"It's a Bomb!" – Material Literacy and Narratives of Making

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ABSTRACT
This paper analyses a series of events in which a discarded box found in a garbage room is examined and taken apart in the context of a makerspace. The participants' inquiry provided a rich and multifaceted experience in various settings, including puzzle-solving, exploring physical and digital materials, engaging people with different skills. The social engagements with and around the artifacts brought certain interpretative aspects to the fore. Situated acts of interpretation worked as ways of building a coherent narrative and a meaningful experience. In the paper, we highlight the relationship between on the one hand the subjects' skills and motivations to understand and make sense of the technology at hand which we call *material literacy*, and on the other hand the specific *material qualities* that encourage or trigger certain interpretations and experiences. The qualities we discuss are: opacity, risk, authenticity, uniqueness, age, and hybridity. This study allows us to reposition the contemporary understanding of makerspaces beyond that of being places for innovation and learning.

Author Keywords
Material literacy; Experience; Taking apart; Material qualities; Maker culture.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Vignette: *"Ok, that's enough for today". I gather my things and get ready to leave. When reaching the door, I spot two young men working in a corner of the room. They are sitting close together, talking with low voices. One of them is holding a battered plastic box. His hands are stained with oil and he is wearing a pair of worn-out jeans. I see circuit boards, cables and metal parts sticking out from the box. He is leaning over the other man's shoulder; both are staring at three computer screens with long rows of code.*

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The man standing wears a dark suit and a tie neatly in place. I walk over to see what is going on:
"What is this?" I ask. One of the men looks at me, "I opened this box and found all this: a microcontroller, cables, this fuse … and some kind of explosive material. I thought that there is something special about it. Now we are trying to extract information from the code." Another bystander suddenly clears her throat, after a second of silence she says: "Explosives? So … it's a bomb!?"
I take a step back and feel my heartbeat racing as I realize that we are all trapped in a basement.
"What – really?", I ask. The man looks at me and responds: "We don't know yet, but it's super exciting."

This event captures the essence of what evolved into an explorative journey for two members at a local makerspace. Like reading a well written crime story, this provided a rich experience with many dimensions such as solving a puzzle; handling explosives, deconstructing hardware and software, engaging people with different skillsets, tracing unknown participants and even trespassing private property. The whole experience ranged over a timespan of more than six years, but discoveries along the way led the participants back two decades in time to uncover the origins of the box.

Activities of taking technology apart and various forms of puzzle solving are common throughout the history of human-computer interaction (HCI), and the field provides several potential perspectives from which activities like this could be understood. Studies of similar engagements - maker activities in particular - have emphasized instrumental purposes and foregrounded aspects such as learning [6, 7, 33, 35], innovation [11, 21, 36, 45] and community building [2, 40, 41]. Such aspects were also present in our case, but on closer analysis it became obvious that they did not capture the essential qualities of what the activity was primarily about. Instead, it became salient that the two main participants engaged in these activities for the sake of the experience itself. Here several separate occasions and activities were tied together through the participants' interpretations of a complex mangle of things, materials, technologies, people, and situations, forming a coherent narrative. Central to the activities and to the overall experience that were formed was how the participants made sense of and interpreted the components and situations at hand. We are aware that all maker activities have experiential dimensions in their own right and do not deny any other aspects that come as effects.

The paper foregrounds the experiential dimensions of maker activities without reasoning about their purposes in the form of specific outcomes. To achieve this, our analysis focuses around the participants' processes of interpretation of the artifact, materials, code and electronics involved. This analytical approach has similarities to interpretative processes of reading, allowing us to portray the narrative aspects of the experiential efforts of the participants, putting to the fore how skills of interpretation and reading a narrative out the objects and components played a key role in forming their experience. Thereby, this lens allows us to see the close relationships between the multitudes of different activities, things, and materials, that were part of this case without foregrounding one before the other. This approach ties back to traditions in media and literature studies, where any object can be understood in terms of text, that can be subjected to an analysis in the form of interpretation and reading. A similar kind of practice has recently been introduced to HCI in the form of interaction criticism [3 and 5]. The kind of interpretative practices we discuss here does however not specifically refer to the analytical reading of a critic or a researcher, rather, it relates to the leisurely oriented reading that people engage with for the experience that it provides. The empirical part of this paper offers an ethnographic description of how the blue fiberglass box (figure 1), in the hands of the two men, becomes an object around which they built an individual and social experience and a shared narrative.

Based on the analysis of this case, we offer three main contributions to HCI. First and foremost, the paper suggests a repositioning of maker activities that reach beyond ideas around innovation and learning by focusing on how makerspace activities provide opportunities for co-creating narrative experiences.

Figure 1. The blue fiberglass box closed.

Second, we highlight the relation between the qualities of an artifact (fig. 1), its making and the experience that participants have around these qualities. We thereby contribute to the discussion on the interplay between computational materials and experience. Third, we position our discussion of the participants' skills and abilities within the broader discourse of what literacy - and in particular *material literacy* - can be about in relation to hybrid digital objects and things.

