Problems with Problems:

Improving the Design of Problem-Driven Science and Engineering Instruction

HOW CAN ENGINEERING PROBLEMS DRIVE LEARNING?

A key shift in learning designed for today's science standards is supporting students to explain phenomena and to design solutions to problems. The Framework for K–12 Science Education draws a parallel between phenomena and problems. In the Next Generation Science Standards (NGSS), **problems** are defined as "situations somebody wants to change" (NGSS Appendix I). Ideally, when problems requiring an engineering solution are used to drive learning, these problems describe real-world situations grounded in compelling contexts that students care about — such as a problem in their own life or in their community. Students are then intrinsically motivated to learn science and engineering *ideas because they want to find solution(s) to the problem.*

Although phenomena-driven approaches to science learning are becoming more widespread, there are fewer examples of problem-driven learning that align to the vision of the Framework and today's science standards.

> ***[Just as] science begins with a question about a phenomenon...engineering begins with a problem, need, or desire that suggests an engineering problem that needs to be solved.***
>
> A Framework for K–12 Science Education

Using problems to drive learning can be a powerful approach to teaching both science and engineering content. However, it's important for this learning to be grounded in situations people want to change. This is different from a task where students are challenged to design something for the sake of a competition or a construction project rather than designing a solution to a meaningful problem.

The chart on the next page helps describe some of the differences between an authentic problem and a design task that isn't connected to a real-world problem.

DESIGN FOR DESIGN'S SAKE	DESIGN FOR SOLVING PROBLEMS
Learning is Disconnected from Problems • Despite being "hands on," a contrived design project may seem irrelevant to a student, decreasing motivation. • Students do not see a connection to a meaningful problem to solve. • There is one final solution, such as the tallest tower.	**Learning is Focused on Solving Problems** • Real-world situations grounded in compelling issues that students care about (i.e., a problem in their own life or in their community). • Students clearly understand the problem and its significance to them or to others they can empathize with. • There can be multiple solutions, and each has trade-offs.* **Understanding trade-offs begins to be an expectation for students in the 6–8 grade band.*

SHIFTING TOWARD MEANINGFUL PROBLEM-DRIVEN INSTRUCTION

Build a dam out of popsicle sticks.	→ A spot in my garden floods every time it rains.
Design a pollinator out of pipe cleaners to see who can transfer the most pollen.	→ Our trees aren't producing fruit anymore.
Build the tallest structure possible out of paper and tape.	→ Children get too hot on a sunny playground.
Design a ramp to make a toy car go as quickly as possible.	→ People get hurt in car crashes when brakes fail on steep mountain roads.

WHY IS THIS APPROACH IMPORTANT FOR STUDENTS?

Designing solutions for authentic, real-world problems and explaining real-world phenomena are central features of engaging and meaningful science and engineering instruction:

- Designing solutions to problems and explaining phenomena are the focus of engineering and science, respectively, as described in the *Framework*.
- Developing science and engineering ideas through the process of solving meaningful problems helps students learn to appreciate the relevance of science and engineering to their lives and for their communities.
- Authentic and compelling problems and phenomena provide an intrinsic reason for students to want to learn, and when instruction follows what students want to learn, students develop a sense of ownership over their learning. Research indicates student motivation and engagement in science and engineering education are *necessary* to reach all students — not merely "nice to have." The National Academies report *Learning Through Citizen Science: Enhancing Opportunities by Design* states that students who are engaged are more likely to be attracted to challenges, learn more effectively, and make appropriate use of feedback. The report *Science and Engineering for Grades 6–12: Investigation and Design at the Center* shares strategies to promote student motivation, including: "(1) providing choice or autonomy in learning, (2) promoting personal relevance, (3) presenting appropriately challenging material, and (4) situating the investigations in socially and culturally appropriate contexts." Grounding instruction in phenomena and problems that are personally relevant to students and that they genuinely want to figure out and solve facilitates all four of these strategies.

HOW CAN DESIGN PROBLEMS BE USED IN INSTRUCTION?

The presence of an authentic and compelling problem in instructional materials is not enough. It also needs to be used in instruction in a way that will effectively support students' learning and motivation. The table below describes examples of what this can look like in the classroom.

USING DRIVING PROBLEMS IN INSTRUCTION DESIGNED FOR THE NGSS

…IS *LESS* LIKE	…IS *MORE* LIKE
After Learning Problems are included at the end of an instructional sequence as a way for students to apply their science learning.	**Throughout Learning** Problems are used to motivate learning throughout an instructional sequence, such that students learn through the process of designing solution(s) to the problem.
Tinkering Students can solve the problem by trial and error without developing or applying science ideas. After enough trials, students may arrive at a successful solution without a deeper understanding of the ideas underlying their solution.	**Science Ideas** To design and improve* their solutions, students need to **develop and use** DCIs, SEPs, and CCCs from both science and engineering domains. For example, students could not solve a local flooding problem without learning and using ideas about regional weather patterns and the water cycle. **Improving designs begins to be an expectation for students in the 3–5 grade band.*
Teacher-led The teacher challenges students to accomplish something. Students may have some choice in how to accomplish it, but they have little ownership of their learning or simply follow directions. The teacher may tell students what they need to learn in order to solve the problem.	**Student-led** Students observe a problem and ask questions that lead to investigations to begin working toward solutions. This process is facilitated and guided by the teacher to ensure that students stay on track toward targeted learning objectives (the parts of the three dimensions students need to develop and use to solve the problem).

ABOUT NEXTGENSCIENCE

NextGenScience, a project at WestEd, works alongside educators to transform science teaching, learning, and leadership through equitable and evidence-based approaches to reviewing classroom instructional materials, fostering meaningful partnerships, and developing system strategies for coherent science programs. Learn more about our work: ngs.wested.org

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