Hackademia: Building Functional Rather Than Accredited Engineers

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ABSTRACT
Hackademia is a semi-formal learning group that introduces largely non-technical students to basic technical skills by presenting them with open-ended challenges in a peer-based, collaborative environment. This project has two main goals: the near-end goal has been to use a collaborative design model to develop a working, scalable model for teaching engineering literacies in higher education, and the long-term goal is to create participatory opportunities for end-users to develop innovative technologies. This paper describes progress towards the short-term goal, and lessons learned from two years of work to develop a semi-structured educational experience influenced by participant desires. Hackademia leverages a participant-observer research model and participatory research methods such as auto-ethnographies, experience blogging, and semi-structured focus groups.

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Informal learning, technology design, higher education, DIY, Participatory Design, engineering literacy, makers

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K.3.2 Computer and Information Science Education, Curriculum, Literacy

INTRODUCTION
Increasingly, we turn towards technology design as a means of solving complex problems and organizing social life. To participate meaningfully in many conversations about design, however, one must be fluent in the language and practice of technology, and those without technical expertise are often excluded from conversations that shape material reality. Our project, Hackademia, aims to broaden participation in conversations and activities surrounding technology design by providing non-science, technology, engineering and math (STEM) university students with functional science and engineering skills, and a vocabulary with which to communicate effectively to those who come from STEM disciplines.

Many emergent educational initiatives are aimed at promoting STEM education (NAE, 2012; NRC, 2009); these projects primarily strive to recruit students to STEM degree programs and retain them as they navigate through a particular STEM degree pathway. While these projects, like our own work, seek to promote a technologically and scientifically literate populace, they are largely concerned with turning out students who have specific and quantifiable expertise and will seek STEM-related jobs once they graduate. Hackademia takes a slightly different approach: we focus on informal skill development as opposed to official notions of expertise, and we also focus on adults. We aim to create functional—rather than accredited—engineers, people with engineering literacies who can apply that knowledge in their everyday life, even if it does not form the core of their careers. The blending of technical and other skill sets allows for powerful multi- and interdisciplinarity, which, we argue, contributes to innovation and creative problem solving.

At issue here is the conception of expertise and how it is wielded within an educational context; while expertise is crucial to the notion of accrediting professionals, it need not be the only banner under which we conceptualize knowledge production. Additionally, we hypothesize that larger societal and innovation goals will be met by producing a larger pool of individuals who have functional STEM skills, even if they are not ultimately accredited STEM professionals. In particular, various industries at the intersection of technology and other fields may benefit from a workforce with truly varied skill sets. Ultimately, a citizenry with engineering literacies is more able to engage critically with technology in both the production and consumption of technological artifacts.

Universities generally wax poetic about the concept of interdisciplinarity, but there is much room for the design of novel educational models to make interdisciplinarity both more pervasive and more successful. We, a professor and group of students at a public university in the United States, believe that traditional modes of instruction in higher education—largely formal and highly specialized (NRC, 2004)—prevent the sort of interdisciplinarity that can lead to the design of disruptive technologies, systems, and processes. We believe that non-experts can be (and often are) innovators, but that traditional models of expertise confine students’ ability to pursue and acquire skill sets that are deemed outside the scope of their current discipline; this narrow sense of expertise is ultimately tied more to identity than aptitude. For example, computer science students are often encouraged to focus more on programming skills and less on design competencies, though many of today’s problems call for an understanding of the interplay
between these skills. Similarly, students in the humanities are not often encouraged to learn technical skills that could help them more effectively participate in conversations about potential social and cultural implications of technologies.

Hackademia—our attempt to address some of the constraints we perceive in higher education and culture at large—is both an educational model and a habit of mind. For two years, we have been conducting an experiment in which largely non-technical students are introduced to basic technical skills in the context of a semi-formal learning group with open-ended challenges. Technical skills learned by participants have included 3D modeling and printing, programming, and basic electronics. Students have engaged in projects in diverse domain areas such as wearable computing, game design, and networked communication systems. Through data collected from participatory design methods and via participant-observation, we have iterated upon the structure of the group in order to generate a viable, replicable, and scalable model for creating functional engineers.