EXPERIENCE AND INTERPRETATION

In Grint and Woolgar's seminal study of the design and use of interactive technology [15] they propose the metaphor of technology as text, which has strongly influenced STS and HCI research. Along with this metaphor follows the idea that the technologies are written by designers and consequently read by users. One central aspect that this metaphor provides is the view of interaction with technology as essentially *interpretative*. Also in work of Akrich and Latour [1] and Suchman [39] related notions of design and interaction as processes of scripting and de-scripting are used to emphasize how certain forms of use cannot be pre-formulated into artifacts, but always goes through processes of subjective de-scription on behalf of the user. Such interpretative perspectives on interaction has strongly influenced HCI research for instance through notions like open-endedness in design [34] and ambiguity [12]. A design-oriented critique of the positions of Grint and Woolgar and other scholars argues that the metaphor of technology as text becomes overly essentialist by suggesting that an artifact could be open to any kind of interpretation [16].

Another way of approaching this is to situate the interpretation of artifacts in a context of narrative and storytelling. McCarthy and Wright [24] explicitly tie the notion of experience to that of narrative. In HCI, narratives have been widely explored, often focusing on creating means and tools for users to create different types of stories. In McCarthy and Wright's conceptualization, they propose that we frame and structure life events in terms of coherent narratives in order to make sense of the world [24]. Thus, the narrative of experience does not necessarily mirror what has occurred, but consist of selective and subjective interpretations constructed for various purposes. This will also be emphasized in our analysis of the participants' interpretations of the components and the disassembly of the blue box, reflecting their tracing of its functionality and origin and how these formed their experience. As substantial interaction design research suggests, the kind of interpretations we can expect users to make from certain artifacts is affected both by the users' different skills and experiences, but of course also by the characteristics of the artifact, in terms of for example affordances, material qualities and constraints [42]. There have been several attempts to conceptualize how the characteristics and behaviors of computational materials affect experience, in terms of for example use qualities [22], or experiential qualities [18, 23, 38]. Related here is also the ongoing

discussion in HCI around materiality and the role of physical and digital materials in interaction design. The material discussion in HCI suggests a move away from the idea that things are either physical, digital or computational to instead approach these as primarily material [10, 37, 44]. This move extends our understanding of digital, physical and hybrid materials and provides a common ground from which to explore these issues, a stance that plays well with the case at hand where the participants engage both with physical circuit boards, as well as with digital code. Conceptually the notion of material can here be characterized as *"embodiments through which properties can be experienced and performed"*, be it in physical, temporal form or state of matter [13]. Building on this view, we think that there is need to further explore how materials shape ways of doing and how practice is rooted in the experience of those materials.

To conclude this brief note on experience and interpretation, we note that experiences in engagements with technology emerge out of interplay of a complex set of factors, involving the participants and their previous experiences, certain qualities of the artifacts and materials, and how the separate activities are situated in a larger context.

What is worth pointing out here is however that to understand the unfolding of experience we should examine both the artifacts with its material qualities as well as the acts of subjective meaning making and interpretation. The question of the role of interpretation for the unfolding of experience becomes especially prominent in the case at hand, where the participants do not engage with technology in the way it was designed for. Engagements with technology, that does not fall into the realm of using or playing, are not as easily understood in terms of people's experiences around them. For activities, such as designing, making or (as in the current case) taking things apart, the lenses used to analyze them tend to focus on instrumental qualities and outcomes, such as learning or collaboration benefits.

MAKING AND TAKING APART

Numerous researchers in HCI have previously explored maker culture and the situated practices and activities that making brings to the fore. In current research, the emancipatory and democratizing potential of making and maker culture is regarded as promising, highlighting making as means to rethink educational approaches [6, 30, 35], spark innovation [11, 21, 36, 45], and to increase interest in and participation with technology [2, 40, 41].

Research on makerspace activities tend to focus on *constructive* practices with numerous labels such as making, crafting, tinkering, do-it-yourself (DIY), repair and reuse [7, 25, 30, 31]. As will be shown in our study, all activities taking place in makerspaces are however not about making. There is also a set of activities that is better described as acts of *deconstruction*, including practices such as hacking, un-crafting and reverse engineering [4, 17, 27, 28, 33].

Examples of practices around taking apart and disassembling electronics and computational things and objects have been extensively explored in HCI, foremost notable as means for fostering understanding and learning. Construction and deconstruction as a form of tinkering or bricolage practice are for example central in Papert's seminal works on constructionism and learning-by-making [29]. Another prominent example of how deconstruction is related to learning is the notion of *reverse engineering*, which can be described as an unfolding process that through careful and structured disassembly uncovers the details and the knowledge that is contained within an artifact [19]. Originating from mechanical engineering education it deals with a detailed study of a product including its material, structure, surface, qualities and operating conditions [8]. To learn what a product is made of; reverse engineering is foremost used in cases where blueprints or layouts are missing and when existing artifacts are to be imitated or rebuilt in a later stage. Scholars teaching the practice describe reverse engineering broadly as a process for discovering underlying fundamental principles that enable a device [26].

Another related practice is that of *hacking*, which originally relates to the activity of finding ways to invade or hack systems, and which therefore possess rather negative connotations. However, as Rosner and Bean point out, this meaning changes when transformed from digital computing to the material world [33]. Previous research in this field includes hacking physical materials such as IKEA furniture [33], self-made tools at the hackerspace [4] or as a starting point for reuse and reconfigurations of material [17]. Ames et al. conclude that these practices *"are often celebrated as a more authentic engagement with technology and a return to old 'cherished' and 'more physical' materials*" [2]. The activities of opening and taking apart computational things have also been explored in the context of interaction design processes, where they become an integral part of the design activities [14], to develop a sensitivity and understanding for the design materials at hand, or for reaching common ground and shared understandings within a design team [28]. Recent work also introduces the notion of *un-crafting* as an attempt to provide a coherent approach to engage with the manifold understandings of taking apart objects, devices and materials [27].

