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PERSPECTIVE

# Critical Making: Conceptual and Material Studies in Technology and Social Life

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**This article provides an overview of a series of experiments in what the author calls *critical making*, a mode of materially productive engagement that is intended to bridge the gap between creative physical and conceptual exploration. Although they share much in common with forms of design and art practice, the goal of these events is primarily focused on using material production—making things—as part of an explicit practice of concept elaboration within the social study of technology.**

**Keywords** information technology, innovation, making, social theory

The article is organized into three sections. In the first section I describe the origins of the project and its connections to similar modes of material/conceptual engagement, including critical design and constructivist pedagogies. Ultimately, while noting similarities to these modes of practice, I see the intention of critical making projects as somewhat different in its explicit mappings between scholarly research on critical social issues and design methodologies and its intention of furthering critical knowledge through joint material production. In the second section, I provide more details about critical making as a specific research and pedagogical strategy, examining its origins in a series of conference workshops that I held in Amsterdam and London. Through these empirical examples I describe some of the challenges and successes that I have had, and, in particular, the role of experience and investment in making critical knowledge relevant. In the third section, I describe more generally some of the reasons critical making provides a necessary adjunct to current and future critical research on computing technologies and lay out a tentative theoretical framework for organizing and relating its results to wider scholarly work. Finally, I end by reflecting on the connections between criticality and innovation, tentatively suggesting that these modes of engagement are more similar than have traditionally been thought.

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## ORIGINS OF CRITICAL MAKING

> "Go and look again at the roses. You will understand now that yours is unique in all the world. Then come back to say goodbye to me, and I will make you a present of a secret."
>
> The little prince went away, to look again at the roses. (Saint Exupery 1971, 86)

Studying the relationship between technologies and social life has proven to be a somewhat difficult task. On the one hand, critical social scholars have long argued that technological developments inhibit human action, "technicizing the life-world" and causing the diversity of human behaviors to be reduced to the ordered circuits and pathways of some sort of gigantic machine.(Marcuse 1941, 1964; Ellul 1964). On the other hand, other theorists have described technologies as essentially liberating, using, in particular, developments in information technology to support their arguments (Gilder 1989; Mitchell 1996). Recent scholarship in interdisciplinary fields such as science and

technology studies tends to balance these more essentialist positions, indicating the co-creation of technologies with social order (MacKenzie et al. 1985; Bijker et al. 1992; Latour 1996; Haraway 1991). However, deterministic positions maintain a strong foothold on a common-sense understanding of how technology and society is related.

This is somewhat surprising, given that our lived experiences with technologies never quite mirror the overly optimistic or pessimistic descriptions of their effects. The freedoms and the open possibilities of Web 2.0 publishing technologies seem overstated when one faces banal online entertainment news sites, or the blank screen of blog software interfaces. But then, the limitations placed on us by Adobe or Apple's digital rights management systems often do not feel quite as limiting as critical legal voices presuppose.

We might put this down to a lack of knowledge in both cases. On the one hand, our inability to feel the optimism and freedoms of the Web may be due to our lack of technical knowledge as to the workings of online content management systems. On the other hand, our lack of sensitivity to issues of digital rights may be due to our ignorance of our own legal rights and thus our ignorance of how these rights are being technically constrained. However true this might be, our sense is that this issue is related to a deeper disconnect between conceptual understandings of technological objects and our material experiences with them. In other words, it seems that when one uses technologies he or she remains aware of their nuanced relationship to society, while when one theorizes about them they seem much more "brittle" and inflexible (Ackerman 2000). I explore this issue in more detail in the last section; it is important to set this out as the main "meta" question driving our research. Briefly put, the issue I want to understand is the seeming disconnect between deterministic, conceptual understandings of the role of technology in social life, and the more material and nuanced understanding of how one relates to them. Our goal is therefore to use material forms of engagement with technologies to supplement and extend critical reflection and, in doing so, to reconnect our lived experiences with technologies to social and conceptual critique.

## Critical Making

The use of the term *critical making* to describe our work signals a desire to theoretically and pragmatically connect two modes of engagement with the world that are often held separate—critical thinking, typically understood as conceptually and linguistically based, and physical "making," goal-based material work.

