The STEAM-Powered Classroom

Charlie Harper

An instructional coach makes a bold case for integrating problem-based learning across the curriculum.

This article is intended to be a message of hope and a call to action for any teacher or leader who dreams of transforming learning in their school.

If I captured your attention with that opening, my next best move, pedagogically speaking, would be to follow up with a problem-based challenge rather than a lot of explanation. So here is your task: Illuminate a small (flashlight) bulb using only one D-cell battery and a single piece of insulated copper wire—and you are not allowed to cut the wire! No spoiler alert forthcoming. If you want to know if it is possible to make the bulb light up using only a single wire, you will simply have to discover the answer through experimentation.

Fun, right? But let's analyze this activity from several school-based perspectives. Students are intrigued and challenged by seemingly non-academic tasks like this that allow for exploration and discovery. If the challenge is presented as a collaborative group activity, they can verbalize their thoughts, ask questions, or make suggestions. There is no apparent right or wrong answer, which—after possibly causing initial low-level anxiety for some—emboldens them and promotes participation. They learn from the experience itself, but also from interacting and communicating with one another. And even the relatively small success of turning on a lightbulb will bolster their sense of self-efficacy.

From the teacher's perspective, the challenge is a thing of beauty because it requires students to use active inquiry, critical thinking, and problem-solving skills. The teacher can move between groups to observe, interject questions and comments, and assess. Meanwhile, students are busy constructing scientific understanding and making learning connections either individually or within their groups. This is an opportune time to scaffold a scientific lexicon by introducing advanced or technical vocabulary. You might use *illuminate* instead of light up. Refer to the wire as a *conductor* from this point on. The plastic coating *insulates*. That thin, high-resistance wire inside the bulb is called a *filament*. Students will be simultaneously handling the components, hearing the terms, and experiencing the content, so learning becomes authentic, engaging, and meaningful. And then there are the possibilities for integrating content and skills from literacy, social studies, and math (for example, informational writing to describe a process; historical research on Thomas Edison; applying simple algebraic formulas to calculate voltage, current, power, and resistance).

This simple example highlights the key tenets of STEAM (Science, Technology, Engineering, Arts, and Mathematics) programming coupled with problem-based learning. I believe it also illustrates a fundamental shift that needs to occur in curriculum and instruction—and not just in science classrooms. STEAM and problem-based learning are based on the principle of learning-by-doing, a powerful and memorable way to learn (Hackathorn et al., 2011). They are also based on the premise that humans have an innate drive to solve problems (Pink, 2009). Instead of reading about electrical circuits and memorizing vocabulary terms—or, worse, being subjected to lectures on the topic—students should be challenged to engage in the actual work. The teacher then assumes the role of a facilitator and coach, which has its own benefits.

Is this way of teaching practical or even realistic, though? That brings us to the leader's perspective, which is more complicated.

The School Leader's Dilemma

As instructional leaders, principals are charged with creating and implementing a shared vision of teaching and learning. Based on my personal experience, this has less to do with conspicuously displayed vision and mission statements than it does with trust and support. Most teachers direct their classrooms on the basis of their administrators' explicit and implicit messages about what teaching and learning are supposed to look like. Unfortunately, those messages don't always encourage novelty, innovation, or risk-taking in the classroom.

In considering the value of the kind of problem-based STEAM learning I've been describing, leaders should reflect on their own instructional philosophies by answering the following questions:

1. Is it more important for students to be able to recall information or to ask questions?
2. Do you believe students' attention must be focused on the teacher for optimal learning?
3. How would you evaluate a teacher who most often responds to students' questions with another question instead of providing answers and explanations?
4. Can teachers in your school easily access a convenient supply of materials, tools, and equipment?
5. Does your school utilize space in creative and flexible ways to expand possibilities and entice learners?

Got your answers? The next step is to consider how your school's teacher-support and evaluations systems—not to mention your own tacitly expressed expectations—can be reconfigured to encourage the kind of instruction you genuinely value and know is important. This may mean de-emphasizing qualities like control and consistency in classrooms and doing more to understand and support instructional practices that foster energy, expressiveness, and enterprise.

A Garden of Possibilities

But teachers who are interested in problem-based STEAM instruction need more than support from leaders. They also need guidance and lesson ideas. In that context, let me outline another simple example—gardening.

