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Nature of STEM

Part A

According to Peter-Burton (2014), "*The nature of engineering (NOE) can be described… as what engineers do in the cyclical design process, how engineering impacts society, and how society impacts engineering.*" Sounds simple enough… until you realize that unlike the Nature of Science (NOS), which has been around the education block a few times, the NOE doesn't come with a tidy, agreed-upon checklist. It's still a bit of a work-in-progress – especially when it comes to K–12 education. But Katehi et al. (2009) attempted to pin it down with three guiding principles, and honestly? They hit the nail on the head.

Here's the thing: most schools don't teach engineering. When I tell people what I teach, I usually get a surprised, "Wait… in high school?" Even in my own building, it's not a class that everyone takes. We typically start with around 48 freshmen, and this year we'll graduate 25 dedicated seniors – 73% of whom are headed off to study engineering in college! That's a stat I'm incredibly proud of. This year our middle school just made engineering a required course for all 8th graders, and next year it'll expand to 7th grade too. For the first time ever, there will be three full sections of 9th grade engineering in the fall. Momentum is building.

Here are the three principles.

Principle 1. K–12 engineering education should emphasize engineering design.
They state that engineering is (1) highly iterative; (2) open to the idea that a problem may have many possible solutions; (3) a meaningful context for learning scientific, mathematical, and technological concepts; and (4) a stimulus to systems thinking, modeling, and analysis. This one's the foundation of everything we do. Engineering is messy, creative, frustrating, and deeply rewarding – and the design process (Figure 1) reflects that. It's not about finding "the answer," but exploring many possible answers. I constantly remind students that good design is iterative – they test, fail, tweak, and repeat until they land on something that works. Sometimes I assign fake monetary values to supplies to simulate real-world constraints. They struggle (and get a bit angry) at first, because they've been conditioned to believe there's always just one correct answer. Watching them unlearn that over the course of the year is one of my favorite parts of teaching. Whether they're building a zipline cargo system, redesigning our school's athletic wing, or creating energy-efficient affordable homes, they're doing the real work of engineers – balancing trade-offs, defending their choices, and applying math, science, and tech in ways that matter.

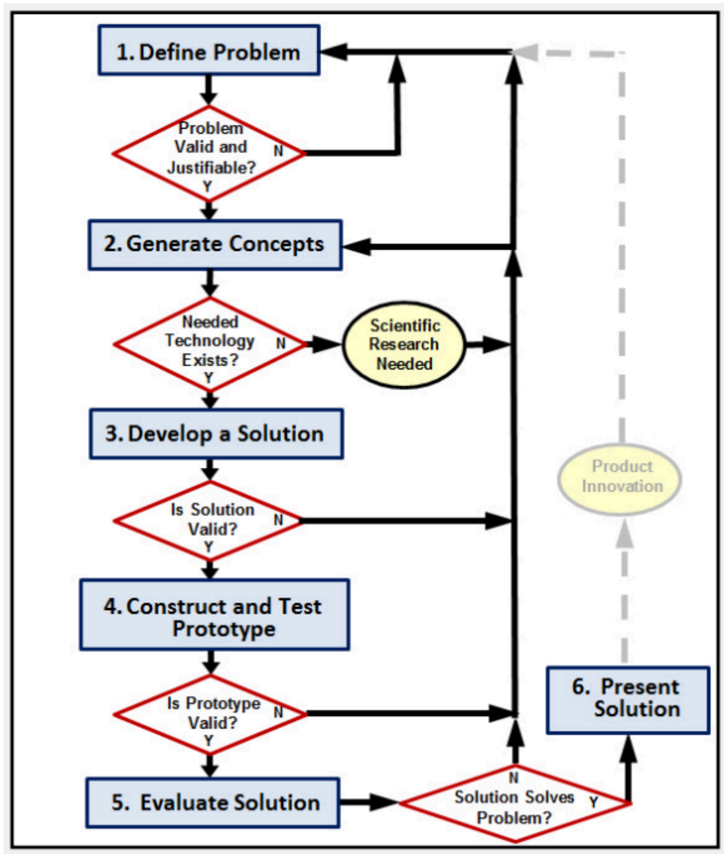

Figure 1: Design Process (PLTW)

Principle 2. K–12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills.

