The Powerful Ideas of Making: Building Beyond the Curriculum

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Abstract

In this paper, rather than consider how fabrication technologies and maker activities can be directly matched to existing standards or allow for more efficient content coverage, I position making as a network of powerful ideas and perspectives that are highly connected to other ideas, personal and syntonic to the learner, and are immediately useful for solving problems of personal importance. Furthermore, I argue that creating learning environments where learners encounter and take ownership of these powerful ideas requires instructors, coaches, administrators, and designers that are committed to creating space for the learner to make meaningful choices, to tinker and explore, and to collaborate. Bots for Tots, a project that engages children in making toys for members of their community, is briefly described to highlight the affordances and challenges of implementing design features that focus on engaging learners with powerful ideas.

Keywords

Constructionism, making, fabrication, powerful ideas, design

The Powerful Ideas of Making: Building Beyond the Curriculum

While the “maker movement” has existed for a decade since the first Maker Faire in 2006, bringing digital fabrication and construction in the form of maker spaces and fabrication labs to schools and into the classroom is a relatively new phenomenon. As scholars, educators, and funders begin to explore the potential, and push for the inclusion of making in the formal education experience, there is a question of the value of these activities. Will the use of high tech equipment such as 3D printers, laser engravers, and microcontrollers improve students’ understanding of content traditionally taught in science and math classrooms? Will these activities lead to a greater interest in STEM related field and the acquisition of “21st century skills?” Or are these “making” activities simply about engagement?

In the current measurement-centric culture of education, the teaching profession too often becomes an exercise of checking off boxes from a list of standards or curriculum. Enthusiastic teachers and administrators may be willing to try something new, but the complex system of national and state standards, assessments, discrete content domains, bell schedules, funding policies, etc., ensures an equilibrium centered on content coverage. While learners engaged in making and construction will likely encounter school sanctioned content or could acquire desirable skills, a tally of marked checkboxes is a poor measure of the value of these activities.

Making and construction is not about becoming proficient with a 3D printer, learning how to calculate resistance, or even about so-called “21st century skills.” Making is about powerful ideas (Papert, 1980). Making is a literacy—a way of reading the world as a collection of resources and materials to be composed, repurposed, and rearranged. Making is “what if?” and “why not?”—of taking responsibility for challenges and obstacles faced by oneself and one’s community and enacting solutions. In this paper I will reposition making as a network of powerful ideas and perspectives that enable action, rather than a set of activities and technologies. I will then describe three features of powerful ideas, aligning each to practices and mindsets common in maker spaces and fabrication labs. Finally, I will provide a set of recommendations for designing contexts and activities that put students in contact with these powerful ideas and illustrate these recommendations by describing the Bots for Tots project.

Powerful Ideas

When we see a list of content to be covered or standards to enact it's easy to assume each carries the same weight and value. And yet, in reality, some ideas on these lists are more important than others. Some ideas are simply more powerful—they provide insight into a large variety of other concepts or theories, they're more intuitive, and they're more useful! In his book, *Mindstorms: Children, Computers, and Powerful Ideas*, Papert (1980) argued that construction, and more specifically construction with digital tools and technologies, has a unique ability to bring children in connection with powerful ideas such as calculus, algorithmic thinking, and Newtonian mechanics that were previously inaccessible. But what makes an idea powerful, and why is construction an effective means of encountering these ideas? Papert (2000) suggested powerful ideas are 1) highly connected to other ideas, 2) are personal and *syntonic* to the learner, and 3) are ideas that are immediately useful for solving problems of personal importance.

Powerful ideas are central hubs in a vast network of knowledge — they are connectors that not only explain many different phenomena, but also provide an entry point into a whole host of other concepts or principles. Ideas such as the particulate nature of matter, recursion, and the attraction and repulsion of chargers are powerful because they are fundamental to our understanding of the world around us and underlie concepts and principles in a variety of domains. Powerful ideas are about diversity and growth — about opening one's eyes up to new ideas, explanations, experiences, and perspectives. Papert (1980) argued that powerful ideas themselves are the most powerful of powerful ideas (p. 76)!

Because powerful ideas exist in a network of knowledge, rather than a list of checkboxes (Blikstein, 2012), the notions of “subject” or “domain” simply don’t apply. Construction and fabrication brings this cross-domain nature of powerful ideas to the forefront. Embedding computation in fashion with a Lilypad Arduino (Buechley, Eisenberg, Catchen, & Crockett, 2008; Kafai, Peppler, Burke, Moore, & Glosson, 2010); controlling a video game character with bananas, clay, and a Makey Makey (Davis, Kafai, Vasudevan, & Lee, 2013; Millner, 2010); programming a soccer-playing robot to score goals (Berland, 2016; Berland et al., 2103); or making a mechanical wooden roller coaster (Blikstein, 2013) each extend across traditional class subjects and engage learners with powerful ideas such as electricity flow, algorithmic thinking, the conservation of energy. Furthermore, such activities connect hobbies explored informally with topics typically reserved for the classroom and can reach across gender and cultural boundaries inherent in some materials, contexts, and domains (Buechley & Perner-Wilson, 2012; Kafai & Burke, 2014; Holbert, 2016).

