Nature of Science

a) engage in a critical reflection of how you address the tenet(s) currently in your teaching. Describe how you currently address the tenets. You may talk about one specific lesson or activity that you use to address the tenet. If you do not address any of them, talk about the way that your curriculum treats the nature of science. (about 1 page)

As outlined in the Next Generation Science Standards, there are three major components of STEM: the integration of scientific and engineering practices, disciplinary core ideas, and crosscutting concepts. These components are further broken down into eight core understandings (National Research Council, 2013). Within the science research program at Manhasset High School, our current curriculum has students critically explore these eight parts of the Nature of Science throughout the year.

In September, students spend time on exploring a topic to understand that "Science Addresses Questions About the Natural and Material World" (National Research Council, 2013). In the first major assignment of the year, students brainstorm potential topics based on their interest in biology, chemistry, earth/environmental science, physics, or computer science. Students must generate three specific questions about what they want to study throughout the year. For example, if a student wants to use machine learning, students can ask questions about what type of data can be processed by machine learning models. This is further developed into the core topic and hypothesis research students pursue throughout the research process.

In October, students begin to broaden their knowledge on the topic and begin to understand how "Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena" and "Scientific Knowledge Assumes an Order and Consistency in Natural Systems" (National Research Council, 2013). Students can accomplish this by reading existing literature in the field using resources such as JSTOR, and Google scholar. In the introduction course, students use a Journal Article Review template as a guide for the most important information to annotate in the papers, such as the need, methodology, and conclusions. Through exploring previous studies in their field, students gain a better understanding of the gap in the existing knowledge base to further the importance of the need to find an answer to the question posed.

By November, students begin to plan their own methodology with the understanding that "Scientific Investigations Use a Variety of Methods" (National Research Council, 2013). This is achieved by adapting protocols from the previous existing literature and videos from Jove. Students also have an opportunity to practice the equipment in a pilot study to practice the various tools in the lab prior to experimentation. For example, students can compare the nature of the data collected from a negative geotaxis versus a photoaversion assay for drosophila, as shown in Figure 1. This provides students with an opportunity to determine the most effective method to achieve the data that aligns with the question they are trying to answer.

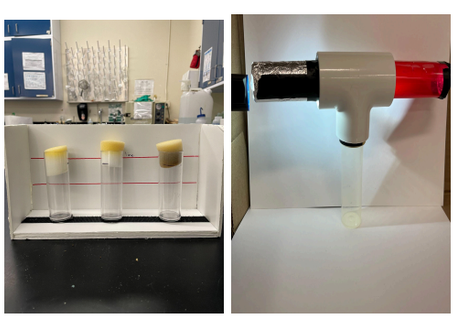

Figure 1: Drosophila climbing assay apparatus (left) and Drosophila photoaversion assay apparatus (right) (Photo taken by Manhasset High School students)

From December to January, students focus on data collection in our lab to understand that "Scientific Knowledge Is Based on Empirical Evidence" (National Research Council, 2013). During data collection, students have access to equipment to collect data for their control and experimental groups. This includes glassware, probes, organisms, etc. for their experiment, as shown in Figure 2. Students record their information in their lab notebooks for further analysis. In this phase of the course, students become more independent within their own project and the teacher often takes a mentor role. As outlined by Tang (2023), this "student centered approach" allows students to authentically experience hands-on science on their topic of interest (Tang, 2023).

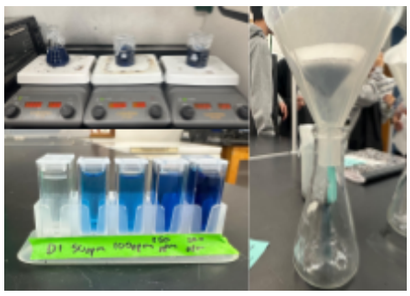

Figure 2: Equipment used to collect methylene blue remediation data (Photo taken by Manhasset High School students)

In February and March, students begin to analyze their data to build an argument. Students spend time using IBM SPSS and Microsoft Excel to input their data online. The data is then analyzed for descriptives such as mean, standard deviation, and variance. Using the programs, students can run statistical analysis tests such as a One-Way ANOVA to determine statistical significance in means between groups. This data can be transformed into visual representations such as linear regressions or bar graphs, as seen in Figure 3 below. This step of the research process has students understand that "Science Is a Way of Knowing" (National Research Council, 2013).

