Building Students' Sense

Practices inspired by the maker movement can build students' sensitivity to design—and empower them to design and redesign things themselves.

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Where does problem solving start? The ready answer is that it starts with a problem. And much of the time this is true: From potholes to pollution, the world's challenges often insistently make themselves known. But sometimes problems aren't so obvious. Researchers who study problem solving have pointed out that good problem solvers are often good problem finders: They see the world in terms of problems to be fixed and find opportunities for solutions where others may not.[1]

Problem finding is important, but it's possible to go back even further in the search for the roots of problem solving. Regardless of whether a problem is obvious or hidden, the impetus to engage with it starts with a sense of agency—a sense that it's possible to reshape the way things are by directing one's actions purposefully. This may seem so basic as to not be worth mentioning. But if educators want to cultivate problem solving at the foundational level, it's important to ask how this sense of agency develops. Over the last five years, we and our colleagues at Project Zero[2] have had

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the opportunity to take a fresh look at this question through our work on a research project called Agency *by* Design.

Problem Solving in the Making

Has a makerspace recently opened up in your district or maybe even in your school? Is there a librarian in your school hankering for a 3–D printer? Do people keep telling you about this thing called design thinking?

For more than a decade, the maker movement—loosely defined by an interest in making, tinkering, and hacking, often centered around collaborative environments that combine various tools and technologies—has captured the imaginations of people across the United States and other countries. More recently, there's been a growing interest in incorporating the practices and ethos of the maker movement into educational settings. This interest in bringing the world of making into the classroom—which we call maker-centered learning—has been the focus of Agency *by* Design.[3] Since 2012, our team has explored the promises, practices, and pedagogies of maker-centered learning. We have visited scores of makerspaces and classrooms across the United States and Canada, interviewed teachers and thought leaders, and worked closely with cohorts of teachers in the San Francisco Bay Area and the Pittsburgh region.

A key question we bring to this work is: What are the student outcomes of maker-centered learning that educators—and students—value most? One of the most consistent answers we hear is that maker-centered learning helps young people develop an "I-can-do-that" spirit. If this sounds like a sense of agency, that's because it is. But it's a very particular type of agency viewed through a very particular lens—a maker lens. Our team has come to understand that one of the primary goals of maker educators is to cultivate young people's sense of maker empowerment, which we define as the inclination and capacity to shape one's world through building, tinkering, redesigning, and hacking.

Problem solving plays a role in maker empowerment because one reason people make things is to build solutions to problems. But makers make for other reasons as well, such as the pleasure of working with one's hands, an interest in learning new skills, the urge to invent, a proclivity for tinkering, or a desire to be part of an interdisciplinary community. Maker empowerment develops not only as a result of being able to find and solve problems, but also—and more fundamentally—by developing a sensitivity to the designed dimensions of the world. Young people who feel maker-empowered tend to see the objects and systems around them as designs, things, and processes that have parts and purposes and mechanisms that can be tweaked or hacked or re-envisioned. This suggests an interesting starting place for cultivating a maker-centered sense of agency: Begin by encouraging students to notice and explore the designed world around them.

Cultivating Sensitivity to Design

Our team has taken this challenge to heart: Through our work with teachers, we've developed several tools and strategies for cultivating students' sensitivity to design. Perhaps the most popular strategy is a thinking routine called *Parts, Purposes, Complexities*. As Figure 1 shows, this thinking routine asks young people to look closely at an object and address three questions: What are its parts? What are its purposes? What are its complexities? The strategy can be used across all grade levels on virtually any human-made object.

The best way to get a feel for how it works is to run a quick mental simulation yourself. Right now, look around you and choose any readily visible object—a notebook, pen, cell phone, the chair you're sitting on, or even your shoes. Begin by making a mental list of the object's parts. For example, if your object is a chair, you might notice features such as legs, a seat, and a back. Maybe you notice the materials it's made of and the way its joints are fastened. See if you can notice at least six features.

Now ask yourself about the purposes of the parts you noticed: How do they contribute to the overall design of the object? To continue with the example of a chair, maybe you notice its legs have horizontal bars between them to provide structural support. Maybe the back of the chair is curved to provide comfort—or straight to encourage the sitter to sit upright. As you explore the relationship between parts and purposes, you may begin to notice ways in which the object is complex. For instance, it may be structurally complex in the way its various parts fit together. It may be complex in how it was produced, how it was acquired, or the intentions with which it was designed. Just consider the complexity of ideas—such as that sitting up and facing ahead is the ideal posture for learning—behind the design of a straight-backed classroom chair!

Students at every grade level have used this strategy to look closely at a wide variety of objects—an eggbeater, a tortilla press, a simple screw, a painting, a cell phone app, an apple pie, a teddy bear, and a toll booth, to name a few. Sometimes students use this thinking routine on their own, but teachers tend to ask students to work in pairs or small groups, and to document their thinking as they go along. For example, as part of a unit on simple machines, one teacher we worked with had his 2nd graders work in pairs to use the routine on a handheld eggbeater—an object that invites close inspection and incorporates the movements of several simple machines.

A teacher who was doing a unit on the U.S. Civil Rights movement of the 1960s had his class use the routine to explore this movement as a system, encouraging students to identify various parts of the movement, the purposes and interactions of those parts, and the ways the movement was systemically complex.

When students learn to explore objects and systems in this way, it helps them become motivated to design something themselves—or redesign something in a better way. We've seen middle school students use the Parts, Purposes, Complexities thinking routine to design stools and other furniture for their primary school peers. Other students have used it to thoughtfully design shower hooks for men in their community's homeless shelter or to suggest new designs for their school's fire drill system.

