Practicing DIYbiology In An HCI Setting

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Abstract
Alongside an expanding community of non-professional biologists, DIYbio is beginning to emerge as a fledgling subdomain of HCI. However, this emerging subdomain is yet to be in the focal point of a long-term investigation to identify the challenges and opportunities of designing interactive systems and tools to facilitate biological practices outside of professional setups. As the first step towards this direction, we carried out an autoethnographic study to practice DIYbiology, by setting up a functional DIYbio space inside our HCI design studio. In this paper we reflect on our autobiographical experiences in practicing DIYbiology inside our lab space and discuss the challenges and opportunities for further HCI research in this particular subdomain.

Author Keywords
DIYbio; DIY, Autoethnography; Citizen Science

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

Introduction
Practices of hacking and DIY have been of increasing interest to HCI researchers in recent years. Several discussions in major HCI forums viewed modern DIYers as "expert amateurs" advancing them beyond hobby craft en-

thusiasts [14, 20]. Recently, DIYbio (do it yourself biology) started to grow as another stem of DIY practices amongst enthusiasts who pursue biology outside of professional settings. This movement aims to make biology more accessible outside of professional settings, with projects ranging from open source platforms such as OpenPCR [10] to local experiments with yeast to embedding bacteria in textiles [3, 7]. Alongside this expanding community of DIYbiologists, the intersection between biology and computation is also emerging as a subdomain of HCI and Design [13, 15], including work that focuses on building interactive systems to support biology research [23, 27].

However, despite the increasing interest of HCI researchers in biology and DIYbio, this fledgling subdomain faces many challenges, ranging from the creative workarounds necessary to conduct biology work in HCI settings to the deeper philosophical, safety, and ethical questions around amateur work with living systems. With this backdrop, our work progresses towards a formal and extended inquiry to identify challenges and opportunities for HCI and Design in facilitating biological practices outside of professional setups. We particularly focus on this area because 1) it is a promising domain for technological innovation, such as new open source platforms for biology; 2) it has the potential to broaden access to biology in maker-spaces as well as educational settings; and 3) it opens up opportunities to crowdsource biology research amongst professionals and non-experts. As the first step of many to follow, we, an interdisciplinary team with expertise and experience in biology, computer science and interaction design carried out a preliminary study to practice DIYbiology inside our HCI design studio. Our work includes setting up and maintaining a DIYbio space inside our fabrication space, exploring affordable materials, building low cost lab equipment and carrying out a set of biological experiments.

In this paper we present our ongoing work and reflect on our autobiographical experiences in practicing DIYbiology inside an HCI setting. We discuss the challenges, opportunities and suggest directions for further HCI research in this particular subdomain based on the outcomes of our preliminary study. Our autoethnographic reflection reveals three future research trajectories: 1) platforms for scaffolding biology expertise; 2) low-cost DIYbio platforms; and 3) systems for crowdsourcing biology research. We believe these contribute towards new and exciting opportunities for interaction design, prompting HCI researchers to productively collaborate with biologists and members of the DIY community and create multi-disciplinary research opportunities across domains.

Related Work

A considerable amount of prior work examines the seams of HCI research, biology, and DIY. These prior projects address several key aspects of biology practices such as teaching and learning, data browsing, visualizing and fostering collaboration. Long term collaborative work by a multidisciplinary team of biology experts, engineers, interaction designers and students, revealed the unique opportunities created through interactive interfaces for biology research. Schkolone et al [22] proposed, an immersive visualization platform to digitally represent DNA and a set of tangible manipulation techniques to support molecular designers in performing difficult spatial construction tasks. G-nome Surfer [23] and GreenTouch [27] are touch-sensitive interactive tabletop applications for collaborative exploration of larger bio databases. Furthermore, another set of HCI research including .net Gadgeteer [28], DIY CellPhone [16] and Fritzing [6], explored methods in designing prototyping platforms for non-expert users to easily build custom electronic devices. Wakkary et al [29] discussed the role of interaction designers can play as hybrid designers mediat-

Figure 1: DIYBio space inside our HCI design studio

ing between author and audience to improve the practices of DIY tutorials. Tseng & Resnick [26] presented design opportunities for HCI community to develop tools to support DIYers to share their creative work online. Building on this body of literature, we focus on a less-widely studied albeit similar setting: our work examines biology work completely outside the professional laboratories and in non-expert DIY-biology hobbyists.