A critical making project involves three stages, analytically though not functionally separable. The project may start from any of these. One stage involves the review of relevant literature and compilation of useful concepts and theories. This is mined for specific ideas that can be metaphorically "mapped" to material prototypes, and explored through fabrication. In another stage, groups of scholars, students, and/or stakeholders jointly design and build technical prototypes. Rather than being purposive or fully functional devices, prototype development is used to extend knowledge and skills in relevant technical areas as well as to provide the means for conceptual exploration. A third stage involves an iterative process of reconfiguration and conversation, and reflection begins. This process involves wrestling with the technical prototypes, exploring the various configurations and alternative possibilities, and using them to express, critique, and extend relevant concepts, theories, and models.

With its emphasis on critique and expression rather than technical sophistication and function, critical making has much in common with conceptual art and design practice, as well as recent work in the area of human-computer interaction (HCI). Relevant examples include critical design (Dunne 2005), critical technical practice (Agre 1997), and reflective practice (Sengers et al. 2005). However, critical making differs from these practices in its focus on the constructive process as the site for analysis and its explicit connections to specific scholarly literature. Critical making emphasizes the shared acts of making rather than the evocative object. The final prototypes are not intended to be displayed and to speak for themselves. Instead, they are considered a means to an end, and achieve value though the act of shared construction, joint conversation, and reflection. Therefore, while critical making organizes its efforts around the making of material objects, devices themselves are not the ultimate goal. Instead, through the sharing of results and an ongoing critical analysis of materials, designs, constraints, and outcomes, participants in critical making exercises together perform a practice-based engagement with pragmatic and theoretical issues. Our sense is that this method can be particularly useful around "wicked problems" (Rittel et al. 1973; Coyne 2004)—issues in which no consensus exists with regard to problem definition, let alone potential solutions. Using a shared process of making as a common space for experimentation encourages the development of a collective frame while allowing disciplinary and epistemic differences to be both highlighted and hopefully overcome.

## Critical Design

In this article, I emphasize the connection between critical reflection on social and organizational issues and provide mappings between scholarship in these areas and specific joint, hands-on prototyping projects. Critical making is thus similar to "critical design" and the other previously mentioned design strategies in its explicit focus on

transforming the imagination and opening up reflexive perspectives to designers.

However, unlike these approaches, my main goal is not to create objects that in their apprehension open new visions and possibilities for observers. Instead, while physical prototypes are constructed and shared with others, our main focus is on the act of shared construction itself as an activity and a site for enhancing and extending conceptual understandings of critical sociotechnical issues. I share aspects of this focus with researchers such as Agre (1997), Boehner (2008), DiSalvo (2008), Dourish (2001), Eisenberg and Beuchley (2008), and Sengers (2008). I therefore situate myself within the area of "design-oriented research" rather than "research-oriented design," following Fallman's (2007) distinction. The closest connection is to constructionist forms of learning in that the process of making is as important as the results.

### Constructivist and Constructionist Pedagogies

It is important to distinguish constructivism (Dewey 1938; Vygotsky 1978; Piaget 1953, 1955, 1970; Bruner 1961) from constructionism. (Papert 1980; Papert et al. 1998; Knorr-Cetina 1997) While both emphasize lived, individual, socially embedded experience as key to the learning process, constructionism[1] emphasizes the importance of actively making things. And although constructivism as pedagogy has a long tradition within the social and humanities education, constructionism has been less applied outside of the fields of math, engineering, and the sciences. Specifically, critical making draws upon three specific aspects of Papert's vision of constructionism. First, Papert incorporates the emotional dimension of learning, noting that the assimilation of new models of the world always involves endowing new understandings with a "positive, affectual tone" (Papert et al. 1998). The importance of affectual relations in meaning-making has also been emphasized in Knorr-Cetina's work (1997) on the relationship between scientists and the "epistemic objects" with which they work. For us, affect serves as a way to begin to understand the importance of personal investment in linking conceptual understandings of technology's potential and its problems to everyday experience. Second, Papert emphasizes the use of *transitional objects*—gears, computers, other physical objects—as a way of connecting the sensorimotor "body knowledge" of a learner to more abstract understandings. Here, he emphasizes that these objects do not just serve to "illustrate" concepts but act as means for projecting oneself into an abstraction. For Papert (and for us) using "computers as material" rather than as a tutor or a tool for doing other work references this role of the computer as a transitional object. Third, Papert, referencing Hawkins (1965) notes the importance of "messing about" with computers in order to overcome the "rigid style of work" typically associated with them. I concur and have organized our critical making exercises (described later) in an open way in order to allow new perspectives to emerge.