The research mentioned above tend to highlight the outcomes of deconstruction activities such as the development of new knowledge and skills, how it aids the creation of novel artifacts, or social purposes such as developing shared understandings as well as fostering collaboration. What have been less explored in HCI research is how taking things apart can be meaningful as an activity you engage in for its own sake. Here we would like to bring to the fore other driving forces that may bring meaning to such activities such as curiosity, the excitement of following traces, or reflecting on interpretations.

METHOD

As part of a half-year ethnography at a local makerspace, this case captured our attention amidst its inquiry process, which is featured as a vignette in the beginning of this paper. The study site is a community driven and crowdfunded makerspace, which was initiated by a group of people in 2013 and located in Northern Europe. The makerspace has more than 100 active paying lab members each month and is in the basement of a startup hub. The six-month long ethnography, conducted by the first author, took place at site with visits between one up to three times a week, observing maker practices and following multiple maker projects, which varied in size and scale. In this case the role of the researcher was the one of an observer, deliberately taking a step back by capturing ongoing activities and practice.

The activities captured in this case, stretch over several months, and the associated narrative has a timeframe that ranges over several years. The presented data is collected using photographs and field notes, taken at site or shortly after the observations. A set of semi-structured interviews was also conducted and recorded, focusing on the participants' recollections of the activities, in order to fill gaps in the story.

Figure 2. The study site: The Makerspace electronics corner.

THE STORY OF THE BLUE BOX

In the following section, we present how the box (see fig. 1) was found and the subsequent investigation that followed. This series of events is organized and presented in five parts: *The garbage room, the box, the components, the code,* and an *epilogue*. In regards to the timeline, we are interweaving different storylines, which stretch over a period of more than twenty years. As time is an important factor in this presented case, it is relevant to note that the participants' various engagements build the primary chronological arc and our involvement through observation and subsequent analysis can be regarded as a secondary level of capturing the ongoing practice.

Chapter 1 – The Garbage Room

Svante is a twenty-eight-year-old man with interest in technologies and machinery, ranging from tools and apparatus to digital, mechanical and electronic gadgets. He particularly likes to explore things that are strange and unknown to him. Svante has a history of scavenging and fishing up weird objects from open waters or searching through private and secluded places. Some of his earlier findings suggest that Svante does not only want to possess the object, but much like a collector does, he creates meaning by following up the object's history, its original purpose and where it came from. Svante is skilled in fixing motors and vehicles. In the makerspace, he is known as a hands-on guy, with skills and knowledge in engineering and fixing tools and machinery. In a previous account, he mentioned that he is often amused about other makers fearing real machinery, fuel and hands-on dirty work: *"The geeks are so very afraid of the smell of gasoline - like as if something would explode right away or something"*.

Back in 2010, while sniffing around in the closed-up garbage room of a large insurance company, trespassing the grounds otherwise closed to the public, he made one particular find. Svante came across a blue box made from fiberglass plastic, measuring approximately 20x35x20 cm. For most people this would seem just like an ordinary robust plastic storage box, of the kind that you would find in any garage or store fishing gear. During the interview with Svante he reflected about his discovery of the box: *"There was a lot of interesting stuff there, but this box just captured my attention. What could it be?"* Only from seeing it lying around amidst garbage, he was drawn to it. Despite being aware of that it would be illegal to take the box with him he could not just leave it there, arguing; "*it was to be thrown away anyhow*". Something in the mere appearance of the box sparked his attention and interest, seeing a possible function of the box from small details on its surface: *"I saw the lid on the box and something that looked like an antenna, ... there was this loop which gained my attention. First I thought it had something to do with measuring radioactive samples"*.

Further on, during a later discussion we asked whether the box could be dangerous. Hence this was of importance, as he responded: *"Oh yes, I was scared, but the box was very interesting. You could say that it sparked my interest. And I just couldn't let it go"*. These quotes illustrate Svante's ability to read possibilities from small details on the box and how this triggers his fascination and excitement for understanding what the box could be about. His previous experiences together with skills in seeing subtle details form the starting point. The box hereby promised an experience that was worth investing significant time; effort and risk. Forming this experience comes through the interweaving of Svante's interest in exploring technical things, searching the surroundings for potentially exciting and adventurous objects that would take him into detours and places where he is not supposed to be, just to build a personal adventure in his everyday life. It is not just any weird mechanical or electronic thing that captures his attention; it is something in the object that suggests exploring the unknown, with an exciting or dangerous potential. Here the experience emerges and develops in situ, and is continuously constructed through

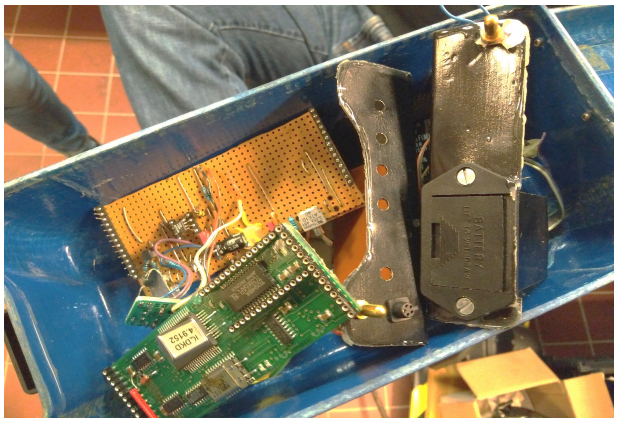

Figure 3. Unsorted components in the blue box

his investigations of the objects characteristics, the place where it is located, and the situational circumstances under which it was found.