My students aren't just building stuff. They're using Newton's Laws to calculate forces. They're wiring circuits and analyzing energy transfers. They're crunching numbers to figure out what's efficient, what's strong, what's affordable. And they're doing it all with real tools – Fusion 360 for CAD (Computer Aided Design), Revit for architecture, Excel for data analysis, and equipment like 3D printers, laser cutters, and even soil-testing gear. They see how the science and math they've learned in other classes come alive in engineering – and how technology isn't just for gaming, but for designing better, more sustainable solutions. I will never forget when students were designing a roof and a very excited student said, "I just used Pythagorean Theorem to figure this out! I never knew there was a reason to know this!" They also reflect on what their designs mean. Is this affordable? Is it environmentally responsible? Could it last? Should it?

Principle 3. K–12 engineering education should promote engineering habits of mind.

The authors state that citizen skills include (1) systems thinking,(2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations. This is the big one.

These are life skills—stuff every human needs, not just engineers. In my classroom, systems thinking means understanding how parts of a design work together and predicting what happens if you change just one piece. Creativity is baked into every challenge, starting with brainstorming wild and wonderful solutions (before they even get into teams). Optimism comes from knowing that failure isn't final – it's feedback. Collaboration? It's constant. They plan, build, debate, present, revise… together. And ethics – we don't skip that. We've had some of our best class discussions around case studies like the Challenger disaster and the Boeing 737 Max. Students don't just learn what went wrong – they argue about why it went wrong and what they would've done differently. This summer, I'm planning to dig into the Titan submersible incident and build a lesson from it.

Ultimately, I don't just teach engineering. I teach young people how to think critically, solve problems, and care deeply about the impact of their work. It's not about turning them all into engineers – it's about helping them become thoughtful, capable, and curious humans. And that's the real power of engineering education.

Part B

My understanding of the Nature of Science (NOS) has shifted dramatically in recent years. I used to think of it as a checklist of facts students needed to memorize. Now? I see it as alive – messy, evolving, full of questions, and always open to change. Appendix H of the NGSS (2013) helped me reframe science not as a body of static knowledge, but as a way of making sense of the world. It's a process – systematic, evidence-based, and inherently uncertain. And honestly, that's what makes it exciting. Since I started teaching engineering, I've leaned hard into this dynamism. I don't want my students to just know what we know – I want them to grapple with how we know it, and why that knowledge can and should change.

In engineering class, this mindset has reshaped how I teach. Engineering isn't just about building stuff. It's about inquiry. It's creative, collaborative, and a bit chaotic – in the best way. I often tell people my classroom is organized chaos. I encourage my students to question their tools, revise their methods, and wrestle with ambiguity. Our work is rarely about arriving at one perfect solution; it's about testing, failing, adjusting, and trying again. That iterative, human, slightly uncomfortable space? That's where the learning happens.

Take the tenet "**Scientific Investigations Use a Variety of Methods**." In my Civil Engineering and Architecture class, students designed truss bridges in Fusion 360, ran simulated stress tests, laser cut the pieces, and then actually built them. Once they had the physical bridges, we brought out the hydraulic press and watched them fail – gloriously. Every bridge told a different story. And students didn't just compare results; they reflected on what their digital predictions missed. This mash-up of digital modeling, hands-on building, and brute-force testing showed them that there's no one-size-fits-all method in science or engineering. Choosing the right approach matters – and it often depends on what questions you're asking and what resources you have.

"**Scientific Knowledge is Based on Empirical Evidence**" is baked into everything we do. From graphing test data in Excel to troubleshooting circuitry, students learn that evidence isn't just something you collect – it's something you interrogate. I ask them to explain anomalies, identify outliers, and revise their claims based on what the data tells them – not what they want it to say.