Similar to Papert's vision, my goal is to make concepts more apprehendable, to bring them in ways to the body, not only the brain, and to leverage student and researchers personal experiences to make new connections between the lived space of the body and the conceptual space of scholarly knowledge. However, I differ from traditional constructionist exercises in focusing on social concepts and scholarly work, rather than math, science, or engineering.

## EVOLUTION OF CRITICAL MAKING

> "You are not at all like my rose," he said. "As yet you are nothing. No one has tamed you, and you have tamed no one. You are like my fox when I first knew him. He was only a fox like a hundred thousand other foxes. But I have made him my friend, and now he is unique in all the world." (Saint Exupery 1971, 86–87)

### RCA/Imperial Event: Systems of Learning

Initial impetus for incorporating material production into critical analysis came from our observation of interaction design students at the Umea Institute of Design. Their methods of developing designs often involved very individual forms of exploration and its articulation through a variety of communicative objects including visual, textual, and material forms. I were struck by the ways these objects served both group and individual functions—students used them to communicate and exchange ideas with other designers, but also as a means for personal exploration and remembering. For some of these students, visual and textual forms dominated, but for others, more material prototyping served as a way of substantively (literally) extending their reflections and thoughts, rethinking previously held ideas, as well as serving as a focus for joint discussion and debate. The use of objects to enhance communication and cognition and simultaneously maintain community is well known within both the design communities and the social sciences and humanities more broadly (Hutchins 1995; Star et al. 1989), as well as in a science or engineering context (Rheinberger 1997; Knorr-Cetina 2000). However, using shared practices of making to enhance critical discussion or social research has been infrequently applied and little studied. I decided to use an invited talk for the joint Royal College of Art (RCA) and Imperial College Systems of Learning colloquium series to explore this potential.

The RCA/Imperial talk was on the debate between advocates and critics of distance learning techniques within university education. My sense was that this debate has

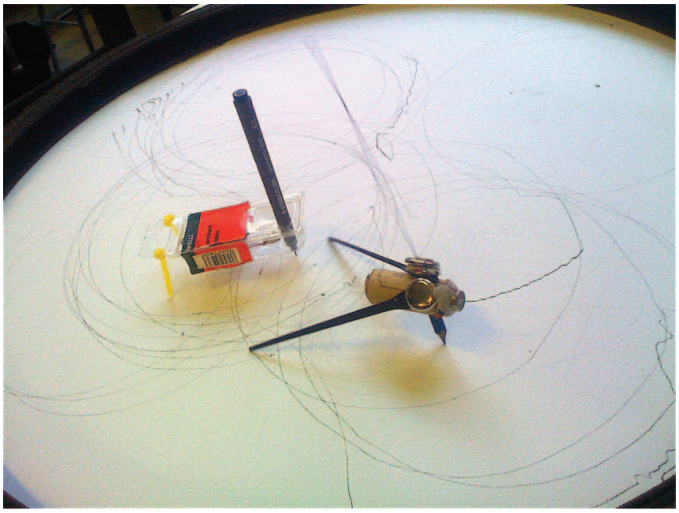

**FIG. 1.** Drawbot. Picture by Ed Burton. (Color figure available online).

stalled, with critics claiming that distance education technologies lacked the sociality of face-to-face interactions and thus turned education into a content delivery system and advocates claiming that these issues had been or would be solved by higher bandwidths, new interfaces, or other novel technological developments. Rather than attempt to prove or disprove these positions, I decided to facilitate a conversation by using a shared making experience to break the proverbial ice, generate rapport, and in general create conditions for an open and honest exchange.

I started the one-and-a-half-hour session with a brief description and overview of the debate. After some brief conversation, I helped the participants organize into teams and provided each with some small vibrating motors (typically found in pagers and cell phones), batteries, tape, glue, toothbrushes, and other craft materials. I described the general notion of a drawbot (figure 1) and "bristlebot" in particular, a type of robot that achieved its movement through the vibration of toothbrush bristles against a surface, and pointed each team toward online resources that would help them build one. After some encouragement, the participants began to construct individual machines, referring to both the online and offline resources. Periodically, over the following forty minutes I interrupted the teams to ask them to reflect on the kinds of help they were getting from digital resources, what help they received from their teammates and others in the room, and how the materials themselves informed their decisions. After they finished and showed off the results of their work, I proceeded to raise the topic of distance education and asked the participants to reflect on how their recent experience informed their judgment or perspective. A quick review of the participants found that few of them had changed their position and that the majority of them, while enjoying the experience, had trouble mapping what they had just done to the critical issues involved.