We selected a Participatory Design (PD) approach in our creation of the Hackademia model because its methodologies were especially well calibrated for the intervention we hoped to create, as they are aimed at uncovering tacit aspects of human activity, and, in partnership with participants, cooperatively designing artifacts, processes, and environments (Spinuzzi, 2005). Designing educational models is an area ripe for a participatory research approach; all too often we assume learning models are working if they result in an improvement in narrowly defined learning outcomes, but participatory design research methods can help illuminate opportunities for learning models that support students along dimensions that go beyond just knowledge acquisition. For example, even within traditional engineering education, scholars encourage educators to attend to student development more broadly, including such things as identity and relationship development (Sheppard et al., 2008). These ancillary goals are best articulated through a participatory approach.

The PD community has also become interested in issues of democratizing innovation and creativity (von Hippel 2005; Björkgvesson et al., 2010). Because our ultimate goal is to create participatory opportunities for end-users to develop innovative technologies, Hackademia is very much in conversation with issues surrounding the democratizing innovation debate, and our long-term vision for the project is to provide a mode of literacy education for adults that can support invention.

As mentioned, previous and ongoing design efforts for Hackademia primarily use a participant-observer research model and participatory methods including auto-ethnographies, reflective experience blogging, negotiated hands-on learning activities, and semi-structured focus groups to derive an effective, co-designed educational model. The overall project has two main goals:

1. The short-term goal has been to develop a working, scalable model for technical skill development in higher education
2. The long-term goal is to create participatory opportunities for end-users to develop innovative technologies.

This paper describes progress towards the short-term goal, and lessons learned from two years of work to develop a semi-structured educational experience where participants’ needs, skills, and desires have a direct influence on the curriculum.

BACKGROUND AND MOTIVATIONS
This project began as a satellite project from the Design for Digital Inclusion (DDI) research group at the University of Washington. The DDI group researches diversity from a design perspective, and it typically works in the domain of Information & Communications Technologies for Development (ICT4D) (e.g., low-cost tools for healthcare, transportation information systems for low-connectivity environments) (Hope, 2012; Anderson, 2010). The Hackademia project arose from the group’s prior work—specifically years of international fieldwork—that highlighted grassroots innovations created by non-experts. At the same time, the lab’s director had become involved with the maker and hacker communities, which mirrored a similar pattern of un-credentialed innovation. Observing these two patterns led lab participants to interrogate how non-experts can contribute to technology design projects in both developed and developing world contexts. The other motivating factor was an interest in investigating inclusivity and exclusionary patterns in US-based higher education, especially among technical communities.

Hackademia is named for a contemporary cultural moment—the proliferation of individuals who refer to themselves as hackers and makers—in conversation with academia. Hackers and makers tend to organize their activities around hackerspaces or makerspaces—community-based gathering places where people collaborate, learn, create, and socialize. Rooted in part in the Do-It-Yourself (DIY) movement, these environments may be for-profit or non-profit, private or public, but they attract people who enjoy figuring out how things work; hackers and makers. “Hacker” used in this context doesn’t necessarily mean a computer hacker who breaks into systems, nor does it refer to hobbyists; rather, the hacker identity combines a DIY ethic (i.e., hands on) with a passion for exploring the unarticulated potential of existing technologies. Physical hackerspaces provide the structure and resources that many individuals need to complete their projects, and they also provide important peer-to-peer teaching and learning opportunities. The maker/hacker movement is growing, as evidenced by the success of magazines devoted to the topic, DIY websites, kits and businesses, and the proliferation of hackerspaces across the globe. The organization hackerspaces.org maintains a wiki listing of maker- and hackerspaces, estimating over 1000 active or planned hackerspaces around the world as of May 2012. The maker ethic that underlies these different community elements emphasizes
lifelong learning by discovery, and exploration that motivates learners to develop self-directed, creative problem-solving skills. It was these elements that helped inspire Hackademia, and that have also inspired recent initiatives by the MacArthur Foundation through their Digital Media and Learning initiative (Ito et al. 2009), as well as a growing movement among museums to include makerspaces as part of their exhibits.

Thus far, researchers have explored different aspects of the hacker and maker movement, including: how makers use online information-seeking tools to access craft knowledge (Torrey 2009), how IKEA furniture hackers express creative identity online (Rosner & Bean, 2009), and what processes and values distinguish DIY communities from other communities (Kuznetsov, 2010).

The design of Hackademia has also been informed by education research and best practices in the design of environments and experiences for informal learning, project-based learning and research-based learning (Baxter Magolda and King, 2004; Kegan, 1994). The grounding of this project in these different research communities provides an opportunity to connect to a broader sense of how learning occurs in non-traditional spaces, as well as how to support learning in these environments.