Powerful ideas are personal. Powerful ideas emerge from our own tinkering and exploring rather than as a set of principles passed down from expert to novice. Complex and nuanced explanations of how we tuned voltage and resistance to automatically turn on a homemade nightlight when it’s dark, or the way in which we passed variables in code to make a video game character jump higher when running, are personal and powerful because we made them work—because they were our solutions, not pre-made programs we simply enacted. Rather than rely upon ordained “experts” to provide explanations of “how things work,” making situates the builder—whether the hobbyist, the seamstress, or the mechanic—as the expert and reveals this work to be serious, valuable, and highly connected to the formal and real practices of the scientist and engineer (Blikstein, 2013; Halverson & Sheridan, 2014). Because powerful ideas are encountered through personal construction they're more likely to connect with our daily experiences, our understanding of how our own body moves through the world, and our intuitions of how things work. This intimate, almost intuitive connection with ideas, alters their accessibility, democratizing these powerful ideas once thought to require years of formal instruction (Wilensky & Papert, 2006, 2010).

Finally, powerful ideas are about action—they are about use and productivity. Powerful ideas are powerful because they help us achieve goals that matter to us. They provide us with the cognitive tools, or physical skills to explain the world around us and to change that world to meet the needs of our communities and ourselves. The powerful ideas encountered in construction allow an incarcerated youth to design, build, and learn to play the guitar (Cavallo, Papert, & Stager, 2004), fourth graders to create math video games for tutoring younger classmates (Harel & Papert, 1990), and children in the poorest neighborhoods of Brazil to film a documentary for the community outlining the dangers and the safety concerns of illegal electrical connections (Blikstein, 2008).

Designing to Encounter Powerful Ideas

While making and construction has as its heart the acquisition and exploration of powerful ideas, creating contexts and enacting activities where the learners encounter and take ownership of these ideas requires an epistemic commitment to knowledge as a constructed thing (rather than passed down or written onto the learner) and a disposition amenable to improvisation. In other words, powerful ideas don't come for free simply because students are using a 3D printer. It takes instructors, coaches, administrators, and designers that are committed to creating space for the learner to make meaningful choices, to tinker and explore, and to collaborate.

A common mistake in designing constructionist environments or activities is to define the learning goal too narrowly. When we develop curriculum or learning goals (or even research questions) one learns to be explicit—to narrowly define a target and to articulate that target in clear and measurable terms. While certainly an important and immensely useful planning practice in most educational design, in a constructionist space, where the learner's personal interests and goals are paramount, we may not be able to fully predict the trajectory, or even the exact character of the learning that is to take place. The goal then should not be to define the specific content or precise parameters of acceptable products, but rather to clearly define the relationship between the available tools, technologies, and representations and the target interactions, experiences and ideas (Holbert & Wilensky, 2014; Kafai & Peppler, 2014). In such a space, *any* meaningful choice made by the learner over the course of the construction will result in valuable experiences and personal insight.

Similarly, activity design should allow for freedom and exploration, even at the cost of occasional stumbling blocks, "wasted time," and seemingly pointless play. In schools where time is at a premium, it is reasonable to desire a finite time of focused and "productive" work. So while a teacher or administrator may want to allow her students to use the maker space, they may also prefer the experience to be scripted and highly orchestrated. But quick and simple activities that result in highly polished products may in fact be detrimental to putting learners in contact with powerful ideas (Blikstein, 2013; Blikstein & Worsley, 2015). Construction is not a linear and one-way path. When constructing, there are many false starts, moments of musing and experimentation, times of uncertainly, and a fair amount of backtracking. But it's in the mistakes, the restarts, and the tinkering where we often have the opportunity to reflect and make sense of encountered concepts (Berland, 2016; Kapur, 2008). It's in the play and exploration where the ideas become our own.

Finally, construction is a collaborative activity (Papert, 1980). The myth of the programmer down in a basement or the maker in the garage working alone is simply not true. Making happens in communities whether they gather in a shared space or an online forum. Construction involves seeking help and providing support (Bruckman, 2000), and sharing components and code to remix existing designs (Brennan, Monroy-Hernández, & Resnick, 2010). This spirit of openness not only prompts support and collaboration, but also encourages the creation of "readable" artifacts so that they can be shared (Papert, 1980). In schools, collaboration is a tricky concept. We're ok with having students work in small groups as long as everyone "pulls their weight" and produces wholly original work. But not all aspects of a construction project require the same amount of work, and likewise, why rebuilt something your neighbor has already created? Powerful ideas aren't only found in the beginning of a project. In fact, powerful ideas are themselves a construction and may only become apparent when multiple borrowed pieces are brought together into something new.