FIGURE 1. Parts, Purposes, Complexities

Choose an object or system and ask:

What are its **parts**?
What are its various pieces or components?

What are its **purposes**?
What are the purposes for each of these parts?

What are its **complexities**?
How is it complicated in its parts and purposes, the relationship between the two, or in other ways

Source: The *Parts, Purposes, Complexities* thinking routine developed for exploring the design of objects by the Agency *by* Design project.

The Design of Systems: Parts, People, Interactions

The *Parts, Purposes, Complexities* thinking routine cultivates students' sensitivity to design because it offers an accessible strategy for uncovering and examining the design of human-made *objects*. But objects play a role in larger *systems*, and systems can also be viewed as designs to the extent that they're composed of interacting parts that contribute to a function or activity larger than the individual parts themselves. Our team developed another thinking routine, *Parts, People, Interactions* (shown in Figure 2), specifically to explore the design of complex systems.

To get a feel for how this routine works, take the example of a chair again. Although a chair in itself can be understood as a

FIGURE 2. Parts, People, Interactions

Identify a system and ask:

What are the **parts** of the system?

Who are the **people** connected to the system?

How do the people in the system **interact** with each other and with the parts of the system?

How does a change in one element of the system **affect** the various parts and people connected to the system?

Source: The *Parts, People, Interactions* thinking routine developed for exploring the design of objects by the Agency *by* Design project.

PHOTO BY KEVIN DAVIS

system composed of many subsystems, it can also be situated within many greater systems. For example, there are chairs—or seats that function as chairs—in classrooms, cars, Ferris wheels, and parks, and on bicycles and airplanes. When placed in one of these contexts, a chair becomes part of a greater system—which itself is made up of many other parts. If we take the example of an airplane, we can begin using the Parts, People, Interactions thinking routine by considering a host of other parts in the greater airplane system. There are chairs—or seats—where passengers sit, but there are also many other parts to this system: restrooms, emergency exit rows, food and beverage carts, safety equipment, navigation equipment—the list can go on and on.

Once we have enumerated the various parts of a system, we can list the various people associated with that system. Within the system of an airplane, there are passengers, flight attendants, the pilot, and copilot—but there are also the ground crew, cleaning crew, booking agents, TSA authorities, and various other people connected to the system. Each of these groups of individuals has different needs and interests, and there is further variation within groups. Although there may be shared needs and interests among different people associated with the airline system—the passengers and flight attendants, for example—there are also competing demands within and across these stakeholder groups. We can consider how these different individuals interact with one another as people and how they interact with different parts of the airplane system.

Problem Solving and "Maker Capacities"

Cognitive strategies like these thinking routines facilitate problem solving because they help students uncover the design-like workings of objects and systems. In so doing, students come to see these objects' malleability. But the strategies work not only by revealing complexity, but also by encouraging certain patterns of thinking that are especially well suited to exploring and interrogating design. From the perspective of the Agency *by* Design

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PHOTO BY BRAD GENTILE

Students at Propel McKeesport School in Pittsburgh document the parts, purposes, and complexities of their balloon car prototypes.

project, we refer to these patterns of thinking as maker capacities.

The Agency *by* Design framework focuses on three capacities in particular: looking closely, exploring complexity, and finding opportunity. Looking closely refers to the capacity to slow down to carefully notice the details and multiple dimensions of an object or system; exploring complexity refers to the capacity to understand how the various parts of an object or system interact with one another to bring about a greater effect; and finding opportunity refers to the ability to see the potential to change a given object or system. Looking closely and exploring complexity aren't typically foregrounded in traditional problem-solving approaches, which tend to be solution-oriented rather than exploratory. But the very fact that these capacities encourage students to press pause on solution-mindedness is what gives them their power: They give learners a structure for exploring human-made objects and systems as the products of human agency, opening their minds to the possibility that objects and systems that have been designed by others can be reimagined and redesigned.

So Where Does Problem Solving Start?

From the perspective of the Agency *by* Design project, problem solving starts with having a sense of agency and seeing the world as malleable. The maker movement is a promising place to look for inspiration about how to cultivate students' sense of agency because maker-centered learning foregrounds a strongly agency-focused student outcome, what we've termed *maker empowerment*. Strengthening students' capacity to look closely at an object or system, explore its complexity, and find opportunities to improve it helps build that empowerment. Seeing the designed world as malleable positions students to feel empowered as makers who are capable of re-envisioning and reinventing that designed world. All this connects to problem solving because one way of proactively engaging with design is to identify design-based problems that invite solving.

We believe situating problem solving in the larger enterprise of cultivating students' sense of agency is a good thing. The goal of teaching young people to be problem solvers isn't only to get them to solve particular problems—it's broader and more dispositional than that. We want students to develop a sense of "I can do that" so they will have the confidence to believe they can change their worlds. EL

[1]For example, see Getzels, J. W., & Csikszentmihalyi, M. (1976). *The creative vision: A longitudinal study of problem finding in art*. New York: John Wiley & Sons; or Runco, M. A. (Ed.) (1994). *Problem finding, problem solving, and creativity*. New Jersey: Ablex.

[2]Project Zero is a research center at the Harvard Graduate School of Education that investigates the nature of intelligence, understanding, thinking, creativity, cross-disciplinary and cross-cultural thinking, ethics, and learning in and through the arts.

[3]Clapp, E. P., Ross, J., Ryan, J. O., & Tishman, S. (2016). *Maker-centered learning: Empowering young people to shape their worlds*. San Francisco, CA: Jossey-Bass.

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