THEORETICAL FOUNDATIONS

From the beginning of this project, we believed that a participatory design approach would help us create and iterate upon the design of Hackademia to make it best match the types of learning desired by students. In order to build the Hackademia model upon best practices in educational design, however, we first turned towards educational theory literature. From this work, we identified several theoretical models that resonated with the primary goals and values of the project. Ultimately, the main value of Hackademia—open-ended challenges as a pathway to skillset acquisition—aligns well with the principles and assumptions of the Learning Partnership Model (Baxter Magolda and King, 2004). Principles of the Learning Partnership Model include: 1) validating learners’ capacity as knowledge constructors, 2) situating learning in learners’ experience, and 3) defining learning as mutually constructing meaning. Assumptions of this model include the recognition that knowledge is complex and socially constructed, one’s identity plays a central role in crafting knowledge claims, and that knowledge is mutually constructed via the sharing of expertise and authority. For example, in the Hackademia environment, open-ended tasks provide students with opportunities to validate their capacity to construct knowledge. More specifically, students are encouraged to take an active role in the design process through the lack of specific external guidelines, either in terms of what skills to learn as well as how to acquire them. This approach meets students where they are at the beginning of the course, it uses their background as the learning framework, and it allows student groups to collaboratively define the pathways of their skill acquisition.

The overarching purpose of the Learning Partnership Model (Baxter Magolda & King, 2004) is to provide an environment and activities that strike a balance between support and challenge, and through such a process there is potential for students to develop into self-authoring individuals—individuals capable of engaging with the complexity of knowledge based on internally defined values and beliefs. By adopting a semi-structured learning model, Hackademia provides multiple ways for both support and challenge to be explored. Self-authorship, which is integral to this learning format, is a developmental theory concerning intellectual, identity and relationship development (Baxter Magolda, 2001; Kegan, 1994). Self-authorship development is characterized as movement and growth along these three dimensions, and, more specifically, this movement is often characterized as moving from growth being externally defined to internally defined. In this case, the traditions of higher education validate students’ identity and knowledge as “technical” through such things as formal degrees and certifications. In activities and environments that provide a balance of scaffolding and challenge, such as Hackademia, there is potential, by contrast, for student growth towards self-authorship (Baxter Magolda, 2001).

Some details about how Hackademia functions within the institutional setting are important. We refer to Hackademia as a semi-formal learning environment because it is an academic credit-bearing activity, but it is not a formal class with traditional instruction or even a syllabus. Instead, students sign up for credit in the sponsoring faculty member’s department. In this case, the institutional structure includes ‘Directed Research’ credit opportunities, which are similar to independent studies but are group-based and usually focused around research projects. There is a dedicated room for Hackademia, with some basic furniture, tools, and supplies. In this way, the Hackademia space functions like a studio environment commonly found in design education environments. When students sign up for credit they are granted permission to check out a key for the room. As Hackademia evolved based on student feedback, we instituted a tradition where students sign up for “office hours” in the room so their co-learners know when other community members are around and available for collaboration. Students are encouraged to bring in a bin and label it with their name to keep parts and projects-in-progress safe from collective sharing (i.e., poaching). Participants are undergraduate and graduate students who come from a variety of departments across the university with a variety of different skillsets. To accommodate the diversity of students, expectations are set at the beginning of each quarter so students know they are entering a learning environment that will be open-ended and collaborative, and that they will be expected to set their own learning goals. Many of these project elements have evolved over time, in part as a result of learning from previous challenges, which we will discuss in our findings section.

Since Hackademia specifically seeks out students who don’t define themselves as “technical” (which is a different criteria than students who are externally credentialled as technical via an academic major or
demonstrable technical skills or achievements) this larger conversation of what constitutes “being technical” is a central component of the initiative. Indeed, for us, the issue of “being technical” is an unarticulated piece of the STEM debate. The negotiation of who gets to call themselves technical or operate as one with technical knowledge within the larger culture drives our project. Outside of specific educational preparation and employability, being a functional—if not accredited—scientist or engineer increases one’s ability to be an informed citizen, consumer, and problem solver—and to participate more fully in an increasingly technologized society. However, what constitutes “being technical” is, admittedly, somewhat of a moving target.

METHODS
In this paper, we analyze three types of primary data, which together inform our findings. The first is a set of autoethnographies, reflective short essays that students write as they join the group, which provide them an opportunity to reflect on themselves as technical learners and doers. Our analysis also builds on co-designed educational activities and experience blogging done by participants. Finally, we report on focus group reflections conducted three times during the two years which provided an opportunity for more formal evaluation of ongoing activities. Four of the co-authors of this paper participated in and/or helped develop Hackademia, and their experiences serve as a backdrop for analysis of these data sets. Each of these datasets also provide a sense of students’ progression through Hackademia, and so they provide a beginning, middle, and ending view of the Hackademia experience from students’ perspective.

