From Unblackboxing to Deblackboxing

What to Unbox

Questions about what to make visible in computational making

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This paper draws on critical perspectives and a specific design case of learning in making with physical computing cards to argue that unblackboxing as a design goal must go beyond technical or computational aspects of computational making. Taking a justice-oriented stance on computing education, we review earlier perspectives on unblackboxing in computing education and their limitations to support equitable learning for young people. As a provocation and practical guide for designers and educators, we propose the idea of deblackboxing, and outline a set of prompts, organized into four areas, or layers – *disciplinary knowledge and practice, externalities, histories*, and *possible futures*. Tools and materials designed through the lens of deblackboxing could provide new possibilities for interaction, production, and pedagogy in makerspaces. We demonstrate how these might be applied in the design of a set of creative physical computing materials used with youth in a weeklong summer workshop.

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1 INTRODUCTION: REVISITING UNBLACKBOXING

This paper draws on critical scholarship to revisit a familiar topic – *unblackboxing*. Designing tools and materials that help young people understand and modify normally "black boxed" objects and processes has been a long-time goal of constructionist learning and making, yet we argue that unblackboxing as a design goal must go beyond technical or computational aspects of computational making. We hypothesize that if young people are able to see and interrogate the multiple systems – social, material *and* computational – upon which powerful tools often found in makerspaces rely, they may gain a greater sense of possibility – a sense that they can modify the tools *and* cultures of computing to better fit their own purposes, values and identities.

We propose the tactic of *deblackboxing*, along with four areas, or *layers*, that designers and educators might consider to better address affective and systematic, not just conceptual, challenges that young people, particularly young women and young people of color, face in pursuing STEM and computing learning. These include *disciplinary knowledge & practice*, the focus of most current efforts to unblackbox technology, as well as three less common areas: *externalities*, *histories & purposes*, and *possible futures*. We then describe common design strategies for making things visible. To further demonstrate possible directions, we briefly describe an early-stage project that engages young people in creative, narrative-driven physical computing projects.

Our proposal is primarily about what is in the background of making – ideas and directions that *can* be taken up, but do not demand it. What would design deliberation of young designers look like if tools and materials were labeled with the name of the person who made or invented it, or how much CO_2 was used in production, rather than voltage amount or company name? How might conversations shift if programming environments first displayed the native language of their developer(s) or displayed funding sources or licensing status. What choices, discussion, and reflections would young designers engage with in processes of making? What values and identities would they display in their products? Not all of these would make tools more interesting or easier to use, yet in unblackboxing, designing computational tools always requires balancing conceptual power, creative power, and flexibility [5,46].

Makerspaces are evolving as they leverage technological innovations from other fields and open up new possibilities. Pedagogies and theories of learning in making are also evolving, yet inequities in computing and STEM fields persist and makerspaces can do more to become truly inclusive spaces that support equitable, not just more accessible, learning. Critiques of tools have highlighted ways that many computational tools embed values that may be in tension and identities of young designers [8,34,41]. creating an ideological gap that can contribute to a motivation and identification gap. Though just one piece of a larger puzzle, this gap is important to close if makerspaces resolve to become places for equitable and transformative learning. To help designers and educators in makerspaces close that gap, we hope to contribute to a vocabulary with which the maker community can articulate and design for values of transformative and justice-centered learning.

1.1 Black boxes

Computational black boxes are useful and powerful – in our everyday lives and in makerspaces. They make it easy for people with very little knowledge of computer science (CS) to engage sophisticated computational systems: from quickly finding learning resources online, to accessing and filtering huge data sets, to building mechatronic pets, to collaborating virtually with teachers, friends and family. In building computational technologies, designers make it possible to do something new. The actions a designer intends a user to do are made easy and intuitive – visible. In service of seamless user experiences, technological blackboxes obscure electronic and computational processes of input, transmission, querying, interpretation, filtering, and more. They also hide social, political and materials processes. Many of these processes link our engagement with technology to histories, values and economic systems that pose a danger to our planet, promote epistemological homogeneity, and perpetuate inequality. Also hidden from the user is what the designer does *not* want them to do, did not think of them doing, or was not paid to help them do.