Although certainly not the success I had hoped for, the event in London served to deepen my thinking on methods of critical making. The first insight involved decisions about what was intended to be made in the constructive exercise. One hypothesis I had was that the lack of connection between the object to be made (bristlebot) and the topic under discussion (distance education) made it extremely difficult for participants to map their conceptual and their material explorations. This meant both that discussion was not facilitated and conceptual understandings were not deepened, but also that participants had trouble investing in the experience. My second and related insight was that individual investment in the object of construction was a key component in critical making. Although I am not entirely sure why, it seemed as if participants did not invest in the object of their shared work, and they had trouble mapping their personal experiences to the critical issues being addressed. These two insights formed important conditions for the creation of our next critical making session.

## Flwr Pwr, Walled Garden: Amsterdam

A conference held in Amsterdam was the site for our next experiment in critical making. I were invited by Virtueel Platform, an organization tasked by the Dutch government with facilitating crossdisciplinary discussions between media arts and design organizations, to contribute to a two-day conference on issues related to Web 2.0 developments. The main concern of the overall conference was the issue of so-called "walled gardens"—did closed Web 2.0 network applications such as Facebook constitute "free riding" and the extraction of value from the network as a whole? The idea for our contribution, what I called the "Flwr Pwr" workshop, was to create a shared construction exercise that could facilitate and inform discussions around the rise of proprietary and closed "walled gardens" on the Internet and provide some common ground for thinking through the social issues involved. More abstractly, the flwr workshop was intended to explore some of the limits of abstract notions of "network" and the ways this notion tends to presuppose discrete, homogeneous, equal agents working within a space of pure and perfect communication.

The "flwr pwr" critical making scenario involved the construction of a physical type of cellular automata. Using pre-assembled and coded components, workshop participants constructed simple electronic agents called "flwrs" that "talked" and "listened" to one another using infrared communication, and displayed the results via preset series

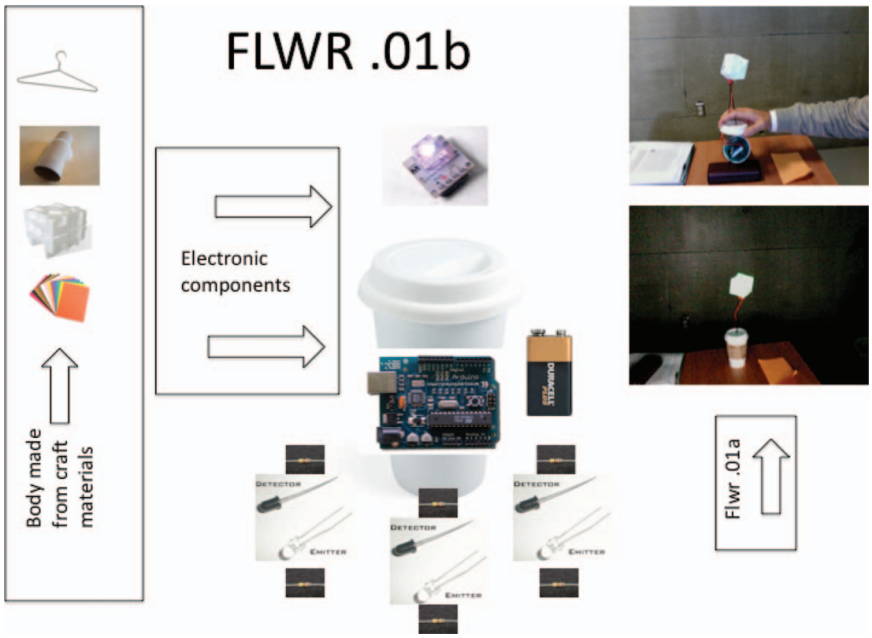


**FIG. 2.** Overview of flwr construction. (Color figure available online).

of colored, blinking lights (figure 2). Each flwr started with a unique pattern and a specific amount of "energy," a variable that decremented a certain amount each cycle. When this value reached zero the flwr "died." The flwrs had three separate modes: They could transmit their pattern, listen for other patterns, or do nothing. Transmitting cost additional energy while receiving others patterns could potentially cause the receiver to change to the new pattern and to gain energy. Each flwr could therefore be configured in various ways—to transmit more (and use more energy), or to be more open to receive others' patterns. These behaviors effected each agent's individual survival as well as the survival of the network as a whole.