The autoethnographies (Patton, 2002) represent the beginning of students’ journey through Hackademia. In these narratives, students self-report their personal experience with technology and characterize themselves as technical learners, including key moments in their developing relationship to technology.

The material produced as a result of the Hackademia meetings and projects—the experience blogging and co-designed educational activities—are the in-progress perspective produced throughout the quarter. These materials include: analysis of activities and how student learning goals are tied to ‘becoming technical,’ a catalogue of successes and failures across the different groups, and 104 blog posts (Hookway, 2008) which characterize students’ daily and weekly experiences in Hackademia, and their progress towards completing open-ended challenges. This work is characterized as participatory design primarily because the involvement of students as part of the design team and data collectors was built into the structure of Hackademia.

Finally, after involvement with Hackademia, students in these pilot offerings were invited to participate in focus groups (Patton, 2002), which allowed a space for them to collectively reflect on their experience in the group. These focus groups helped us understand to what extent participants experienced Hackademia as an opportunity to increase their level of technical skill, consider their own definitions of what it means to be technical, and develop motivation and self-efficacy towards being a technical learner (Turns, 2010). Students were also encouraged to provide the focus group facilitators with feedback about the structure of the group and activities, and ideas for future iterations of Hackademia. Two of these three reflective activities were organized and conducted by a faculty member who was not affiliated with the project. The organizing faculty member participated in those two focus groups as a research subject. The first focus group, conducted in November 2010, consisted of four students involved in the inaugural Hackademia group. The second focus group, conducted in June 2011, consisted of five students, and the third, conducted in December 2011, had nine students. The conversational, reflective nature of the focus groups have made them invaluable tools for soliciting critiques from students about structural elements of the Hackademia group and identifying opportunities to better scaffold future students across many dimensions of the learning experience.

Students remained involved with these initial offerings of the group in overlapping waves, providing consistent input into how the educational model eventually evolved. When students enrolled in the group, they were told explicitly that they would be both participants and subjects – conducting research with and about themselves and their classmates. Their role in helping us learn about how people learn, and consequently create a better model for future learning, was explicit in both recruiting documents and in the discourse throughout the meetings.

Finally, for the analysis of written artifacts (the autoethnographies, blog posts, and reflection focus group notes) we used thematic analysis in order to better understand the nature of students’ experience participating in Hackademia (Miles & Huberman, 1994). In order to ensure rigor, two authors conducted each of the analyses and conducted member checks (Yanow and Schwartz-Shea, 2006) in order to make sure the students’ experiences were accurately characterized.

Hackademia in Practice
We conducted experimental Hackademia sessions for two years. This timeframe includes eight academic quarters (the ninth just concluded), with two of those occurring over the summer with much decreased activity. Across those eight experimental terms and the current pilot model, 27 students participated. Figure 1 shows the students and the amount of time they spent in the group. As you can see from the overlapping cohort, there were some consistent voices through much of the active design stages; not represented below is the continued involvement of the third-line contributor, a student who after three terms began helping to coordinate the group, who continued to research alongside everyone, and who is a co-author on this paper.

The advantage of having students participate over multiple quarters meant they were able to experience the changing nature of the educational model they helped develop through their reflection and contribution, and thus their ongoing suggestions benefitted from having experienced both failed and successful approaches in other terms.
Initially, participation in Hackademia required students to commit to structured and unstructured time. There was a weekly meeting time that the faculty facilitator attended, and students gathered on their own during other times. Meetings with the facilitator were explicitly reflective sessions, and while most of the time her approach was playfully characterized as “benign neglect,” it became clear during the first quarters that some direction was required at a few points, including constraining the potential problem space and helping guide the group to an appropriate leadership model. The analysis that follows helped to guide our revisions of the group structure. For example, as time went on and more iterations of the group were tried, those weekly meetings with the facilitator increasingly became a mix of hands-on activities and conversation about the learning that was happening for individual students, skills they’d like to explore, specific pathways for next steps, suggestions for community contacts who can help them with their projects, and comments about the learning reflection on the blog.