Chapter 2 – The Box

Coming back from the scavenger hunt at the garbage room Svante was eager to know what the box would contain. First, he started considering the character surface, trying to find out how it could have been constructed. It had protected areas on the sides and when looking closely he could see that there were things embedded underneath the fiberglass. On closer inspection, he reflected that*: "I could see that the box had protection from each angle. It has reinforced walls, top lock, the base and everywhere else."* He opened the sealed box with tools from his garage. On the question on what would be the worst thing that could happen he responded: *"It could explode or go off in some kind of way. I just hoped it wouldn't have any long-term effects. But even if I would have known that it's dangerous, I would have opened it anyway."* Obviously, this was not the first-time Svante had been opening sealed objects. The fact that it might be dangerous did not make him hesitate to investigate the box further. Instead they seem to be one of the primary motivations for carrying on. However, it turned out that the box in this case was basically empty. There was no explosion, no valuables and no treasure inside. The only thing was that caught his attention were some metal contraptions on each side (shown in fig. 5a). Disappointed that there seemed to be nothing more to it than just an empty box, Svante saw no immediate urge of proceeding. He left the box lying around in his apartment and at some point, it ended up in the back of his wardrobe, and he lost interest for several years. During that time the box served a different purpose such as storing cigarettes. However, it's mere presence reminded Svante of this unsolved mystery. *"But you know this box annoyed me and my friends for a long time. I had it like five years where it was just standing around but always wondered, what its original purpose might have been"*. Instead of just tossing that project aside, he kept it and continued having ideas, but still lacking proof he did not know how to proceed.

In this first step of inspection, the visible surface of the box is investigated (fig. 4a), revealing details that contribute to the initial ideas and first assumptions about the construction of the box and its origin. The potential danger and risk that became apparent were fundamental to the experience that he started to build around it. That something might go wrong fuels his curiosity and determination to explore. The opacity of the box and the limited clues of its intended purpose also made it interesting, suggesting a potential challenging investigation. Despite this, at this point he did not see enough potential in where the exploration of the box could take him, leaving it lying about in his apartment serving practical or no apparent purposes. This long and ongoing time period further builds up its status as an unsolved mystery.

Chapter 3 – The Components

In January 2016, Svante decided to bring the box to the makerspace. What sparked him to continue to further investigate the box was a key moment while sitting around with friends in his apartment, and the blue box suddenly caught his attention, he recalls: *"It was the texture and the color, it was exactly the same as CIT boxes have"*. The rifled distinctive texture of the box was specific features he recognized (fig. 4a). Realizing that it could be a CIT (cash-in-transit) box turned out to be a big moment for Svante, as he had recently come across a case with similar textures and patterns. This realization motivated him to investigate the artifact again. Now, starting to form and idea of the purpose of the box, made Svante curious about the different parts, and how they were constructed. This time around Svante decided to break into the two metal compartments on each side of the box, revealing a mixture of cables, boards, microcontrollers, lamps and battery components. Figure 3 shows the inside of the box with the components dragged out from their original position. Seeing this spurred his engagement wanting to understand what the box could be about: "*It became really interesting when I discovered the PCB boards and the microcontroller and not just mechanical but also electronic parts*". After closely inspecting the boards several times, Svante discovered that one of the PCB boards carried a vague black imprint from a well-known security company next to the chip (fig. 5b).

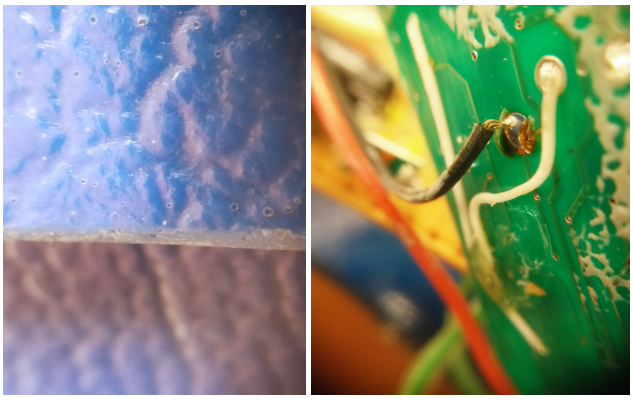

Figure 4. a) Pattern and texture of the box in detail. b) Close-up on soldering on the battered PCB board.

"*Suddenly I was a thousand percent sure that it must be a CIT box. And then I wanted to know so much more!*" These findings triggered Svante to dig deeper not only into how box was constructed and what was for, but also into the larger story around the box, who made it, for what purpose, and why it ended up in that locked up garbage room. The reason for bringing the box to the makerspace in the first place was to ask other members for help and to share the experience. This time he asked a skilled programmer, Ola for help.