Numerous research studies underscore the merits and positive effects of garden-based learning (Blair, 2009; Han et al., 2015; Wirkala & Kuhn, 2011), findings that I can attest to from my own experiences. Gardening is problem-based learning by nature and highly amenable to rigorous STEAM instruction. The engineering design process is inherent in any horticultural endeavor, as are life skills and character development. Seed packages are rich with math and science content, including measurement and fractions, calendar and times, maps skills and geography, and climate and seasons. Gardening is also perfect for teaching experimental design and variables (that is, dependent, independent, control, and confounding). Indeed, garden projects provide a relevant context for many core ideas in science, including the basic needs of organisms, ecosystems and habitats, food chains and webs, physical and chemical properties and changes, classification, weathering and erosion, symbiotic relationships, cells and microorganisms, conservation, and sustainability.

And consider the possibilities for interdisciplinary links. Imagine 5th grade students growing their own Victory Garden at school while studying WWII in social studies, plant classification in science, ratios in math, and persuasive writing in language arts. Learning standards from every subject and any grade level can be easily applied to create an integrated learning unit. From raised beds to square foot gardening, aquaponics to aeroponics, horticulture offers creative and innovative projects that incorporate every tier of Bloom's Taxonomy.

Everyday Problems

The key is to start with common, everyday problems for which solutions already exist and that will interest students and offer multiple discoveries and learning opportunities. (See sidebar for additional lesson ideas.) Often educators will start with their content standards, but then struggle to find engaging activities that directly relate to what they must teach. I prefer a backward-design approach—start with any essential question that relates to a problem or project, view it through an interdisciplinary lens, and then connect as many relevant standards as possible.

Here again, school leaders can be instrumental in removing the barriers that prevent teachers from fully embracing innovative instructional models. One such barrier is a rigid curriculum scope and sequence. Curriculum maps and pacing guidelines are useful in some circumstances, but they can inadvertently restrict opportunities for integrating inventive projects and ultimately limit teachers' creative potential. Similarly, regimented benchmark assessments that dictate that certain learning units be taught within specific time frames can create pressure on teachers to use direct, teacher-centered instruction and address subject areas in isolation. Flexibility is foundational to instructional success in STEAM-focused, problem-based learning.

Another common obstacle is a lack of resources and materials, and I'm obviously not referring to textbooks and worksheets. If possible, leaders should budget for appropriate supplies and materials, but schools can also make a coordinated effort to collect and organize a range of household disposables that can be repurposed for projects. Plastic water bottles, egg cartons, bottle caps, paper towel or toilet paper tubes, bubble wrap, glass jars—all of these can be useful. If budgeting doesn't allow for tools and equipment, parents and local business partners are usually enthusiastic to donate hand tools, safety glasses, work gloves, and even power tools such as drills and saws. Creating room for a makerspace or innovation lab—or even just encouragement for teachers to do so—can also be helpful.

Teachers should be given opportunities to attend educational conferences and visit nearby STEAM-focused schools. It may not be feasible to send entire faculties, but selected individuals can host teacher workshops to share what they learned. Most of the ideas I share as an instructional coach, including the ones in this article, were learned through taking regional professional learning courses, attending state and national conferences, visiting established STEM/STEAM programs and schools, and reading content-specific periodicals.

Cultivating an Inventive Spirit

The possibilities of STEAM and problem-based learning are limited only by our fixed mindsets and restrained imaginations. Schools must cultivate an inventive spirit that invites risks and welcomes failures—and learns from both.

Although the projects I've highlighted may seem unconventional, STEAM and problem-based learning together represent a pragmatic approach to school improvement, offering the potential for academic gains, collaborative and social-skills development, enhanced communication, and increased family engagement. I can attest from my own experiences that the benefits are substantial, but they can only be realized by courageous educators who not only dream of transforming learning in their schools but also are intrigued by and embrace the challenge of change.

EL Online

For a discussion of other STEM projects, see the online article "Problem Solving in Education: A Global Imperative" by Dennis Shirley and Pak Tee Ng.

STEAM-PBL Lesson Ideas

These simple hands-on activities can offer rich interdisciplinary learning opportunities for elementary and middle grade students.

- Use the engineering design process to design and construct a gingerbread house. (Instead of a traditional holiday craft, this can become a fully integrated STEAM unit.)
- Design and build bird houses, feeders or a bird reserve, observatory, or aviary. The Great Backyard Bird count is another way to encourage scientific citizenship.

- Construct a lasting work of environmental art that provides ongoing learning experiences, such as a terrarium, bog, or bat house.
- Use cinematography, graphic design, or web design to create a public service announcement or run a public awareness campaign addressing a current issue.
- Plan and prepare a single meal that meets predetermined criteria (drawing from specific learning standards) and stays within a given budget.
- Submit a field trip proposal and plan every aspect of the trip, from transportation and admission costs to parent permission slips.
- Build a first aid or supply kit for a Civil War soldier based on the technology of that time.
- Watch the inspiring video "Caine's Arcade" and then have students design and create their own games for a school arcade.

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