As such, blackboxed tools can pose problems for young people trying to learn and become in makerspaces. Resnick and colleagues [45] observed that opaque circuit boards inside contemporary devices hinder investigation of how they work, hide decisions and trade-offs designers made, and lead to "bland" tools that fail to create a sense of connection and ownership for learners. The unspoken norms and values baked into the tools through their logics and aesthetics also reflect assumptions about imagined uses and display cultural narratives about who is meant to use these tools [33,41].

1.2 Unblackboxing

In response to these critiques, designers have for decades been working to create educational technologies and experiences that help “unblackbox” computation. To *unblackbox* is to make a tool or phenomena - often technological or scientific - more transparent. The goal is to make visible how something works, and ultimately to increase learner or consumer knowledge and agency. On strategy for doing this involves developing reconfigurable, easy-to-use, and often open-source components, such as consumer-friendly boards, like the Cricket or Micro:Bit, and materials with creative potential, such as e-textiles, and using them to engage novices in the creation of their own computational artifacts and tools. Another strategy involves creating tools, such as Scratch and Snap, in which underlying processes are more visible and legible to novices. These strategies contribute to an ethos of do-it-yourself, knowledge sharing, and openness that is common in makerspaces.

In addition to supporting comprehension and inquiry into computational functions and code, unblackboxing technology can increase motivation, inspire a personal connection to tools and domains, and foster critical and interdisciplinary approaches to computation [45]. Unblackboxing also has the potential to make computational participation more equitable by making learning about computational concepts and practices more accessible to young people and second and by opening new purposes for computing. Unblackboxing efforts focused on technical aspects of computing have the potential to reveal the world as designed, and therefore designable. This realization can help young people see the relevance and potential power computational tools. Yet progress on diversity and equity in making – and education more generally – has been uneven and more needs to be done.

Embedded in the metaphor of unblackboxing is an implicit belief in the sophistication and inscrutability of technology, and a belief that disciplinary knowledge is the greatest conceptual challenge. Unblackboxing as a design tactic for fostering equitable learning is based on the idea that the difficulty and opacity of computer science are the central barriers to greater participation. However, inequity does not arise from, and cannot be solely addressed within, the conceptual domain [1,32,44,55,56]. Marginalization, not underrepresentation, is the fundamental problem – a result of historical actions and hierarchies that have deliberately privileged White male power. The need to address the cultures of computing becomes ever more urgent as our reliance on blackboxes in commercial, political life and educational increases. It is no surprise that with increased ubiquity, computational tools reflect, not remedy, the inequities, biases, and injustices that structure the societies from which they arise.

Technical complexity alone is not suppressing the participation of young women and BIPOC youth in STEM spaces and pathways. Computing’s social and historical baggage also contribute. The “ideological distance” between young people with these tools in their hands and the initial contexts of development can actively constrain to what uses young people put these tools and who they feel the tools’ intended users are [51,54]. Focusing on unblackboxing only the concepts of computational tools fails to decrease this distance and encourages a view of achievement based around individual ability and economic gain. To achieve equity goals, business-as-usual of makerspaces could bring into clearer focus the social, economic and environmental systems that make computing possible, and which present real barriers to participation [22,50]. Though pedagogical approaches for doing this in making programs and spaces are well underway [10,11,23,53], we believe those efforts will be aided by more clearly articulating design goals that can inform design of the tools taken up educators and learners.

2 DEBLACKBOXING

While we believe the concept of unblackboxing is a powerful one for designing hands-on, expressive engagement in making, it needs to help young people look under the hood of computational devices *and* computing as a field – a set of histories, relationships, and human systems. This view returns to the foundations of unblackoxing as a critique of social systems [19,38] and aligns with continued constructionist programs that aim to position young people as critics, producers and civic participants [48,49].