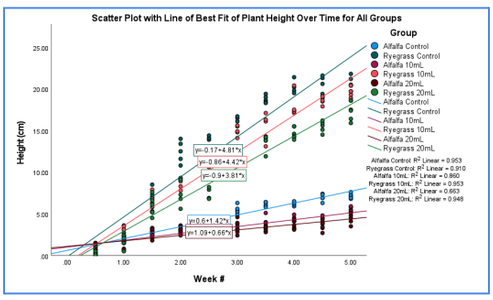

Figure 3: Scatter plot of data from student project (Photo taken by Manhasset High School students)

By April, students begin to understand that "Science Is a Human Endeavor" (National Research Council, 2013) by communicating their findings. This is done through two major components: the research paper and poster board. The research paper consists of 18 pages covering an introduction to the topic, explanation of methodology, analysis of results, and discussion of the conclusion. The posterboard is a summary of the research paper, as shown in Figure 4 below.

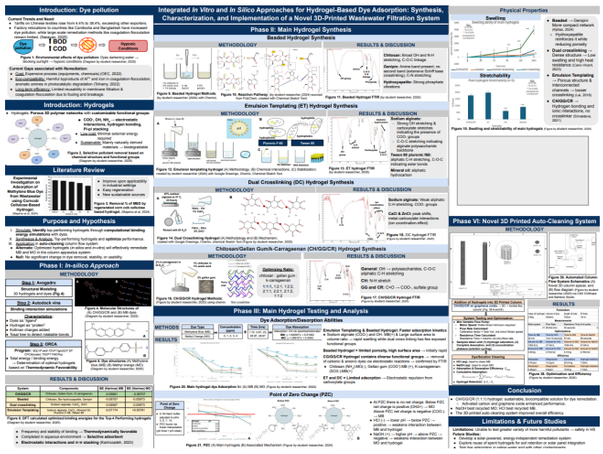

Figure 4: Example student poster board (Work completed by Manhasset High School student)

In May and June, students prepare for peer review for revisions and feedback from professionals during competitions. During class time, students are partnered with another student to read through their research paper and give constructive feedback prior to printing in our journal. This provides students with an opportunity to share their findings with classmates as well as revise information to be understood by another high school student. Outside of the classroom, students are invited to share their work at local competitions such as LISEF, LISC, WAC, and SAAWA. Through this process, students are challenged to communicate their findings and answer questions about their work. Students then can use the feedback provided by the judges to evaluate and reflect on their work to understand that "Scientific Knowledge Is Open to Revision in Light of New Evidence" (National Research Council, 2013).

When thinking critically about the current research curriculum at Manhasset High School, our research courses have opportunities for all eight understandings to be addressed throughout the year. However, there are still opportunities to address the nature of science explicitly. For example, the research class does not critically discuss how our pursuit of knowledge is innately human and evolves based on our currently accepted paradigms. Next year, I should spend more time clearly discussing how science research is a human endeavor.

While the nature of science is core to the research courses at Manhasset High School, this type of learning is not available to the core content courses. For example, students who take AP Biology or Regents Chemistry may never have experiences with the human element of presenting information when the concern of the class is focused on the content for major assessments. Especially when reading the article from Ladson-Billings (2003), it is important to recognize the privilege Manhasset's science research program brings for these select students (Ladson-Billings, 2003). This makes me consider the lack of access, resources, and budget to all students to engage in all eight understandings of the nature of science.

b) consider how you might enhance your teaching to address the tenet(s) outlined in Appendix H. You may review and cite resources from the course as well as others (please cite them). Discuss specifically how your thinking/understanding of the "nature of" is dynamic. (about 1 page)

When reflecting on the Nature of Science, there are some gaps within the curriculum and my own teaching that can be enhanced by incorporating the nature of science. As outlined in Appendix H, there are eight core understandings of science, with students at the center of the learning process (National Research Council 2013). While my current science research courses have a strong alignment to the first four science and engineering practices, I often overlook the last four understandings associated with the crosscutting concepts.

One way that I would like to incorporate more of the crosscutting concepts within the nature of science within my classroom is to collaborate with other departments. As discussed by Kelley and Knowles (2016), creating more explicit cross content connections can make science more engaging for students (Kelley & Knowles, 2016). For example, students who are researching microplastic pollution in the Manhasset Bay can incorporate their Social Studies classes by researching policies and regulations. Through collaboration, students can see different perspectives about the topic and leverage student interests. This will help students understand how science can be used to address questions about the material world.

