorite part of the unit?	How interesting did you find the unit?	How could the unit be made better?
labs	1- Not interesting	do more activities
photosynthesis	1- Not interesting	by doing more labs
the videos and charts we made	1- Not interesting	less computer work. more text book and paper.
learning about dead zones	1- Not interesting	more details about dead zones
the labs	2-somewhat interesting	more labs
flow charts	2-somewhat interesting	we could of done more labs
labs	2-somewhat interesting	do more activities
everything	2-somewhat interesting	more activities
Probably the final thing. It was fun to get to show how the dead zone look an work rather that have to tell how they work.	2-somewhat interesting	Taking more notes
the labs	2-somewhat interesting	IDK, It was pretty good in general.
Writing the story time project	2-somewhat interesting	i think you should do like
none of it	2-somewhat interesting	more details about dead zones
Photothysis	2-somewhat interesting	more detail on respiration and more time to study
the bill video	2-somewhat interesting	More group experiments with stations and activities.
Learning about something I didn't even know was a thing	3-Interesting	Less written work. Maybe have easier to understand/better written questions.
My favorite part was making the short story, because we could be creative.	3-Interesting	It could be made better by having more fun labs.
photosynthesis and learning about plants, i guess	3-Interesting	More explanation on how dead zone's work
bill nye	3-Interesting	i dont know
running lab where we ran down the hall and then measured the level of	3-Interesting	Maybe do a fun lab with the photothysis

CO2 that was being produced by our bodys		
Doing the projects because you got to be creative and it was fun.	3-Interesting	Explaining the connections between all of the things we learned and Dead Zones more.
watching a small clip of what it is like in a dead zone	3-Interesting	more hands on labs
I have to say the Bill Nye was my favorite	3-Interesting	More visual examples about dead zones and how they effect the environment.
Dead zone story time project	3-Interesting	give more constructive feedback on assignments.
Making the dead zone story from a sea animal's perspective.	3-Interesting	More labs. Other than that it was good.
The two drawings we did was an interesting way to see what we knew and how well we knew it.	3-Interesting	have more time to go deeper
my favorite part was the final project story.	3-Interesting	Do more physical stuff. Like hands on stuff and things.
The videos on dead zones	3-Interesting	I thought we could've talked more as a class about how photosynthesis and respiration affect dead zones
watching videos on dead zones and doing the dead zone activity [final model]	3-Interesting	i think there could have been more labs because they always make things more fun
running and breathing into the cup of weird yellow water and figuring out how long it takes for the weird water to change colors.	3-Interesting	If we did a lab that relates to the dead zone and how the effects happen that'd be pretty cool but otherwise I think it was a good unit.
work time when we could get caught up on assignments we were missing and we didn't do ect. It was very helpful and chill.	3-Interesting	i would have to say that it could be a little bit more descriptive
	3-Interesting	I think that it was the best it could be for me, personally
	3-Interesting	More hands-on activities
	3-Interesting	Less boring videos, instead explain to us in your words.
	4-Very interesting	More interactive.
	4-Very interesting	it could have been better by more interactive labs
	4-Very interesting	More labs and videos although this unit had many the more the better
	4-Very interesting	more videos on the topics since at least for me it is more interesting than just typing notes and listening

	4-Very interesting	more notes, no posters on the wall. Instead of reading the different articles to each other we should just learn it from the teacher because its less info and less detail and legitness when it comes from lazy teens.
	4-Very interesting	I think it would have been better if we spent more time on learning one subject then switch to the next; rather than mixing things up and learning about different things all at the same time.
	4-Very interesting	cooler examples maybe?
	4-Very interesting	More work in the lab book and on the computer so it's all in one place. More note taking; longer and more detailed explanations in the slide show.
	5- My mind was blown	