Methods

Our interdisciplinary team (referred as "we" in this paper) consisted of 3 researchers from different backgrounds.

- P1: A biologist with no prior exposure to engineering
- P2: A computer engineer with no prior experience in biology
- P3: An interaction designer with some experience in hands on biology

Throughout the process of setting up our DIYbio space and creating biology tools, we applied autoethnographic methods to gain insights into the challenges and opportunities behind novice participation in biology. Auto-ethnographic methods have been widely applied in HCI [17, 19, 21], and are specifically beneficial for uncovering details that may seem unremarkable with traditional HCI methods where users and researchers are separate. These methods are particularly appropriate for our research: since there are no existing HCI DIYbio labs to be studied, reflecting on our own experiences will reveal rich insights into how these types of spaces and communities can be set up. To this end, we thoroughly documented our work using a variety of formats: lab journals, voice recordings, photographs, videos, blog posts, etc. We carried out this study over a period of 10 weeks and it consisted of following three major steps.

Setting up a DIYbio space and infrastructure

As the first step of our autoethnographic study, we set up a Biosafety Level 1 (BSL-1) facility inside our HCI design studio (Figure 1). Our studio is physically connected to a fabrication lab, a hardware and woodworking shop, and a black-box theatre. This flexible space supports open ideation, rapid prototyping, and iterative feedback across domains and communities. A BSL-1 facility, by definition, provides a space to work with organisms that do not pose a risk to human beings or the environment [1]. For example, E. coli JM109 is a strain of E. coli that is non virulent and generally considered to be safe to handle. With the introduction of the BSL-1 lab work, we tightly enforced number of safety practices such as safe sharp handling, having easy access to running water and cleanup infrastructure and personal hygiene requirements (e.g., no eating) which were already in place, but less seriously practiced before. Then, with the prior experience of P1, we explored the equipment necessary to carry out simple biological experiments such as bacterial cell culturing. In this process we were well aware of the potential financial constraints that might be faced by real world DIYbio communities. We opted to adhere to a budget of around 1500$ as a realistic amount for DIY community settings, often opting for workarounds to pro-

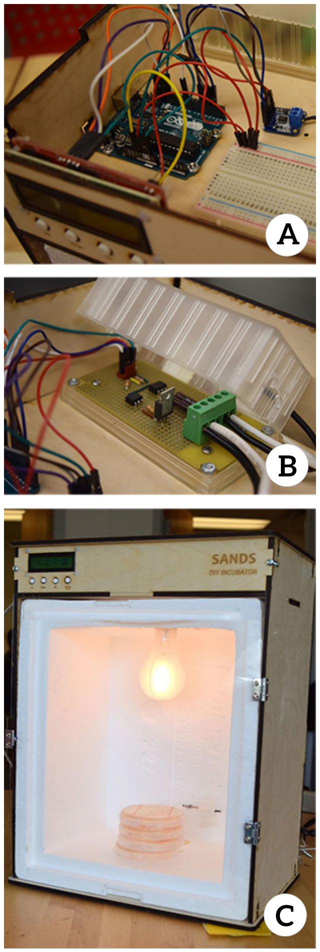

Figure 2: Low cost DIY incubator. (A)Arduino based electronic circuitry. (B) Custom built AC phase control module. (C) Final physical design.

fessional equipment. In this direction we took two alternative approaches—appropriating commonly used low-cost equipment and building from scratch using low cost components. As a low cost alternative for a centrifuge, we used a Dremelfuge [4] with Dremel rotary device. Further we used bleach and Clorox wipes to clean up spills and sterilize our work while using a regular refrigerator to store samples. We adapted a common pressure cooker with a pressure gauge in the place of autoclaving equipment for sterilization.