The flwr toolkits were constructed using the arduino microcontroller and development environment. A simple wiring harness was made, consisting of a programmable RGB LED (red-green-blue light-emitting diode), an infrared LED, and an infrared receiver. Workshop participants could then build custom enclosures made from craft materials, insert the wiring harness and arduino, and program the resulting custom object by plugging it via USB into a laptop computer. The physicality and individualistic construction of the flwr "cell" made the resulting network different from traditional cellular automata in that communication within the network was not "pure," nor were individual agents homogeneous. As our goal was not simulation or predictability, I assumed the incommensurability of agents and imperfect communication to be a resource rather than a problem—an assumption I talk about more fully later.

The objectives of the workshop were to use the flwrs, the shared experience of making, configuring, and reconfiguring them, and the interactions I observed between them to explore the themes of the conference. Of particular interest to us was to think through some of the structural characteristics of network technologies and the possibility of individual agency and emergence within them. To cast light on these issues I adopted various concepts from critical literature on information and social organization and made metaphoric linkages between these concepts and particular configurations of the flwrs receiving and transmitting behaviors. In particular, I singled out three concepts and metaphorically "mapped" these to specific ways to configure the actions of the flwrs. These included the idea of generalized exchange and gift economies (Kollock 1999; Mauss 1990), the notion of the information commons (Benkler 2006; Hardin 1969), and a concept of information "neighborhoods" extended from the work of Jacobs (1992). For each of these, a specific code subroutine was written as a way of metaphorically operationalizing these concepts. For example, if the flwrs were configured to use the "gift economy" subroutine, all patterns received from other flwrs would cause the receiver to change to the received pattern and gain energy. If configured to use the "information commons" routine, only patterns flwrs did not currently display would count. And if "information neighborhoods" was chosen, then only patterns that had not been held for the last four times would be processed and the rest would be ignored. By changing variables in the code and including or excluding these particular

**FIG. 3.** Flwrs and participants. Photo by Annette Wolfsberger. (Color figure available online).

**FIG. 4.** Flwr and participants. Photo by Annette Wolfsberger. (Color figure available online).

subroutines, workshop participants could set up their flwrs to communicate differently.

We started the session by briefly outlining some of goals already described, in particular the idea that the building process would help us think through different social theories about networks. As I noted the different ways to configure the flwrs, I briefly described some of the social theories noted earlier and linked them to the ways the code subroutines metaphorically operationalized these theories. I were careful here to emphasize the metaphoric nature of this operationalization, stating explicitly that the code behaviors were reductive insubstantiations of the complex human activities the theories were intended to generalize. Also, I noted that the flwrs were not intended to be a simulation of social activity but instead acted as a diagrammatic representation (figure 3).

Following this brief overview, I encouraged participants to install the necessary arduino software, to familiarize themselves with the microcontroller and the provided wiring harness, and to examine the precoded flwr software. Following some discussion, the participants began to install requisite software, to play with the hardware and the flwr code, and to use available craft materials to construct their individual flwrs. Despite the differing levels of existing technical knowledge among participants, everyone seemed to quickly engage in the activity and had little difficulty constructing and coding their own individual flwr (figure 4).

In other work (Ratto & Hockema 2009) I have described more fully the outcomes of the workshop. For this article, a few aspects are most relevant. First, the deliberate linking of social theories and technical systems worked well, with the language of the various social theories providing resources for participants to describe relations they observed between flwrs. For example, I started by encouraging the participants to set their flwrs to use the "gift economy" subroutine and to try and maximize the longevity of their flwr. Predictably, many of the participants configured their flwrs to transmit very little and to spend most of the time listening for others' transmissions. Equally predictably, this rapidly caused the overall network to "die" as individual flwrs lost energy. This encouraged a conversation about the notion of "generalized exchange" and the reciprocity of the "gift," language that was quickly appropriated by the participants in describing their flwrs' behaviors. Equally, and somewhat more suprisingly, this also engendered a conversation about the dependency of the success of the flwr network on interactions that were external to it, namely, the negotiations of participants as to how much each flwr should listen and how much it should broadcast in order for it to be a "responsible" member. The moral rather than functional dimension of this and later debates among the group helped overcome doubts I held as to the reductive aspect of the theory-technology mapping (more on this later).