As mentioned previously, Hackademia is a semi-formal learning group that provides academic credit to students, but is not generally tied to students’ major degree programs. Because of this positioning, recruitment takes time and effort. Since the first offering of the group, students have been recruited through a mix of email announcements and word of mouth. Most rounds of advertising involve emails to advisors in other departments where the supervising faculty member has personal contacts. Recruitment announcements present the group as a learning and research opportunity, and they provide details on whether a technology theme is part of the upcoming term. For example, in the debut term, students were invited specifically “to participate in a hands-on exploration of how nontechnical people acquire technical skills.” For this first offering, the group was given a specific task: assemble a kit-based 3D printer, a Makerbot Cupcake (see Figure 2). The Cupcake shipped disassembled, with no instructions. All material for constructing it resided on a wiki, and there were extensive user forums. Students were directed to these resources and told to “figure out how to put it together” as well as capture their own research and learning activities. We developed forms and protocols for logging which sites had most value for our learning, and we created a collective blog for chronicling and reflecting activities. Each Hackademia group since then has continued with explicit reflective activities about their learning, which forms the core of our data presented below.

The Hackademia project is ongoing, incorporating new students each quarter, and evolving in format. Our initial goal when we began the experiment was to develop an understanding of how nontechnical adults learn technical skills in an unstructured setting. As we analyzed our data and experiences, and as we present in the findings below, it became increasingly clear that the road to becoming technical had to do with many more factors other than actual technical skill acquisition. The process of becoming technical involved a combination of identity and instructional issues.

FINDINGS

Our findings here are drawn from autoethnographies, experience blogging, and reflective focus groups, and they focus on lessons on both the form and function of the Hackademia experiment.

Self-efficacy and Identity as Drivers of Technical Skill Acquisition

Each student who participates in Hackademia begins by writing a short, reflective piece about their relationship to technology. These autoethnographies (n=27) represent students’ view of themselves as technical learners at the moment of starting their participation in Hackademia. The autoethnographies were designed to cultivate a self-reflective stance among the students and heighten their awareness of themselves as active participants in the design of the educational activity. Autoethnographies are a means of “studying one’s own culture and oneself as part of that culture” (Patton, 2002, p. 85), and they offer personal stories and “translucent windows into cultural and social meanings” (Patton, 2002, p. 116); they were also an efficient way to provide a shared understanding of where one’s peers were in terms of technical backgrounds. Additionally, the activity provided background information for the facilitator, which helped
guide decisions about creating useful starting activities that would leverage students’ prior experiences.

The autoethnographies also provided initial insight into the demographics of participating students. These students had a range of prior experience with technology and identified a variety of ways in which technology had impacted their lives. More specifically, the autoethnographies revealed the following two main themes: (1) acknowledgement of others’ influence on their recognition and identification of themselves as technical and (2) recognition of the role of technology as social capital.

Most of the students identified a specific person who played an important role in their use of technology, such as a parent, teacher, or friend, as well as how these individuals affected their attitudes toward technology. For example, a few students commented about how their parents’ career in technology had affected what technology the student was introduced to. Even further, a few students described family members as “tinkers,” which had an impact on how the student viewed the world. One student remembered a specific incident in which his father supported his development toward becoming a “tinkerer,...curiosity runs like a thread through my childhood...I can still remember my dad handing me that first unfortunate dash-radio, telling me I could take it apart.” In these instances, the support of others (e.g., teachers, parents, siblings, cousins, and friends) helped the students first conceptualize their potential ability to be technical, and even then in the process of becoming and identifying him or herself as a “technical” person.

Many of the students recognized the importance of their domestic environment, independent of school or community resources. The influence of the domestic environment was both positive and negative in terms of students’ sense of self-efficacy with regard to technology. These differences were often grounded in economic class.

Many students described their first introduction to technology from within their homes with a family computer. One student described his family as technology early adopters: “growing up, my family and I have stayed pretty up-to-date on the latest technology, especially when it comes to having the resources that are important tools for my education.” Furthermore, for several of these students, access to such technology ignited their interest and passion for technology. While many students recognized that family social capital affected their introduction to technology by providing access, other students, mainly older, non-traditional and immigrant students, recognized the implications of their family not having such access to technology. One student explained coming to recognize the importance of technology in a way that contrasts sharply with the childhood ‘ever since I can remember’ memories of the earlier student: “I grew up in a very poor family with 5 siblings. We didn’t have much and not until close to junior high school was I able to really enjoy technology and understand how it could work for me.”