In comparison to Svante, Ola is more into software, computer security, and hacking. As both men continued to explore the insides of the box together, and inspecting the different parts more closely, two elements caught their attention: the two PCB boards and the microprocessor. When commenting on the soldering work on the PCB boards (fig. 4b). Ola reflects: "*This looks like a mix between thru hole and surface mount construction, so this may probably have taken place right within the transition phase*". What Ola suggests here is that the dominant construction method for electronics between the 1960's –and 1990's was the thru-hole mount method, which was then replaced by surface mounting. Telling that this form of combination is noticeable in the boards, the electronic construction could be traced back to the mid-90s. In further discussing the properties of the board Svante said: *"Something which is kind of interesting is how much that is made with a proper printed circuit board and how much of is made on a prototype board" (*see fig. 5c*).*

They also agree that the work on some of the PCB boards is "*impressive soldering*", here switching focus from the materials to relate to the handcrafting skills of the person making the box in the first place. Ola continued that another way of telling apart an old circuit board from a new one is the way in which the angles are drawn in the circuit boards pattern (fig. 5b). He recalls, "*Back in the 1970's people used hand-drawn circuits, which then tended to have no corners at all, but they were replaced by 90 degrees' sharp angles and today we have rounded corners instead. [...] So that is indeed an indicator and gives information how old this object might be"*. When inspecting the board closer, Ola starts arguing that the included chip (visible in fig. 5b) tells a story as well since; "*this chip is socketed which means that it must be removed for programming and that tells us two things: Firstly, it's old because if you compare it to new systems, they use other systems for circuit programming.*

Arriving at this point of the exploration the object was taken apart; the fixture pieces were broken order to gain access to the internal components. Svante got in contact with Ola, and the makerspace electronic corner (shown in fig. 2) served as a space to meet and explore the different electronic, mechanical and computational components. The focus here shifts from looking at the entire object to instead investigate its constituent parts and materials, searching for clues to further their understanding of the box. By inspecting the components in detail, reading from the materials with Svante and Ola's combined skills, they made it possible to start forming two images: One of the functioning of the object through knowledge of the content's various physical and digital qualities and the idea of the box being a prototype which is read out from traces the material provided. Secondly they start to envision the original maker of the box, reflecting on the skills and identity of that person.

Chapter 4 – The Code

At this point Svante is convinced that it is a prototype for a CIT-box they got their hands on. However, the physical explorations still did not provide a complete picture. Svante "*really wanted to know more*", which led them to take a closer look at the digital content. This was the main reason why he asked Ola for help so they could extract information from the chip itself. When discussing the qualities of the chip Ola reflected: "*It was just a matter of knowing that it would store something and then we just needed to find out what*". Using an imported chip reader from China he got hold on some rows of code. "*First it looked like weren't gonna be successful. There was just so little information*". Ola tried different software to access what the chip had stored but several of them failed. Finally, he decided to try and crack the information by using a disassembler, (a piece of software that translates machine code into assembly code). Since each assembly language is specific to a computer architecture this made this procedure challenging, but information on its brand and serial number provided Ola with a clue on where to start (fig. 5b). The software then "*literally disassembles it. It's really an obscure software. It's not something a lot of people need to do, basically it's virus researchers or people that crack applications*". The extracted assembly code provided Ola with a structure he was familiar with and could interpret. In one of the interviews, Ola reflected on the assembly process and explained the steps of the software more thoroughly: "*What it's doing now while working through the program is that it's basically going through all*

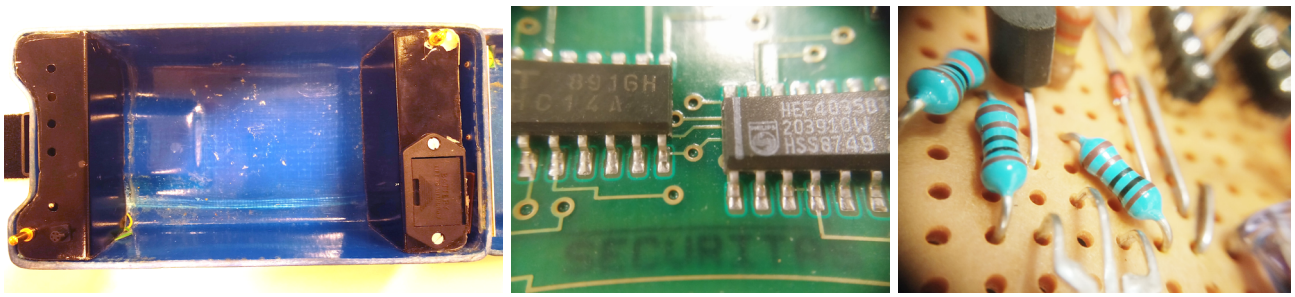

Figure 5. a) Re-assembled box with metal components on each side. b) PCB board with 90 degree sharp angles, also showing the socketed chip and security imprint. c). The prototype board closeup.

those possible parts so that it can work out like all the possible options at all the places the program would go and then it makes a map of this". The assembler code as such is not very user-friendly and demands a certain level of expertise to interpret. The screen then showed long rows of line numbers and data strings: "*In order to find the code you need to scroll down lots and lots*". Ola explained that the program "*is doing a lot of guesswork. But technically if you would run this through a compiler it should actually spit out the original program in the end*". At this point Ola had a quite good picture of the overall workings of the code. However, Svante was curious in finding information that could help him trace the origin of the original maker. Ola explained: "*I looked which one has to do with anti-piracy and these strings had the name of the company in them*". In another string, he also found a date indicating when it was built. Furthermore, an important observation from the reading of code was that it had a lot of blank space: "The *program just didn't take as much room. It kind of makes sense that they were gaps as they normally aren't filled up completely, so it's probably an early prototype*."