Borrowing a lens from critical pedagogies, we propose reframing unblackboxing as *de*blackboxing, bringing in the notion that a primary goal should be to *desettle* [4] technology – to challenge normative assumptions about who, what and why computation works as it does – not just make it more understandable. Just as Resnick and colleagues had a vision of unblackboxing for “intensifying” a learner’s relationship with their computational instruments, design for making needs to intensify the relationship between learners, computing, and new imagined futures in and with computing. We believe this can involve the design of materials and technologies, going beyond onramps that lead young people into existing system and toward models of transformative learning in which the goal is to modify, hack, remix and re-envision how both technical and social systems can operate, and for what.

2.1 Layers of transparency

Through a lens of deblackboxing, designers think strategically about what aspects of computing and computational tools might hold the greatest power to propel a shift in young people's relation to technology, not just their knowledge of it. Yet opening a black box can be overwhelming. Like unblackboxing, deblackboxing must involve careful decisions about what will offer learners the greatest leverage, both in the immediate tasks and longer-term trajectories. As a provocation and practical guide for designers and educators, we propose a set of prompts, organized into four areas, or layers (Fig. 1). For each layer we list three key questions. Though the layers have some overlap with each other, they each highlight a dimension that we believe is critical to building understanding of computing and helping educators and learners confront existing perceptions of computing cultures – who computes, why, and what it can be used to address.

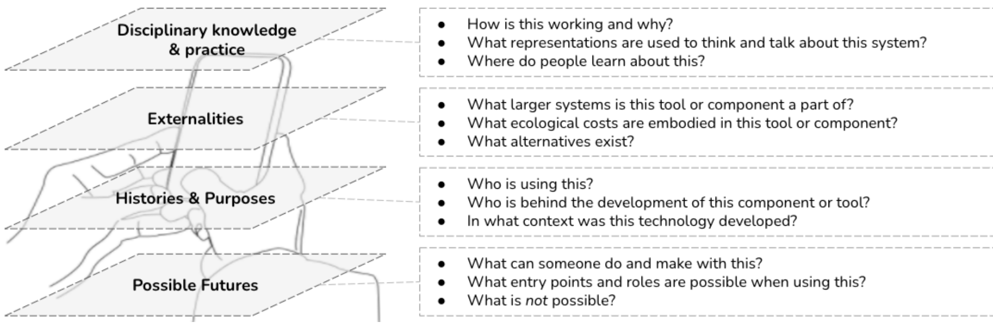

Figure 1: Deblackboxing "layers" of transparency with questions that the design of tools and materials might help answer

2.1.2 Disciplinary Knowledge & Practice

Being able to more clearly see and make sense of the technological systems through which computational devices function is important to understanding, modifying, and ultimately creating. Making visible the practices and concepts of computer science and electrical engineering has been a primary design approach of unblackboxing and remains important to building the capacity of young people. Similarly, making visible and understandable the forms of symbolic representations and manipulation that have been defined by disciplines can help people participate in continued learning, as well as share their own ideas with others, build on the work of others, and decipher where bugs and vulnerabilities might lie. What many might think of the "content" – the established curriculum of CS concepts and practices – we frame in terms of disciplinary "agency" [18,40] to foreground how expertise, built over the history of these fields, can both limit and become powerful to young people. Thinking about what kind of knowledge would give people the greatest leverage to act with computational tools, designer might try to make visible:

- **How is this working and why?** Where are "loops" and what are they doing? Where is electrical current flowing in a circuit? What is a resistor doing, and how?
- **What representations are used to communicate and think about this system?** How does this circuit you've created look in an electrician's diagram? How does the block program you've created look in text?
- **Where do people learn about this?** What department, field, or schools teach people more about this?

2.1.2 Externalities

The central role of materials and their physical properties is exemplified by the "Silicon" valley, named for the semiconductive material that made modern computing methods possible. However, where materials come from, how they are produced, and how they are distributed, have consequences for social and ecological systems. The term *externalities* is often used to refer to the economic and social costs that may be unseen to a consumer because they are born by people and places far away. Externalities often reflect regional and global inequalities, ranging from involvement with forced labor, to waste stream impacts, to privacy and civil rights concerns, to the impact of a technology on interactions and relationships. To help young people develop a critical understanding of the degree to which technologies – or components within them – might align or conflict with their values, designers might try to make visible:

- **What larger systems is this tool or component a part of?** What companies, governments, or communities are involved in these processes, and who benefits or is harmed? What data is gathered and where is it going?