The most useful findings from the autoethnography assignment emphasize the importance of understanding one’s history as a component in determining the extent to which one sees him or herself as technical. In addition, the themes of social network-based introduction to technology and realizing the social capital represented by technical knowledge helped us recognize some of the emerging and essential components involved in labeling oneself as a technical person. A focus on this labeling made it clear that defining oneself as technical or nontechnical was an act of language more than a recognition of skill. Additionally, findings about the importance of one’s social network to technical skill development led us to pursue ways in which our students could connect with informal technical learning communities situated outside of the University. These findings additionally reinforced key elements of the learning partnership model discussed earlier, which led us to focus Hackademia as a pathway to self-authorship.

Connecting Outside the Academy
Throughout the experimental phase of Hackademia, students were encouraged to make use of community resources such as local hackerspaces, social gatherings of like-minded people at lectures or special events, online communities, and individual domain experts. In every quarter – including those largely characterized as ones where the project output (though not student learning) was a failure, students leveraged these resources with enthusiasm. These connections meant that even in the terms when little actual technical skill acquisition occurred, it was clear that students were gaining lifelong learning skills by connecting to learning communities outside of the university. The facilitator made them aware of some resources, but did no actual outreach on their behalf. Groups took the initiative and coordinated field trips to interact with communities outside of the university engaged in similar activities. Many of these forays outside of the academy ended up as fodder for the reflective blogs kept by the students.

Experience Blogging Cultivates Reflection
Since the beginning of the project, students were asked to document their experiences by maintaining a blog for the duration of their participation in the semi-formal learning groups. In addition to documenting daily interactions and tasks, the blogs provided a place for students to articulate and set goals, to reflect and explore their motivations and experiences, and to experiment and discover their evolving narratives of self and identity. Through blogging, students publicly depicted their actions and involvement with technology, declaring their interest and progress to themselves and the world.

In keeping with the self-structured nature of the semi-formal learning groups, the blogging activity was left to the students’ discretion; the frequency, topic, and length of each post was determined by the author. As such, the blogs document an array of topics from a variety of perspectives and sometimes even present a single event from multiple perspectives. The aim of the blogs was to provide another window into the learning process, including the inevitable frustrations and victories the students faced.
Some students augmented their blog posts with photos, which ranged from external influences and sources of inspiration to pictures of successfully wired LEDs and self-portraits, as well as images of broken parts and failed endeavors. Photos take a little extra time and preparation to upload, so the images provide additional insight into the things students deemed important enough to document with both words and images.

The blogs were intended as places of reflection, but for some students, the blogs served as daily logs of activity devoid of personal commentary. Such blog posts seemed almost perfunctory, and did not achieve the goal of providing insight into the learning process. In one case, three students visited a local hackerspace located off-campus and then wrote three individual blog posts about the experience. This blog activity had the potential to provide a snapshot of each students’ learning at a single point in time, along with their varying responses to a single shared event. However, the outcome was three blog posts that documented only the actions of each team member, with little interpretation, even when the students described struggling with and subsequently achieving a task: “When we tried to light the LEDs with the device, it didn’t work...After a while, we figured out that it wasn’t our wiring that was wrong, it was that the LED was just dead... When we wired together two new LEDs, they both lit up.”

Some students did use the blog to reflect on their experiences, and noted changing attitudes with surprising clarity and marked self-awareness: “I realized that I was feeling much more relaxed and willing to enjoy the process of collaboration than last week.” Another student remarked on his lack of participation and how this changed over time as he waited patiently for the other team members to catch up with him: “As for myself, I stood on what felt to be the periphery, quietly listening and building... and waiting.” Here, a student expresses the sense of a new identity, moving from “noob” to someone who is responsible for their own learning: “I’m a noob... This research group has not so much grown me as it has allowed me to see areas in which I need to grow... Perhaps that means I’m now more responsible for what I do...” Students occasionally attributed their growth directly to the research group experiences: “In the past few weeks I have bought a few sensors to experiment with and I’m starting to think about projects beyond this class that I can possibly incorporate into work or just for fun... In the beginning of this class, I wouldn’t even have thought of this being possible.” Another student recounted her plan to build a computer and observed, “this really did happen, and it wouldn’t have happened nine weeks ago.”

