The Nature of Engineering in My Work

I am working in a new role this year as the Instructional Specialist of Design Innovation, Creation, and Expression (DICE, formally known as STEM in my school district) for grades K-12. I facilitate the use of the Fabrication Lab, a makerspace that until this year has been underutilized. Part of my role is to offer STEM activity opportunities to middle school students during their WIN ("What I Need") period once a week. I also assist teachers who want their students to use technology in the Fab Lab to complete projects for their content area. For the past 22 years I have been a high school science teacher and I feel very comfortable with the tenets of the nature of science however I find that this year my work more closely aligns with the tenets of the nature of engineering. I am not as familiar with the nature of engineering but I can see the potential for engineering to be the context that allows the other elements of STEM to be integrated.

Some significant challenges that face teachers trying to teach engineering at the K-12 level are that the NGSS engineering learning standards are still relatively new to most teachers, there are no state-level or national assessments, and there are very few professional development/certification programs for teaching engineering. Fewer than 6 million out of 56 million K-12 students have received formal engineering education and only about 18,000 teachers have received professional development training in how to teach engineering (Katehi, Pearson, & Feder, 2009). It is no wonder that engineering remains so vague in K-12 education. Even so, a few tenets of the nature of engineering are apparent. I will illustrate how they have been realized in my work in the Fab Lab this year so far, admittedly, most often at the level of an ad hoc infusion of engineering concepts.

Principle 1: Engineering Design

The engineering design process is highly iterative, open-ended, and requires systems thinking. With middle school students I have hosted Destination Imagination Instant Challenge activities and the Science Buddies Engineering Challenge where students need to design something aligned to specific criteria and constraints. The students discover that there are many possible solutions and are eager to make modifications to their designs to see if they can be improved. Most recently students had to create a gravity-powered transporter device that would carry pennies down a ramp using only the given materials. The design that carried the most pennies the farthest distance would be the winner.

Principle 2: Incorporation of Mathematics, Science, and Technology

As part of a project with the AP Physics class the 12th grade students came to the Fab Lab to build marble launchers. They had to use calculations and formulas they learned in class to determine the angle of launch in order to hit a constant-velocity toy car at a given distance. Students worked in teams to plan a design, create a prototype, and then built their launcher. Students used CAD software to design elements to be 3D printed, they used measurement tools to make precise cuts of their PVC pipe parts and wooden dowels. They used video

analysis software to analyze their test launches. This was the ultimate integration of math, science, engineering, and technology and the students loved it!

Principle 3: Engineering Habits of Mind

Our school district has a “special” class in the elementary school called Young Engineers. In this class students in grades K-5 meet once in a 7 day cycle with a teacher (other than their normal classroom teacher) who teaches them about the design process and the habits of mind of an engineer. These include (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations (Katehi, Pearson, & Feder, 2009). They start the year with time to explore the materials and be creative with “free builds” and as the year goes on the teacher introduces new concepts like criteria, constraints, and budgeting for materials. I have visited this class and had several conversations with the teacher (who unfortunately is retiring at the end of the year) in an attempt to help build a more cohesive program with a natural progression into what the students do in middle school.

Enhancements Needed to Address the Tenets of the Nature of Engineering

Principle 1: Engineering Design & Principle 2: Incorporation of Mathematics, Science, and Technology

The previous example listed about the AP Physics class is the only example of a fully integrated STEM project in our school district. And it is the only project of its kind in that year-long course. It came about because the teacher of the class is very interested in engineering and technology himself but even he struggles with making the time needed for such a project within the curriculum of an AP course. I would like to work with more teachers to help them design integrated STEM courses but I am facing many obstacles. One is that there is no available PD time for these discussions and curriculum work because the calendar for the year is already planned for other things (which shows that the district may not hold integrated STEM instruction as a priority). Another challenge is that most teachers are preparing their students for standardized tests and so they do not feel that they have the time in their curriculum to let students learn through problem-based learning and design projects. I have planned to focus my efforts on working with teachers who are teaching elective courses that do not have state exams and I have asked for permission to host a summer workshop to do the curriculum work necessary to revise these courses. In this way I hope that more elective course teachers will include design elements in their curriculum but I am not certain that there will be integration of multiple facets of STEM unless teachers from several departments are willing to attend the summer curriculum work session at the same time.

Principle 3: Engineering Habits of Mind

A special class that meets only once every 7 school days does not allow for a consistent development of content and skills. Students must be reminded and retaught at every class

meeting about what was learned in the previous class. Additionally, this stand-alone course does not integrate with what the classroom teacher is teaching about math and science. The next step is for me to facilitate the conversation between whomever is the new hire for the position of Young Engineers teacher and the classroom teachers so they can develop projects that compliment what the other is doing in their classrooms. There is not anything that I can do about the programming due to the school structure at this point since I am not an administrator.

Integration of the Nature of Science

The nature of science is the human need to know and understand the world around them. This understanding is always changing in light of new evidence. Science is dynamic and being a scientist requires a sense of curiosity and wonder. In many ways the Nature of Engineering and the Nature of Science overlap. This is probably why NGSS has grouped these skills together in the dimension called Science and Engineering Practices. Scientists and engineers must make observations and develop questions and possible solutions to test. The “scientific method” is actually much more like the “design process” in that scientists must refine their experiments and test again. They also need to interpret their data using mathematical and statistical analysis. Scientists and engineers must use systems thinking and be aware of how one thing affects another and may lead to unintended consequences.

I would like to include the Nature of Science more explicitly in my work in the Fab Lab. I think I can do this by using scientific problems as the context and engineering practices as the tool to develop solutions to the problem. I taught AP Environmental Science for over a decade and we discussed and learned about many new technologies that could potentially alleviate our environmental problems. I never felt like I had the time for students to explore building or designing alternative technologies for themselves. In this new position I have the chance to bring the two together. This year I am working with a student on altering a RC car to run on a hydrogen-fuel cell and have begun discussions with another about how to design a more efficient at-home composting machine.

Next year I would like to add a hydroponics system to our Fab Lab. In my previous job I taught a course on hydroponics and the students learned a lot of botany and chemistry but they did not have the chance to think about the design of the systems themselves and how they could be improved. The potential for the engineering of systems that improve our options for feeding the world’s population with nutritious food is exciting.

I am working to build relationships with the science teachers in the elementary, middle and high schools. Once they have more trust in me I hope to be able to convince them to include engineering design elements into their curriculums but as I mentioned before, those who have state tests at the end of the year are more reluctant to add anything new to their courses.

References

Katehi, Pearson, & Feder. Engineering in K-12 Education. National Science Foundation. 2009
https://www.nsf.gov/attachments/117803/public/1b--Eng_in_K-12_Ed.pdf

NGSS Appendix F: Science and Engineering Practices
https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

NGSS Appendix I: Engineering Design
https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL_V2.pdf

NGSS Appendix H: The Nature of Science
https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Science%20Standards%204.15.13.pdf