- **What ecological costs are embodied in this tool or component?** Where is this metal mined from - by who and with what processes? How much energy is involved in making and running this component?
- **What alternatives exist?** What other hardware or software components could be used instead of this? What other ways to make this are there? Where is it possible to modify this component or replace it?

2.1.3 Histories & Purposes

Computing stories are often elided into singular narratives of genius innovators – often White and male. Yet progress in computing - like any field - is developed by communities that have often been led and propelled by women, people of color from around the globe, and LBGTQ engineers and scientists [43]. The work of Black and Brown innovators, of women innovators and scholars, have been made invisible and so a goal of transparency must include making their narratives, counternarratives, and contributions visible, especially toward the goal of increasing young people's sense of ownership, agency, and possibility. Through this layer, a goal of deblackboxing is to make the culture, languages, and people of computing and creating – past and present – legible in concrete and current manifestations. Another instructional design tactic is to make visible the economic, political and personal forces that influence both form and function of technologies [29,36,40]. It is important to make visible to young people that trade-offs and decisions are made to suit particular goals, and that technologies are not neutral or inevitable but the result of histories and systems that they can play a part in. To help young people see how power and people have shaped computational tools, designers might make visible:

- **Who is using this?** Where else is this component used in everyday life? To what uses has it been applied, for better or worse - in commerce, in community organizing, in policing, etc.?
- **Who is behind the development of this component or tool?** What individuals and communities helped build this tool? How did the development evolve across people and events? Who is benefitting from use of a tool or material?
- **In what context was this technology developed?** Who paid for development of the Micro:Bit and what forces – politics, economics, personalities – influenced the current version? What alternatives and trade-offs were considered?

2.1.4 Possible Futures

For people who have limited experience with the tools or materials of computational making it can be difficult to see what kind of production and action they make possible, and where it's possible to act, modify and tinker. Facilitating the ability to see the affordances of computational tools, and where to reach beyond them, is important goal to which making is well suited. Possible selves might also be made more visible by displaying the multiple roles that a particular technology might facilitate. What is *not* possible can also be important to make visible since it often reveals the purposes for which a tool was developed. For example, it may not be possible to connect two technologies, to translate language within software [52], to turn off geographic or other data tracking, or to structure narrative interaction in new ways [34]. These limitations often make visible the biases of current technologies and motivate modification and creation. To make the possibilities of a tool more evident in the tools themselves, designers might make visible:

- **What can someone do or make with this?** How can this tool be used as a part of community projects or personal interests? How can this tool facilitate new ways of relating to people? What questions might this help someone ask?
- **What entry points and roles are possible when using this?** How many different kinds of work tool are there - coding, storyboarding, documenting, circuit building, coordinating, etc.? What ways of collaborating are possible?
- **What is *not* possible?** What is difficult and impossible to do with this tool? Why not? What features have been removed over time? Where has this tool been resisted and why? How did it change in relation to resistance?

3 EXEMPLARS & DIRECTIONS

We pose these layers as *what ifs* that we do not yet have a clear vision yet but believe need to be engaged with to provoke new design directions and partnerships. The design tactics below highlight a few possible directions.

3.1 Labels, shapes & layers

Unblackboxing has often used surface features to make visible underlying computational concepts, using component names, like a "forever" block, and labels to show learners what is happening. These range from simple text, such as on the Micro:Bit, to more sophisticated efforts like augmented reality applications display where electric current is flowing (Fig. 2). For parts of a system that are untouchable, labeling honors a right to know what is happening and what users are complicit in.

Figure 2: On the back of the Micro:Bit, components, such as the processor and BLE antennae, are labeled [37]; A LightUp AR tablet app makes circuit concepts visible to learners [31]; the shape of the Bluebird microcontroller evokes new communities and possibilities [17].