Similarly, I was struck by the sense of investment each participant felt for his or her flwr. Soon after building them and putting them into "dialogue" with other flwrs, participants began to call them "aggressive" or "passive" and to give them characteristic descriptions such as "grazer," "carnivore," or "immortal." Rather than see these as mistaken anthropomorphisms, our sense is that these descriptions reveal an affectual relationship to each flwr and a strong desire to understand what participants saw as their "motivations." One reason for such language was the ways

in which each flwr "pushed back" on the behaviors coded into them by participants. As noted earlier, the physicality of the agents and the ways in which they were individually crafted meant that their behaviors did not always entirely match what their creators coded—the flwrs were unique and the ways in which they communicated were not always predictable. Some flwrs, for instance, were excellent broadcasters and, given similar configurations, would quickly overwhelm and dominate all the other flwrs in the network. Others seemed shy and hesitant to accept the patterns of others. This language—dominate, shy, hesitant—was often used despite clear acknowledgment that such behaviors came from intended and unintended choices they had made in physical construction, the location of the infrared LED or receiver, or the power of the battery—emerging, as it were, from the bodies of the flwrs. In this sense, the heterogeneity of the flwrs served as a resource for relating the larger social experiences of the participants to the flwr garden. I discuss this issue in the final section.

In preparing for this event, two concerns were raised by colleagues: one, that the reductive nature of this mapping would cause participants to "technologize" the complexity of the social theories and turn them into stepwise operationalizations; or two, that the running of the flwrs would be seen as a simulation of social life and that the observed behaviors and results would be thus understood as being predictive of human social life. Our sense is that the framing and ongoing discussion about the limitations of both theory and technology and, more importantly, the material experience of engaging with those limitations help defray both risks. However, and this is more problematic, it remained (and remains) quite easy for external viewers to misunderstand either the intention of the exercise or the relevance of its results without extended commentary such as this article. What makes the flwr project understandable *is making*. Without material engagement in the project of building and configuring a flwr it is easy to view the resultant objects as an interesting (or uninteresting) illustration of technical possibilities or of social theory but ultimately limited in their ability to innovate either one. In one way this is true—neither the technologies nor the social theorizing that emerged from the flwr project could *separately* be considered novel or innovative. However, the ability of the participants to engage with the social theories presented to them and to develop and share new understandings was intimately related to the joint conceptual and materially productive work. Future critical making experiments will push this envelope further.[2]

## FUTURE POTENTIAL OF CRITICAL MAKING

> "Goodbye," said the fox. "And now here is my secret, a very simple secret: It is only with the heart that one can see rightly; what is essential is invisible to the eye."
>
> "What is essential is invisible to the eye," the little prince repeated, so that he would be sure to remember.
>
> "It is the time you have wasted for your rose that makes your rose so important."
>
> "It is the time I have wasted for my rose—" said the little prince, so that he would be sure to remember.
>
> "Men have forgotten this truth," said the fox. "But you must not forget it. You become responsible, forever, for what you have tamed. You are responsible for your rose. . ."
>
> "I am responsible for my rose," the little prince repeated, so that he would be sure to remember. (Saint Exupery 1971, 87)

In the previous sections, I have attempted to contextualize critical making as a mode of engagement. Although I have only just begun to experiment, I hope the empirical examples described here demonstrate some of the potential value of relinking conceptual and material work. Obviously, there are a number of important issues, first of which is the balancing act that must occur between technical and social scholarly expertise. Obviously, I see this issue as at least partially the result of patterns of disciplinary difference which maintain the separation of the technical from the social. Nonetheless, currently the distance between these two areas of knowledge remains vast—often even within the geography of the university campus. However, there is an important need for critical makers that can reintegrate technical and social work and thereby innovate both. One development that mitigates the difficulty of the technologies involved is open-source hardware and software and the communities of artists, designers, and engineers that provide support. Our flwr project made much use of the arduino environment and its communities, in main part because of the access to technical knowledge they facilitated. Our intention is to continue using such resources, given their potential to innovate not just who can use complex computer technologies but also how they might be used.