Another way that research can better incorporate the nature of science is by fostering partnerships with experts outside of the classroom. In the paper by Kelley and Knowles (2016), the authors state how authentic science needs connections "a community of practice" (Kelley & Knowles, 2016). To achieve this, our research program should encourage students to partner with outside labs or build relationships with local community groups. For example, students can partner with the NYU ARISE program to gain access to advanced FTIR and SEM analysis of biochar samples. Additional influences can help students gain a different perspective regarding their project and increase breadth of knowledge beyond what is capable in the school lab.

Lastly, our research program can better incorporate the nature of science by incorporating more of the understanding that "Science Is a Human Endeavor" (National Research Council, 2013) into research. Currently, students are not always explicitly confronted by the human element of research. Even in the way the papers themselves remove the personal pronouns or declare inconsistencies as "human error", science is so quick to diminish the human element. However, exposing students to local competitions and receiving feedback from experts in the field, as shown in Figure 5, can re-introduce the human layer within science and research.

Figure 5: Manhasset students competing at various local competitions on Long Island. Faces are obscured to protect student privacy (Photos taken by Manhasset High School students)

To me, the nature of science is clearly dynamic and open to change. Prior to the implementation of the Next Generation Science Standards, I did not engage in science with students at the center. This would mean that students were not asking authentic questions about science and engaging beyond completion of tasks. To students, science was a class of previously accepted facts and lacked the human dimension and student involvement. However, as Tang (2016) outlined, there are a multitude of ways to incorporate student centered learning such as problem-based learning, adaptive teaching, and student centered feedback (Tang, 2016). In research, the independent nature of the class provides students with the opportunity to be at the center of their projects. This allows students to feel empowered by science, something I had never considered possible with the traditional way science was taught. By centering science and science research around the student, students can truly begin to understand science as a human endeavor.

c) read an additional document from the list above that addresses the "nature of" a different discipline. Identify 3 ways in which your content area overlaps with the second area that you selected.

In addition to the Nature of Science itself, it is important to consider integrating the principles of engineering and design. As outlined in Appendix I of the NGSS standards, engineering and design are defined by three major components: defining engineering problems, designing solutions to engineering problems, and optimizing the design solution (National Research Council, 2013). While the overlap is not always explicit between science and engineering, there are parallels that can be drawn between the engineering and design standards and the science goals of my research courses.

One way the research program currently supports the NGSS engineering standards is by developing ways for students to define problems from an engineering perspective. As stated in Appendix I, students can break down a large problem into smaller problems (National Research Council, 2013). For example, in September and October, students can create questions on how to find less expensive alternatives for pollution monitoring by identifying a specific pollutant to measure. Through defining the problem from an engineering perspective, students can integrate engineering practices within their scientific learning.

Another way the current research program incorporates the principles of engineering is by tasking students to design solutions to meet specific criteria. In science research, students can achieve this through planning methodology in November with specific criteria and constraints outlined. For example, students can evaluate different neural network models on the accuracy to classify 5 specific natural disasters from images, as shown in Figure 6. By considering specific criteria within the design, students can begin to incorporate engineering practices from a science research perspective.

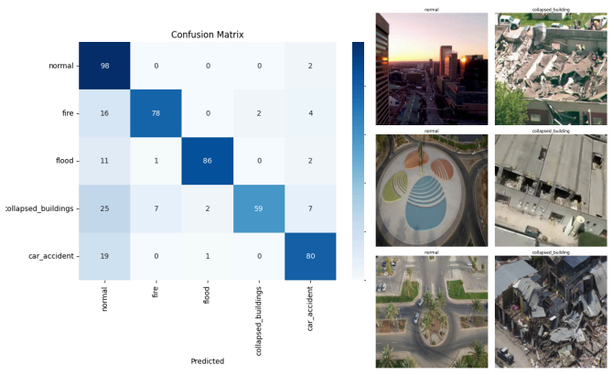

Figure 6: Confusion Matrix of the model with example data set images (Work completed by Manhasset High School student)

Lastly, research has opportunities to incorporate the nature of engineering by optimizing solutions through testing. This is often done through multiple iterations of a methodology or assays during laboratory data collection in December and January. For example, students can choose to design 3D printed skin scaffolds through multiple ratios of seaweed and cellulose to optimize wound healing. By creating multiple iterations of the same product, students can naturally create connections between engineering practices and science.

In my own classroom, there are opportunities for overlap in science and engineering. This is crucial since the success of integrated STEM is contingent on accessing content from across disciplines (Nadelson & Seifer, 2017), especially engineering.

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