This tactic can go beyond making disciplinary concepts of computing visible and can be employed to deblackbox computing in the dimensions described above, such as in when addressing issues of language diversity and bias [52]. For example, at a very basic level, instead of labeling components and what they do, designers could include what a component is made of, what its ecological footprint is, or what words for a component are used in other communities. This might be done with text (Fig. 3), as well as shape, with information integrated into the form and use of a tool, without getting in the way of intuitive and purposeful engagement.

Figure 3: Snapshot of "Product Environmental Report" for iPhone [2]; cereal box designs and county of origin labels all make visible otherwise hidden aspects of everyday products, such as what things are made of and how they are made [26]; a Girls Garage Feminist History of the Band Saw provides an example of social history embedded in technical learning environments [16].

Labeling is a familiar strategy for making visible qualities of both products and systems of production. Foods and fabrics have temporary or permanent labels that make visible what they are made of so people can make decisions about how to use them, or what health and environmental impacts might be. However, labels often also highlight social dimensions, such as what country something was made, who made it, or how it was made – information with which users can reason about who benefits, how they personally might be impacted, and what they value.

An alternative to labels are more implicit design cues or vernaculars. At the risk of descending to "pink washing," using non-conventional shapes, colors, fonts, or languages, can make visible priorities, cultures, or identities of the designers, as well as intended users. Though these may not often be thought of as "unblackboxing," we see design vernaculars as 1) making visible possible futures of computing, and 2) making visible, through their contrast to conventional designs, the cultural histories, aesthetics, and values that most often guide development of technology.

A key challenge to integrating visual information into designs is cognitive overload and time constraint. One solution may be creating layers or configurations that can be turned on or off. These options might also address the challenge of facilitating engagement in a complex space, allowing educators to foreground different dimensions in different projects. Assuming that beginner tools would not be able to include multiple deblackboxing dimensions, layers might also be used to support trajectories of increasing complexity, wherein dimensions of visibility are added as learners gain proficiency. In programming for example, learners might move from Scratch or Cricket LOGO to Arduino, or from MakeCode to JavaScript.

3.2 Attending to structure

How technologies work plays a foundational role in what becomes visible through their use. Going beyond surface features is essential to making visible and malleable the normative logics that are embedded in technological tools [42]. Block programming languages are not only easier to use for novices, but in their configuration and visual language, analogize key concepts of algorithms. They are structured to demand input and/or action in key areas, thereby bringing learners attention to ways that programs work. Microcontrollers like Arduino, Lilypad and Cricket were structured to be flexible enough to allow users to learn through constructing their own devices [7]. Data Flow software for controlling sensors and actuators highlight where and how data is transformed [6]. At the intersection of form and function, these designs show how components of a system "want" to work and fit together, and what possible roles might be taken up. Using new materials like thread and stickers, toolkits like e-textiles and paper circuits allow designers to "see" how computational systems work as they construct their own, but also make alternative futures for computing visible. Between labeling and structure are aspects of design like programming language [27] and error messages [28] that make the function of a tool more legible to novices without specialized knowledge.

3.3 Designing for emergence

A third strategy is for aspects of computing to become visible through interaction with materials. This can happen through intentional design for remixing, salvage and bricolage [35] – that is, designing for parts to be carried out of and into computational systems. This can result in surprises that surface limitations and assumptions behind technologies, and challenges that force learners to contend with important concepts [14]. Open source and craft-based systems hint at these possibilities: being able – or even required – to carry components and materials between systems can make visible what assumptions have been built into systems; combining with everyday materials can help imagine how computing might go beyond what existing developers have already designed for. Instead of designing for fluid interaction in which users look through or past the tools at hand, designers might think about where breakdown might surface particular aspects of computing [20,30]. Some existing strategies for learning in computing and making provide possible models, such as intentionally designing for – and supporting encounters with – bugs or setbacks [15,25,47].