Let me end by explaining the quotations from de Saint Exupéry's *The Little Prince* that have preceded each section.[3] They speak to what I have detailed as an important component in critical making, namely, the role of investment in connecting lived experience to critical perspectives. The quotes tell the story of the little prince's recognition (with the help of the fox) that caring—not just in terms of feeling but also in terms of applied, responsible work—is what makes objects in his life come to have meaning for him. Caring, in the sense used in *The Little Prince*, means more than just "caring about"—it means "caring for." This distinction is one I see as exceedingly relevant for linking conceptual knowledge and our daily experience. "Caring for" seems a necessary step toward reconnecting society and technology.

In the preceding descriptions I have shown the importance of investment for the critical making exercises. I hypothesized that a lack of investment made it difficult for the participants in the London exercise to engage—in other words, to "care for" the critical matter at hand, even though their attendance at the colloquia demonstrated some "caring about" issues of distance education. It is important to note that this was due to a lack of deliberate mapping between the making assignment—building robots—and the critical issue. Participants found it difficult to link their experience of building the robots to the issues of distance education and thereby had trouble investing in either during the course of the exercise.

Conversely, investment in the Amsterdam exercise was high, in part because of the deliberate, though reductive, mapping between social theory, which gave us a conceptual grasp on the critical issue of "walled gardens," and the applied, hands-on work of building and configuring the flwrs and the flwr network. The ways that the flwrs "pushed back" and did not always do exactly what their authors intended, rather than being an issue, gave added weight to the relationship between person and technology and in some ways encouraged the "messing about" that Papert (1998) and Hawkins (1965) found so important.

Another way to consider this issue is to relate it to what Latour has called "matters of fact" versus "matters of concern" (Latour 2005). For Latour, the gap between these two "matters" lies in a false modernist distinction between the material stable relations of the natural, unreconstructed fact (over which I appear to have no control) and aspects of the world that are or should be our concern (Latour 2008). I might argue that conceptual but deterministic social theories treat technologies as "matters of fact" and therefore as a backdrop to the indeterminancy of social action. While I might "care about" their "effects," they are not properly our concern—not something I should "care for."

In recent work, Latour has used the extension of design to more and more domains to argue that people are increasingly recognizing the "designed" rather than "discovered" quality of artefacts, a recognition that reopens them:

> When things are taken has having been well or badly designed then they no longer appear as matters of fact. So as their appearance as matters of fact weakens, their place among the many matters of concern that are at issue is strengthened. (Latour 2008)

This is an aspect of our work that I would like to highlight. Ultimately, critical making is about turning the relationship between technology and society from a "matter of fact" into a "matter of concern." I see this as requiring personal investment, a "caring for" that is not typically part of either technical or social scholarly education and have tried to draw out some of the aspects of what this might both theoretically and materially require through both our experiments in critical making and the brief reflections in this article. There are two final points I want to make.

## Future Work

First, although my focus has been on how critical making can deepen conceptual understandings, I also see it as a possible venue for technical innovation. One insight I have had is that the practices and modes of engagement that are typically called "critical" and those that are equated with creativity and innovation are quite similar. This seems worthy of more deliberate analysis, given the equating of criticality to destructive and innovation to constructive work that tends to be the norm within many (but by no means all) technical environments. Obviously, this is not much of an insight, given the prevalence of the phrase "constructive criticism." Still, I hope in future work to more explicitly examine this connection at the level of practice.

Second, while I have mainly spoken about overcoming the divide between technical and social scholarly work and education, I also see much need to overcome more tenuous but by no means less restrictive divides within social science and the humanities. In the end, the divide between theories and scholars that address "enacted" relations between humans and their environment (Bruner 1961; Noe 2006; Varela et al. 1993) and scholars and theories that focus on more critical transactional and systematic societal and institutional relations (Marcuse 1964; Castells 2000; Robertson 1992) makes it extremely difficult to relate critical theory to a more individual level of daily life. This separation is in no small way due to the differing "matters of concern" between these scholars and the institutional, disciplinary contexts within which they work. Our hope is that critical making can both help reconnect the material/conceptual domains necessary to connect technical and social work, and also serve as a new trajectory for re-relating the differing dimensions of our relations to objects that are currently divided among various social science disciplines.

## NOTES

1. For a more complete bibliography to the foundational texts of constructionist approaches, see http://ocw.mit.edu/OcwWeb/Media-Arts-and-Sciences/MAS-962Spring-2003/Readings/index.htm

2. A recent university MA course developed by the author has attempted to push this envelope further, mapping specific making exercises to critical information issues such as digital rights management

and information visibility and public space. The results of this work will be detailed in future writing.

3. I thank Stephen Hockema for directing me to these quotations

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