The process of extracting, disassembling and assembling the code from the chip provided two important clues that contributed to Svante's hypothesis about the history and construction of the box. First Ola could read out the year it was created (1996) and a name that could lead to people who built it. Secondly, the fact that there was lots of blank space on the chip strengthened their assumption that the box was an early prototype of something that would later be refined. Here they drew a conclusion that its maker was an individual inventor that had been working on the box on his own. This example also put to the fore the need for specific tools and knowledge. Here Ola's specific skillset came into play; he knew which hardware and software to use and how to read out data from old and discarded systems. By hacking into the system, being able to make meaning of the code and its underlying logic provided the missing pieces of information.

In a similar way as chemists' mixes in other materials (reagents) to spur a chemical reaction that may give clues about the chemical composition of a sample, the code is here "mangled" using a tool to make it give away clues. Additionally, the activities have clear illegal connotations, in regards to how to gain access to presumably pirated and cracked software, how to use them to hack into systems and to read out information. Here the notion of risk-taking and danger reappears, and the fact that the activity is playing with these elements work as a motivator.

Epilogue

"*I found the person who developed the box, I was at his home and actually talked to him yesterday*" Svante exclaims with delight a couple weeks after they could decode the program on the chip. To continue the search Svante had used the information from the program to find the specific company. By searching the Web, he got hold of more information on the company and its owners, realizing that the business, which was founded back in 1989 had been active until just recently. Svante had concluded that as the date of the box's chip dated back to 1996, the company had to be older than twenty years. The search pointed him to different addresses and people, which he had called by phone but without finding the right person. On a last attempt Svante, had decided to visit one of the addresses, but nobody had heard of the company or the owner before. Disappointed he went back to his car, but still convinced that there must be a way to find the origin of the box. As he had "*already come so far*" there was no idea of giving up at this point. Based on the company name he could find yet another address which he decided to try in person instead. After a short drive to a residential area, he found himself in front of a house that was only accessible by key code. He saw an older lady inside, standing on the stairs so he waved enthusiastically. The woman opened the door and with the blue box under his arm he asked for the company and its CEO, who was supposed to live there. "*That's my husband you are looking for*" she responded. Svante had finally discovered Carl, the person he was looking for. Carl was a retired engineer who has been working within the security sector for the past thirty years. "*Carl was more than surprised but also amazed to see the old box again. He said that it has been twenty years since he last saw the piece*". Even though he could just spare a couple of minutes, Carl briefly told Svante the story behind the box.

It turned out to be just like Svante had anticipated; the blue box was a prototype for a CIT case. But not just any prototype: The box was the first prototype of its kind and included novel technology, which then, turned into a series of security cases for many years to come. Carl and his colleague were the first to work with liquid colors in that context: "*These were the first and companies actually still use liquid paint today, but this model is the first CIT case which has been approved and this one was the first prototype, which then later after iterations went into mass production*".

This was the point when Svante finally got all the answers to what the box was made for. The story was hereby tied together when Svante saw Carl's astonishment while confronted with this object from his past. The linking element in this final step here were the *digital traces* that Svante had found online both about the company and the people that had left them. To finish the search and taking the project to its end was critical to his whole endeavor. This allowed him to tie all the different elements of his experience together into a coherent narrative with a coherent ending.

The experience had involved a significant amount of technical explorations and social interactions. Svante drew advantage of the social networks around the makerspace to discuss his findings and ideas and could engage people at the site with different skills to draw out certain clues and discover traces, that finally allowed him to trace the box all the way back to its original maker.

DISCUSSION

A blue fiberglass box that turned out to be a prototype of a CIT-case filled with explosive material, electronics and digital components played a central role in this ethnographic account of unpacking the functions and history of the box. The question we would like to ask is what this story tells us in regards to design research, concerning experiences and interactions with technologies in makerspace settings? We have positioned this as a kind of narrative experience. Clearly, the box was in no way designed or intended to work as an object for someone to build a social and personal experience around. It was built to explode if someone tried to break into it, no more than that. Nevertheless, the dramaturgy provided by the explosive character of the box and the interpretations of the participants provided potential for the experiences that emerged.

The main points that we would like to make from these accounts, regard to how the experiences that are formed and the engaging and exciting story that the participants create for themselves, rely on their abilities and strong motivations to deconstruct and interpret the properties of the objects and materials that they encounter. To use a phrasing of Grint and Woolgar: *"The user is encouraged to find in her dealings with the machine an adequate puzzle for the solution which the machine offers"* [15: p. 73]. In a similar fashion, the participants in our study very much treated the box as a puzzle which could be solved by reading the associations to an overall narrative that could be made by interpreting the various objects and materials. The dramaturgy itself is a driving force and motivator that relates to previous experiences and future expectations. By conceptualizing the participant's abilities of interpreting the box as a form of close reading of its qualities, we aim to foreground essential aspects of what it means to understand, engage with and experience technology.