Designs might create "seams" [13,21] where particular externalities, values or histories are hidden, and invite users to make decisions about accepting that externality or seeking other ways to accomplish the same function. Educators and designers might design for actions or tasks that intentionally bump up against those structures, such as when interrogating how narrative structures designed into [digital storytelling and game creating environments limit cultural practices of Indigenous youth [24,34]. Designing systems to include old technologies or components may prompt consideration of how computing has been shaped.

4 CASE: PHYSICAL COMPUTING CARDS

Currently we have an early-stage project that embarks on the work of deblackoxing. We are developing a kit of physical computing materials and activities for use in makerspaces, school clubs, and community-based settings. The kit is comprised of a set of paper cards that scaffold construction of analog and digital sensors using materials such as copper tape, inkjet printed circuits, brads, and paperclips. The cards are designed to work with a Circuit Playground Express (CPX) microcontroller that has onboard LEDs and can be programmed with MakeCode programming language.

Our design of the materials and activities was guided by ideas from constructionist learning, creative computational participation, and culturally responsive and sustaining pedagogy [39,49]. *Make* cards feature guide marks and instructions for assembly, as well as some disciplinary information like voltage and resistor values and symbols. Paired with each sensor card are *In the World* cards, which show students where these sensors exist in their everyday life, and *STEM Connect* cards that provide knowledge about what's happening in the circuit and code. The cards are all similar in size (¼ page) and tone to facilitate easy engagement within the flow of designing, building and instruction. Larger *Design* cards (8/5x11) feature built-in prompts.

Structurally, the cards allow learners to add layers of transparency (recognizing the oxymoron) as they add and juxtapose cards. *Make* (sensor) and *Design* cards fit physically and electronically into the CPX and can be placed directly on top of each other, embedding prompts and possible uses directly into the substrate upon which learners build. The familiarity of craft materials and extensibility of circuit and code allowing young designers to bring conductive materials (wire, keys, jewelry), scavenged electronics and other educational electronics into their projects. Like with conductive thread, this can invite in existing knowledge as well as investigation of circuit concepts. Where they are used, unfamiliar materials, like an inkjet-printed flex sensor and conductive paint, are leveraged to shift the feel of computational making to feel personal and relatable.

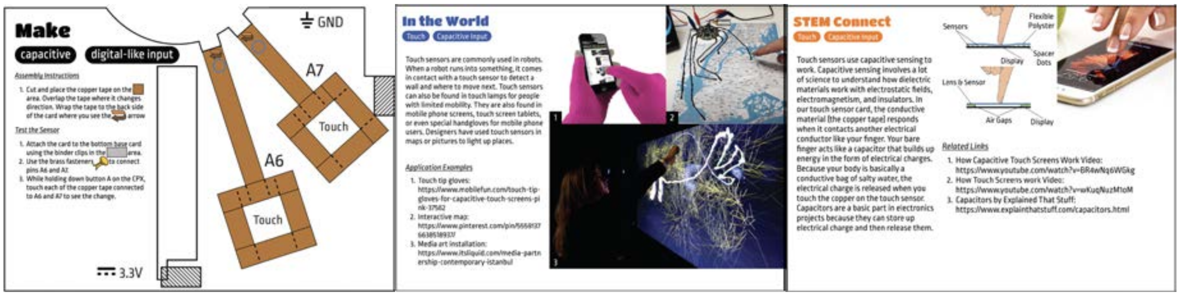

Figure 4: A capacitive touch sensor card, alongside In the World and STEM Connect cards in the physical computing kit.

With the cards, young designers learn about computing through building their own computational systems. However, the design (and default code) also leaves many processes opaque with the goal of prioritizing creative engagement and personal narratives. We attempt to balance conceptual power with creative power and flexibility, smoothing creation and investigation enough for the designers' visions to take shape, while allowing those visions to come into conflict with material challenges, default behavior of the code, and assumptions of our team and of the CPX designers. Two initial activities – the *Map* and *Messages* projects – were designed to surface stories young designers, and prompt them to think about what they want computing to do for them.