Analysis of the blogs revealed the importance of communities of practice to the students. The students most often worked as a small group in a dedicated space on campus. However, their tasks (e.g., building a 3D printer or learning to use an Arduino) necessitated reaching out to virtual and physical hacker/maker networks. In Seattle, where the research takes place, there is a robust network of makers who gather at different spaces and events to exchange ideas and socialize. Students blogged about their experiences at Metrix: CreateSpace, a workshop open to the public, and DorkBot, a monthly themed maker/hacker event. Almost without exception, the blog posts describing interactions with the larger hacker community revealed a keen appreciation for the expertise available in these spaces. Students also reflected on their preconceived notions of the types of people they would encounter. One student’s description embodies the tension of being an outsider quite well; at first, she admits she is intimidated, presumably because of the expertise of the people she anticipated meeting. Immediately after, she alludes to the hackers as “nerds”: “I was quite intimidated by the thought of going to Metrix Create:Space. I pictured a dark dank nerd-filled space with the air of intellect and closure. Instead of the cold shoulder, they gave us a tour of the shop and we were shown a room that housed the 2 in-house Makerbots, the different materials used, and a laser cutter (not part of the Makerbot process, but cool nonetheless).” The student’s perception of technological proficiency as exclusionary suggests that she sees herself as an outsider, someone who lacks technical expertise. A teacher at Metrix was described as lacking a “demeaning tone,” suggesting that the student expected to be condescended to and noticed when she was not.

The findings from running successful and failed groups over the past two years has given us a model for running our current Hackademia groups. The results from the autoethnographies and the blogs have also helped to establish a framework within which we can situate the larger activity in which we’re engaged: creating functional engineers who are poised to be innovators.

**Constraint and Scoping**

Throughout the two years of experimenting with models, open-ended invitations to choose a project were generally met with bewildered stares. Small, structured activities like asking students to blog about possible projects in a constrained space (e.g., wearable technologies) or posting projects they liked and explaining why they liked them, did not provide enough structure to enable meaningful dialogue and generate forward motion. Eventually, the facilitators tried handing students a list of potential projects, across multiple domains that they could read about and select from, or even use as inspiration for their own choices. Invitations to blog or use the group email list to discuss project ideas and collectively narrow the group’s choices also yielded little focus. Projects in the group were not individual, and so deciding on a project required group coordination. Negotiating multiple pathways for individual and group contribution proved difficult. Additionally, the tension between balancing openness and constraint proved an ongoing challenge for group facilitation.

The terms during which students were given a defined task (i.e., build a Makerbot) were ones where activity started early, students found a larger support community outside the group quickly, and where the greatest challenge was leadership models. The terms where students needed to select their own projects, by contrast, started slowly with at least two largely wasted weeks, and
they left the students feeling unmotivated to explore possibilities for their learning.

The most notable failed project attempt occurred in the first year of the experiment, and that example provided valuable lessons in the importance of scoping. In the second and third quarters, one student wanted to experiment with motion capture. He had turned a giant television screen into a touchscreen. He championed a project that would use his technology, and the rest of the group brainstormed a project to wrap around the technology. They eventually settled on an interactive story. The general shape of the project was a wearable bracelet using either infrared or Bluetooth that, when worn into the room, would launch a character in the story. That character would respond to the presence of whoever was in the room. The project was ambitious, and we recruited outside experts to help the students. However, the project eventually resulted in a frustrated group of students and little progress. As we reflected on the project, we came to understand several factors that may have contributed to the students not completing the project. One of the most important factors we identified was the importance of appropriate scaffolding to match the project scope and constraints.

**High Expectations Require Significant Scaffolding**

That previously described project was very ambitious, and while the students were enthusiastic about the high expectations placed on them, the facilitator failed to provide appropriate scaffolding mechanisms for the skills they required to succeed. Later in the term the group began working on small chunks that would be achievable, such as pairing an Arduino microcontroller with an infrared sensor, but it was too little too late.

By contrast, within Hackademia we now introduce basic skills to students through a set of structured activities designed to encourage peer interaction and provide tangible products of success. The Hackademia tagline, “Creating Functional Engineers One Blinky LED At A Time” is taken seriously, and during the first week students self-organize to each gain experience programming an Arduino microcontroller to make an LED blink. They build a little programming and electronics experience in that first week, and they blog in order to reflect on the activity. We also make pop-up cards using copper tape to build circuits and light LEDs. Both the Arduino and the card assignment are designed to scaffold students in acquiring specific skills they can leverage later as they work on more complicated projects. The Arduino activity gives them an experience writing code to make hardware do something visible; in order to succeed they need to learn about and leverage online code libraries. This in turn forces them to explore the extensive online community around certain technical areas. The copper tape circuit activity is a crafty project that introduces them to very basic ideas about circuits. Since it also involves glue sticks, scissors, and colored paper, it’s a great opportunity to have a conversation about how technical skills are often contrasted with crafting activities and assumptions about gender that are embedded in that distinction.