Bots for Tots

In the previous section I argue that construction activities that put learners in contact with powerful ideas require an open design that allows for learners to make meaningful and personal choices, flexibility and space for tinkering and exploration, and opportunities to share and collaborate. In this section I briefly describe the Bots for Tots project to highlight the affordances and challenges of implementing these design features.

The Bots for Tots project tasks elementary children to design and build a "dream toy" for younger children in their community. Workshop sessions engage participants in interviewing stakeholders, brainstorming and critiquing, prototyping, and construction. In a recent implementation of the Bots for Tots project (see Holbert, 2016 for a detailed description), fourth grade students (ages 9-10) from an elementary school located in a highly urban Northeastern US city were invited to attend a free, five-day "making workshop" with the explicit goal of designing and building toys for their school's pre-kindergarten (preK) class. Participants were divided into design teams and each assigned to 2-5 preK "clients." Teams interviewed their clients, asking them to describe a dream toy—a toy that they've always wanted and imagined, whether or not such a toy exists! Fourth grade design teams were then tasked with building these dream toys over the course of the next five design sessions.

An important feature of the Bots for Tots workshop was to leave the design space open and up to the preK client and 4th grade designer. Because design teams interviewed 4-6 preK children at once, multiple "dream toys" were described. Rather than restrict toy construction to a particular genre or available equipment, participants were free to create a toy in whatever way seemed most appropriate to meet the requirements of the client. All design teams chose to find a way to integrate the many ideas into the toy design and did so in innovative ways such as merging ideas into one toy—such as Tayla and Inez's "shopkins" plane car—or creating multiple objects that worked together—as was the case in Kelly, Raquel, and Kyle's toy that included a pony doll riding a skateboard. Furthermore, designs utilized diverse materials and technologies including laser cut acrylic, sewn fabrics, repurposed toy parts, sensors, speaker devices, and other electronic components. While this variety of materials and participant designs adds complexity to the planning and implementation of a maker workshop it allowed participants to gain experience and expertise with ideas and practices personally relevant to their goals. So for example, while Tayla, Inez, and Juan gained valuable experience drafting and measuring components that would eventually be cut on the laser cutter, Kelly, Raquel, and Kyle wrestled with ratios and patterns while planning the design of a doll and its clothes.

Likewise, the design process and construction activities were not a linear process. Participants engaged in extensive brainstorming sessions to consider ways of merging proposed dream toys and to share ideas between projects. Paper and craft prototypes varied widely both between groups as well as between members of the same group. In some cases, participants even began constructing a toy only to discover a day or two into the process that their design had fatal flaws! While the large number of abandoned designs and false starts could be perceived as lost time and resources, these prototyping and debugging phases foreground necessary design considerations—such as the importance of units when engaging in measurement—and highlight the large space of design possibilities.

Finally, participants in the Bots for Tots workshop frequently shared and critiqued toy designs. As one group worked on a combination plane and car toy another group decided that they too should include a car component to satisfy their preK client. However, rather than simply copy this idea they converted the car to a skateboard to be used with their in-construction doll. Groups also offered advice and suggestions for one another's designs. For example, one team suggested they needed to build a toy that combined a car and a plane. When discussing which materials to use when making the wings and wheels, a participant from another team suggested something "squishy" so that the toy would be more pleasant to hold. Another designer quickly spoke up stating, "I disagree that the wings should be squishy! isn't it an airplane and is supposed to fly? So how's it going to fly if the wings are squishy!" This atmosphere of collaboration encouraged participants to continually improve of their own designs as well as to be invested in the work and designs of their colleagues resulting in not only shared ideas, but also shared expertise.

Conclusion

In this paper I have argued for a renewed focus on powerful ideas rather than to use making and construction to simply motivate typical classroom activity or to deliver standardized content and skills. The value of the maker movement isn't in learning to use a 3D printer or gaining ambiguous 21st century skills. Rather it's an opportunity to create learning experiences that allow for meaningful choices, provide space for tinkering and exploration, and engage learners in productive collaboration.

The maker movement has been an exciting reinvigoration of Papert's constructionist call to action. The grassroots enthusiasm for fixing, improving, and repurposing existing objects offers an opportunity to connect people of varying education, background, economic status to powerful ideas that were previously only attainable to the "priestly few" (Wilensky & Papert, 2010). Bringing digital fabrication and making to classrooms and schools provides the necessary infrastructure for empowering the learner to take control of his or her education. Putting construction in the center of the curriculum isn't about throwing away the checklists, or neglecting the standards. Rather construction and making allows us to infuse those lists with personal stories and histories, with meaning and communal values, and ideas that have the power change the world around us.

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