Just like the ability of reading, interpreting, and writing text is so much more than understanding the words and sentences on pieces of paper, *material literacy* as shown here, is about the ability to deeply engage with, take apart, contextualize, and create rich meaning – even stories – from a technological artifact. Our analysis shows that the complexity of the abilities involved in people's everyday technology encounters cannot be understood merely as "on-off" skills, but are of highly multifaceted and nuanced character depending on actors, settings and technology. An important elaboration of this interpretative process comes from the extended timeframe in which the participants' experiences are situated. These processes cannot merely be understood from what happens at a particular moment, but what needs to be put in relation to events, activities, and memories that extend over longer periods of people's lives.

Just like the interpretation of a piece of text depends on the specific historical and social contexts and situations in which they are encountered, the interpretation of a technological artifact has similar characteristics.

Material qualities

In interaction with technological objects, like the blue box, certain characteristics or *material qualities* emerge that encourage or trigger certain interpretations or experiences in people's engagements with the objects. These qualities are on the one hand inherent to the artifact, but are also *relational*, as the unfolding of experience is highly dependent on the relationship between the subjects' skills and motivations to understand and make sense of the technology, and the specific material qualities of the object at hand. We argue that the concepts of material literacy and material qualities become especially useful when exploring practices such as taking apart, un-crafting, making and hacking hybrid digital-physical objects. Here we identify six central qualities of the artifact and its constituent materials that that we believe were particularly important for how the activity played out. We also believe that these qualities are translatable to other areas of interaction design research:

Opacity – Given the original purposes of the box it was clearly designed to reveal as little as possible about how it was constructed, providing as few clues as possible to anyone wanting to break into it. Its character as a riddle that would be very difficult to solve is one of the primary driving forces that makes Svante curious. For Svante and Ola, the box is however partly transparent, allowing for inspection of the internal electronics and the assembly code, but require a combination of specific skills and tools to interpret. HCI has a history of designing objects for experiences in quite the opposite way; aiming for maximum transparency. Design-wise, this could be understood in terms of a continuum between opacity and transparency that is relational to each subject. The experience is thus shaped by this relationship between opacity and transparency and the nuances that arise from the participants' interpretations. In this case the interpretation by the participants allows them to see enough leads or clues, while still preserving a sense of mystery in the interaction.

Risk – An important attribute of the box is the fact that it contains explosives. The possibility that the box might blow up at any moment introduces an element of danger and risk, which influences the experiences of engaging with the box. Svante is from previous experiences aware of potential risks of tampering with the box, but this does not seem to discourage him from further explorations. Rather on the contrary: the explosives seem to add an element of excitement to the experience. The element of risk as part of an experience has previously been discussed by for example [20] as part of a discussion on the differences between interacting with digital versus physical media. It is noted that interactions in the physical world are associated with a more general sense of risk, as actions cannot be undone, and as you may get physically hurt. Further, risk can be used as a design parameter, since an increased level of risk typically leads to increased engagement and more careful and deliberate actions [20]. What is also notable here is that Svante's expertise and previous experience suggest that he can

estimate the potential danger, while the element of risk still becomes an important dramaturgic element in the narrative that is being created.

Uniqueness – In their investigation of the box, Svante and Ola concluded that this object is a prototype, meaning that it is not mass-produced, and probably just exists as one instance, at least in this particular form. Previous discussions on how we appreciate uniqueness in interactive artifacts point to how uniquely crafted objects are always imperfect, and how the uniqueness of the produced outcomes can be linked to the skilled work of the crafts specialist [43]. The insight that the box is a prototype seemed to sustain their interest and made them see more value in the box than if it had been part of a series of identical CIT boxes. This uniqueness and the fact that is a crafted object, signals that someone has invested time, skills and effort into creating a single artifact.

Authenticity – In their study of bookbinding practices Rosner and Taylor discuss how objects gain the attribute of authenticity as a result of use and interactions with the material: "*It is through our continued interactions with material, and the impressions we leave on it, that deeper attachments evolve*" [32: p. 2668]. In our case, Svante and Ola showed an interest and a fascination of the original maker and the context for which the box was aimed for. The box revealed certain traces of these, such as in the "*impressive soldering work*", or in the imprints on the circuit board pointing to a security company. These traces, together with the place of discovery and the specific purpose for which the box was built, contributes to the sense of authenticity and points to a history of previous engagements.

Age – That the box is for a computational object relatively old, is an important ingredient in the engagements with it. The age adds to the sense of mystery and an important part of the inquiry concerns determining the age of the object. Here Svante and Ola can approximate the age of the box, as the circuit boards holds certain signifiers that point to specific time periods. Such age-related properties have previously been described in terms of *material traces* that" concretize *a unique location in time and space and highlighting the humans' role in recognizing that distance*" [31: p. 1651]. Also, as the box no longer fills its original purpose, it can be considered obsolete, or even dead. Nevertheless, through their engagements, Svante and Ola bring it back to life, as it becomes the center of their inquiry. Similarly noted by Jackson and Kang – "*As work with found, broken and obsolete objects makes clear, there are 'lives' to our technologies beyond the contexts and functions for which they were originally designed*" [17: p. 457].