In a week-long summer workshop conducted with six young designers (three young Black men, and three young Black women, ages 11-14), we piloted a first version of the cards. In interviews, the young people in the workshop, most of whom had little previous computer science experience, talked about learning about conductivity and circuits, enjoying the copper tape (despite – or because – they also found it frustrating), and being surprised by the novel combination of materials. They also reported realizing that the everyday devices around them were made by real people, who must have really wanted to do something – a realization made when they experienced the difficulty of building both circuits and code. We found that among many of the participants, being about to "figure things out" and "actually build things" – even when that created messiness – played a role in coming to see their own capability and progress. (See [14] for longer discussion of these findings, and [39] for discussion of card design process).

Figure 5: Map project using the capacitive touch card and Message project using the potentiometer card

We also however realized some limitations of the approach: especially given the difficulty of supporting and troubleshooting virtually, challenges of circuit construction made it difficult for some of the young designers to engage in deep investigation and took time away from learning about code, a goal that several of the young designers expressed; *In the World* and *STEM Connect* cards were not used as fluidly as hoped; and although the projects inspired work that did seem personal, inquiry into power, politics or explicit perceptions of computing were limited.

We are continuing to develop the cards. Currently, we are engaged in a 4-month co-design process with two teachers who lead CS classes and extracurricular activities with primarily Black and/or Latinx students. We will be working to redesign *Make* cards with their students and communities in mind, develop additional card types to introduce histories and externalities, and hone activities and pedagogical moves to engage young designers with both critique and imagining. We are exploring the idea of creating multiple versions of the sensor cards that would foreground one dimension in an introductory project, then shift to another, taking up new versions across progressive projects.

5 CONCLUSION

As an expansion of the familiar idea of unblackboxing, we have posed *deblackboxing* as both a goal and a design tactic for designers and educators working in making. Deblackboxing encourages us to design for the transparency and visibility of a field, not just a set of technologies, and make not just *computation* more transparent, but *computing* – the social, political, and environmental infrastructure, power relations, networks, and cultural practices that shape how computational devices work, how they look, and for what. Though we write about design, our goal is not to motivate resources that *deblackbox* the dimensions outlined above, but rather that prompt and support a *process* of deblackboxing. In this view, transparency is a characteristic of the activity, not the artifact – visibility not provided *for* young people in makerspaces but produced *by* people. We have outlined questions in four areas that we believe would be fruitful to design for – *disciplinary knowledge and practice, externalities, histories, and possible futures*. We do so acknowledging the limitations of our efforts to date and recognizing that deblackboxing might not be accomplished by using one tool, or in a tool at all, but distributed across pedagogical structures and activities, social configurations, community networks, and more. Co-design, community partnership, and collective action are vital and active areas of innovation [3,9]. Similarly, recent work in equity and justice-centered pedagogies for making and computing education [32,51] share a goal of helping young people see the social systems in operation and see themselves as political actors. We focus here on design because tools and materials contribute to the conditions in which educators (as well as parents, community members and others) work. While much can be accomplished by continuing to develop the pedagogies with which we put existing tools to use, we believe that more can be accomplished if tools evolve alongside, providing new sparks of curiosity, reflection, discussion, critique, and imagination. Also missing from this discussion, but central to our aims, is the importance of making young people and what they already know visible in making and computing spaces.

Why continue to rely on this metaphor of black boxes? We see value in building deliberately from the aspirations for creative, agentive, and critical production that inspired initial conceptions of unblackboxing. We hope to sustain a critique – at the heart of early constructionism – of inscrutable systems that shape so many of our interactions and connections, without revealing their own. We also see value in providing new metaphors for makerspaces, alternatives to *making*, *producing*, *fabricating*. Unblackboxing and deblackboxing imply taking apart, seeing and critiquing. Expanding these metaphors expands what is valued in makerspaces and is an important project for the evolution of making education that is inclusive of many identities and values [12] As an action, not attribute, deblackboxing reminds us to decenter learning in makerspaces from technology and not to recenter on the individual, but rather on the relations between people and the many systems – technological and social – they inhabit. As a prompt and practice, deblackboxing invites us to pick a question, begin talking, sketching, and imagining.

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