Building a low-cost incubator from scratch
In addition to appropriating existing materials, we set out to design an incubator using only low-cost, simple materials and popular off-the-shelf components (Figure 2). We used a general-purpose incandescent light bulb as the heating element, Styrofoam box as the insulation material and an Arduino Uno development board with some basic electronic components. In contrast to other DIY incubator solutions available online [12, 2, etc.], our focus was to build an incubator with a high precision temperature control which comes close to the commercially available ones. To achieve such level of accuracy we built a custom electronic circuit to precisely control the AC voltage supplied to the heating bulb. This circuit consists of two optically isolated sub circuits—Zero-Crossing detector and AC trigger circuit with a Triac. A K-type thermocouple combined with Adafruit MAX31855K amplifier was used as the temperature sensor. In the firmware we used the Arduino PID library, and the parameters were tuned manually to calibrate for our lab space. Further, a user interface was implemented using a 32 character LCD and 4 touch switches enabling basic user interactions such as setting target temperature. At the end we posted step-by-step guidelines for replicating this incubator in Instructables web site [9].

Cell culturing experiments
Culturing cells is one of the many widely used practices in hands-on biology. For the purposes of this study we decided to explore our ability to culture E. coli JM109 cells in our DIYbio setting (Figure 3). One of the most important facets of culturing cells is to remain aseptic while working in order to avoid contaminating samples. We started out using lyophilized E. coli JM109 and inoculated basic LB agar plates while working on a sanitized surface and under the protection of a bunsen burner. All plates were created following Edvotek E. coli culturing protocol [5], a Lyophilized E. coli JM109 bead was placed on a sterile LB agar plate and rehydrated with 10ul of LB broth and then spread across the plate in order to isolate colonies. Plates were sealed using parafilm and incubated for 24 hours at 37C in our "homemade" incubator. The next type of cell culture that we examined was a basic E. coli broth culture. We followed a procedure described by Addgene [8] for our broth cultures, 5ml of sterile LB broth was aseptically inoculated using a single isolated E. coli JM109 colony via a sterile inoculating loop. Broth cultures were left with loosely closed caps (in order to allow for gas exchange) and incubated for 24 hours at 37C using the same incubator. The LB agar cultures worked remarkably well considering the constraints of our lab setting: we were able to both maintain sterile cultures and isolate colonies consistently. Furthermore, we were also able to consistently maintain sterile broth cultures. However, the incubator that we built did not have the ability to shake our broth cultures and as a result, our broth cultures ended up growing in biofilms instead of having the cells being well distributed throughout the media.

Auto-ethnographic Reflection and Implications
There is much interest in the intersection of biology and HCI, and practical insights into how to set up a DIYbio lab within an HCI context could serve to advance this area. We

Figure 3: Culturing cells inside our DIYbio setting

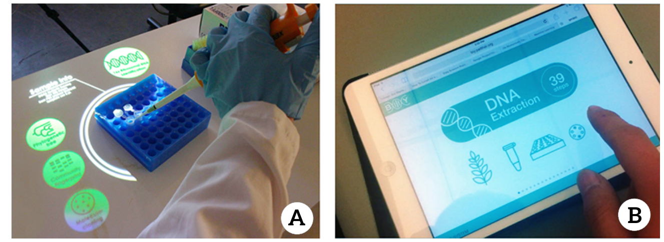

Figure 4: Conceptual prototypes of interactive biology learning platforms using (A) overhead projection and (B)an iPad application

proceed by discussing some of the insights, design opportunities and new research questions that emerged from our experience.