Hybridity – In the presented case, the box is disassembled into its constituent materials, electronics and code. Svante can make sense of most of the electronics, plastics and explosives, but when it comes to the details of the electronics and the software, he needs the specific competences and skills from Ola. The way of approaching artifacts as hybrids, forming compositions of different materials is addressed by for example [44], who uses the term computational composites to describe artifacts that have both digital and physical components. A main argument made is that the composite artifact is more than the sum of its parts, with its own unique qualities. In a similar manner, even though our box can be described in terms of an assembly of materials and components with specific qualities, the unfolding of experience of the two participants needs to be understood in relation to a composite whole. Also, the material qualities outlined in this chapter should not be considered independently, but rather in terms of how they come together forming a hybrid around which the experience is built.

Here we have outlined a set of qualities to help us further the understanding of how the material characteristics of the box interplay with the unfolding experience. Although these identified qualities could potentially aid the design of new interactive artifacts, the point we want to make here is, that the experience is not a direct effect by the specificities of the artifact itself, but rather unfolds in the interplay between the qualities and how the particular subjects engage, interpret and make sense of them in their situational and social context.

Material literacy in Makerspaces

We have framed the participants' engagement with technologies and the social processes around them primarily as an experientially oriented process with similarities to that of interpreting and reading texts. We suggest that this process can be understood through the notion of material literacy, which puts the relation between the interpretation of the objects and materials to the fore, and highlights how such a process contributes to the formation of an overall experience. This is not to say that all the different activities the participants engage in should be understood as a form of reading, but rather it points to the centrality of a kind of meaning making from which the participants build a narrative form of experiencing the activities. By framing users' interpretative activities in this way, we aim to put the rich flora of different objects, things, technologies and constituting materials under scrutiny on an equal level. Rather than treating engagement with a piece of code as essentially different than the analysis of the texture of a fiberglass case, we argue that when processes such as these unfold, we should see the variety of ways of interpreting - and in a sense making 'readings' - of the objects and materials at hand, as part of the same kind of meaning making as in building a coherent narrative experience. Grint and Woolgar formulate this in their discussion of technology as text: "*The organization of the text hinges [...] on associations made available within the text and between the text and reader*" [15: p. 73].

The forms of experiences made possible by interpretative practices in relation to hybrid objects should not be looked upon as a form of linear reading from a literary point of view. Rather this resembles a hyper-text form of reading in which

associations of the various elements of objects are meaningfully woven together into a narrative whole. This interpretative practice can be understood in terms of a continuous process in which various pieces of 'text' and material are meaningfully put together [9].

The notion of material literacy provides a means of bridging technology as text and technology as material. Interpreting technology is largely about being able to deal with the technology's hybrid character defined by a multitude of material qualities. This advances a way of thinking about literacy with technological artifacts that opens for new types of engagements, interpretations, and experiences, with consequences not only for maker activities, but also for the understanding of human technology relationships. As we have shown, such deeper engagements with technology may go beyond mere straight-forward interpretations such as prescribed use scenarios. The metaphor of technology as text influences many facets of HCI, especially the development of an interpretative characterization of interaction. However, here we hope to be able to expand what maker and hacking activities are about – through a characterization – that emphasizes elements of interpretation, narrative and hyper-text reading. We find that this provides ground to contribute to the HCI-oriented perspective on the discourse around literacy and digital literacy and how new forms of these may take shape in hybrid digital and physical environments.

As we have argued, a central ability that the participants of our study demonstrate is that of treating the physical and the digital as fundamentally intertwined. Thus, being literate does not imply considering the digital as a domain of its own separated from other objects and things around which we build our interpretations and experiences of the world. As shown in our study, interpretation of such digital and physical hybrid objects may take place in highly social contexts, thereby providing grounds for collaborative forms of actions, ranging from co-reading code, joint explorations of electronics and construction materials, and co-theorizing about how objects are constructed and assembled. Importantly, interpretations of these objects, things and materials then go beyond merely understanding and making sense of them, but include how such processes contributes to the rich variety of experiences of our everyday lives are formed.

CONCLUSION

The overarching aim of this work has been to take a closer look at the activities that takes place at makerspaces, where we propose the notion of *material literacy* as means to further the understanding of how experiences unfolds in the engagements with objects and materials. We hope to have opened a discussion that goes beyond ideas around innovation and learning and to highlight makerspace activities as spaces for co-creating narrative experiences. In doing so we have shown and expanded notions of literacy and how these should be understood in digital and physical contexts. The point that we hope to have reached is that makerspace activities can look very different and relate to a wide variety of things. To understand such activities, and people's relations to artifacts and technologies in such settings we need to widen any pre-conceived notions about what making and hacking is about, and furthermore, about how we invite other kinds of activities that rarely have been the focus of attention. Another set of contributions relates, in a more immediate sense, to interaction and experience design practice.

We identified a set of material qualities; opacity, risk, uniqueness, authenticity, age, and hybridity that were crucial for the unfolding experience and that arguably should be relevant also for similar settings. Our claim is not that these can straightforwardly be translated into design, of for instance new treasure hunt technologies. Rather, we point to the importance of thoroughly considering how such qualities touch upon the personal and social driving forces behind people's engagement in various activities, the wide range of skills and interests that people have, and how those aspects may interplay in the design of new things and technologies.

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