And let's talk about "**Scientific Knowledge is Open to Revision in Light of New Evidence**." This one's my favorite. I use real-world examples constantly – debates over the environmental trade-offs of lithium batteries, new findings about microplastics in drinking water. Students see that science changes, not because it's flawed, but because we are always learning more. I frame revision as a strength, not a flaw – because it means we're paying attention.

With "**Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**," I try to show students that these frameworks are not dry rules – they're tools. When we study projectile motion, for example, kinematic equations aren't just symbols on a page; they help students predict how far a zipline payload will travel or where a dropped object will land. These laws are ways of organizing what we observe – and they're powerful when students see them in action.

"**Science is a Way of Knowing**" really comes alive when I let students bring their own experiences into the classroom. Whether they're connecting a design to something they saw in their neighborhood or referencing a cultural perspective on resource use, I want them to see science as a lens – not the only lens, but a meaningful one.

To address "**Science is a Human Endeavor**," I integrate stories of real engineers – people who made bold, messy, sometimes ethically fraught decisions. My students read about the Challenger disaster, Boeing 737 Max failures, and (soon, I hope) the Titan submersible. We watch, read, and then debate. It gets loud (and fun). But in that noise, students confront the very real impact of STEM decisions – and their responsibility as future designers.

Finally, for “**Science Assumes Order and Consistency in Natural Systems**” and “**Science Addresses Questions About the Natural and Material World**,” I anchor projects in local, tangible problems. We’ve tested water quality, redesigned school spaces, and analyzed energy use at home. When students use STEM tools to tackle something they see and feel, science stops being abstract. It becomes a means of navigating - and changing - the world around them.

Through it all, my students learn that science (and engineering) are not about being right. They’re about being curious. And for me, as a teacher, that shift – from answers to inquiry – has been everything.

Part C

After reading *How Technology is Reinventing K–12 Education* (Spector, 2024), I found myself nodding a lot – because this article gets it. It captures how tech, especially artificial intelligence, is not just this shiny add-on to our classrooms; it’s changing how we plan, teach, assess, and connect. While some of the tech feels like sci-fi (hello, VR walk-throughs), a lot of it is already part of my daily rhythm. And sometimes, it's saving my sanity.

Let’s start with AI – because I use it **every. single. day.** ChatGPT has basically become my lesson-planning sidekick. When I have a half-baked idea and a random collection of supplies, I can throw it all into ChatGPT and get ten scaffolded project options in less time than it would take me to Google one decent blog post. I also use it to help speed up grading. I’ll feed it the project prompt, rubric, and even a screenshot or student write-up. Does it get everything right? Not even close. It struggles with math, misreads visuals, and can’t catch nuance. But it gives me a quick draft of feedback, which I edit and refine myself. It makes the whole grading process faster – not lazier. I’m still looking at every project, I just don’t have to start from scratch each time.

More importantly, I teach my students to use AI, too. Not to cheat – but to think. When they’re modeling in Fusion or trying to design something specific and don’t even know where to begin, ChatGPT can walk them through it step by step. It doesn’t replace trial and error, but it helps them get unstuck, which is often the hardest part. It’s become another tool in their creative toolbox – and mine.

Now, about Virtual Reality. I’ve wanted to use VR in my classroom for years. My students create 3D floor plans in civil engineering, and the software actually supports VR walk-throughs. Imagine walking through a house you designed, seeing your ideas come to life in full scale. That would be such a powerful design and reflection tool. But like a lot of dreams, it always ends up on the "when we have time" list – which, let's be real, is a very dusty list. Still, it's something I want to make happen.

Then there's data. The article brought up concerns about student privacy, and I feel this one deep in my bones. New York's Ed Law 2-d is well-intentioned – we absolutely should protect our students' information. But the rollout has been a nightmare. Programs I've used for years, ones that entire units are built around, suddenly become unusable because the company won't sign the paperwork. So the district blocks the software… and now what? I don't have hours to rewrite full curriculum units mid-year. And it's the students who lose out on tools they love and learn from.

At the end of the day, technology isn't just "something extra" in my classroom – it's embedded in how I think, teach, and connect students to real-world skills. But we need flexibility, support, and time to use it well. Because the potential is enormous – but only if we're actually allowed to access it.

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