Interactive systems for teaching hands on biology work
Apart from P1, other members of our team had limited or no prior hands-on experience carrying out biological experiments. Thus, P2 and P3 had to go through a learning phase under the guidance of P1 before becoming fluent with basic lab techniques and protocols. This phase consisted of learning best practices, safety protocols, arrangement of tools, proper usage of the workbench surface and step-by-step procedures of the experiments. By reflecting on our own learning experience we envisage the challenges and opportunities for interaction design research to build interactive systems for teaching hands on novice biology work. How can in-situ applications intuitively visualize procedures and protocols and provide feedback to reduce error? What is the desired granularity for representing biology protocols (overview vs. step-by-step tutorials) and how can systems adapt to the expertise of the user? How to provide instruction without causing cognitive overload or interruptions during hands-on work? To this end our future work will focus on flexible hardware—tablets, projectors, or smart phones—to develop interactive teaching systems that are appropriate for a wetlab biology context (Figure 4). For instance, a tablet or phone could be incorporated into a lab bench to provide in situ tutorials, video instructions, and real-time feedback. Alternatively, a projection, coupled with acoustic sensing might appropriate the entire workbench as an interactive surface. Further, we will test preliminary low-fidelity and functional prototypes in workshops with biology hobbyists and non-experts. These workshops will adopt co-design and participatory design methods to identify effective visualizations and interactive elements that maximize biology learning outcomes, particularly outside of traditional laboratories. We believe, findings from these iterations will lead to the development of final, functional systems that enable beginners to perform basic biology protocols using open source tools.

Low cost DIYbio hardware platforms
Throughout the process of building a low cost incubator, we tried to directly utilize components that are popular and easily available for DIY communities as much as possible, such as the Arduino microcontroller and low-cost sensors. However, in order to achieve the greater level of accuracy required to perform biological experiments successfully, we had to design and build some electronic modules from

scratch. This process required a considerable knowledge of basic electronics and prior hands-on prototyping experience. Even though we had sufficient expertise within our group, it may be challenging to gather such diversity knowledge and experience within real-world DIYbio communities. Furthermore, the process of building low cost tools comes with some undeniable safety concerns as well, especially when working with mains AC voltages. In the initial testing stages of our incubator, a firmware bug in the AC power control mechanism nearly caused a fire inside our lab. Hence, designing low-cost tools that can be easily and safely replicated by real world DIY communities is a challenging task and it also encompasses opportunities for further research in HCI and Design. In this direction, we will build on other open-source DIY electronic platforms, including OpenPCR [10] and Pearl Biotech [11], which rely on off-the-shelf hardware to perform Polymerase Chain Reaction and visualize the results of gel electrophoresis. We envision other DIYbio electronic modules, which can be easily used with existing hardware prototyping platforms to build low-cost bio equipment. To this end, we started designing an Arduino-compatible AC phase control module with a custom made PCB, safety enclosure and solder-less connecting terminals to be used in our incubator design. We will iterate on the systems we develop by gathering feedback in participatory design workshops among real world DIY communities.

Platforms for collecting and sharing DIYbiology data at scale
Building on the traditional citizen science model, wherein trained but non-professional volunteers gather and analyze local information [30, 18] we envision the opportunities in DIYbio research for contributing towards large scale crowd-sourced biology. Choosing correct types of biology activities to be crowd-sourced and breaking up the aspects of professional work into components to be completed by amateur practitioners are major challenges in this direction. In a DIY design perspective we see opportunities for appropriating laboratory equipment such as microscopes, PCR machines and incubators as citizen science tools that gather data for distributed research experiments. This might enable professional biologists to crowdsource aspects of their research amongst hobby communities, similar to other initiatives that involve citizens in the collection and sharing of scientific data [25, 24]. Furthermore, designing data collection and sharing platforms and implementing proper data validation mechanisms to ensure the credibility of information will open up more research opportunities at the intersection of HCI, biology and engineering.

Conclusion

In this paper we presented the findings of our autoethnographic study in practicing DIYbiology inside our HCI studio. Our findings reveal the challenges and opportunities of practicing DIYbiology outside of professional setups. In particular, our work suggests three directions for future multidisciplinary research: 1) interactive educational platforms for scaffolding biology expertise; 2) low-cost tools for performing biology work in non-professional settings; and 3) citizen science systems for crowdsourcing DIYbio research. Above all, we hope to have shown how DIYbiology can be practiced in an interaction design setting, and hope to proceed with building HCI systems at this intersection. We wish to extend our work by gathering the expertise and techniques required to carry out more complicated protocols and experiments such as bacterial transformation and bacterial genome editing inside similar environments.

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