The lesson from the touchscreen project failure was that in addition to scoping, structuring learning for more extensive projects is important to leverage student enthusiasm and create pathways for their later success. Ultimately, though, the group had signed on to the project without understanding the complexities involved or having a shared vocabulary which led to another central tenet of Hackademia.

**Shared Vocabulary**

In addition to the rather spectacular failure described above, we had quarters where students spent months trying to get a single question answered. When the facilitator connected them with individuals who had necessary domain knowledge (in one case, RFID technology), the students were unable to elicit the required information from the subject matter expert. As a result of the touchscreen and the RFID examples, we became acutely aware of the importance of shared vocabulary, especially as we reflected on the way the touchscreen project was selected without participants understanding all of the technical issues inherent in the design.

Access to technical vocabulary and concepts is absolutely essential to being able to gain actual technical skills, but it is difficult to create opportunities to acquire basic building blocks of both vocabulary and concepts. If you never learned the difference between a Philips and a Flathead screwdriver, how would you come to recognize that difference? As a result, Hackademia takes vocabulary very seriously.

We begin each term now by performing an inventory of the lab’s materials and supplies, relabeling drawers as necessary, and rearranging their contents so they are meaningful to the group. While this looks like a basic housekeeping task, it is a mechanism through which all students are introduced to the names and functions of different tools. It provides a common vocabulary and assures students have some basic understanding. It also gets them comfortable with saying “hey, what’s this called?” As we go through tools and materials, we also discuss what kinds of tasks each tool is good for, and the concepts related to the tool and its use. We have also begun making short videos to create a video vocabulary resource and connect to the community outside the university.

**DISCUSSION**

Participant input drawn from two years of Hackademia in practice has been instrumental in helping us refine an educational model that helps students move towards self-authorship and acquire STEM skill sets. In particular, our participants have helped us grapple with the complex notion of what it means to “be technical,” and they have helped us identify several future directions for Hackademia to pursue.

**On “Being Technical”**

As discussed earlier, understanding what constitutes “being technical” is a central component of this project. The autoethnographies provided a starting point for us to understand the ways in which students categorized themselves as technical or non-technical (or somewhere...
in-between) at the outset of the project. In the autoethnographies, many students offered strong, absolute statements about their technical identity (e.g. "I have never been particularly savvy with technology..." or "I have always viewed this world from a mechanical perspective").

When we held reflective focus groups with three Hackademia groups at the end of the term, our goal was to understand how elements of this self-conception might have changed after participation in the group. We were also interested in understanding whether or not the students experienced an increase in material technical skills. The focus groups generated both straightforward insights in terms of technical learning outcomes, and more nuanced and complex insights about identity issues, or, what it means to “be technical.” All students in the first group reported themselves as having acquired a range of technical skills, and an ability to collaborate with others in getting technical questions answered. Though they had acquired specific technical skills (building a Makerbot, for example, which requires mechanical and programming expertise) participants in the first focus group discussed amongst themselves at length whether or not they considered themselves to be technical. The students compared their own considerations of themselves as technical with whether or not society would allow them to claim this identity. The students described the difficulties of defining what it means to “be technical,” but that being considered technical by society at large carries cultural capital. All students agreed that there are material and social advantages to a technical identity, but they struggled to find clear or consistent definitions that aligned internal and external expectations of what it takes to "be technical."

**Making Hackademia a Success**

Students also provided us with feedback on what was successful for them, which has helped us refine the Hackademia model across academic quarters. In particular, students in the first focus group discussed four salient features of their experience: 1) an invitation to participate came from someone with whom students had a personal relationship, 2) the level of technical difficulty involved with the project was manageable, 3) an invitation to be attentive to and reflective of their learning experience was engaging, and 4) they felt a sense of belongingness with other members of the group.

Additionally, this group reported that some of the most important aspects of their experience occurred through field visits to locations outside of the university—a local meeting of electronics enthusiasts and an electronics workshop at a local makerspace, for example. In future iterations of the group, we have encouraged the students to participate in activities like these, as they were identified by participants as particularly important.

Students in the second and third focus groups reported that informal learning in general is not easy, but despite the difficulty inherent in this type of learning, once you are able to “make something work” or troubleshoot technical difficulties, it is very rewarding. Students in the third group suggested the addition of a common book or shared resource that participants in the next iteration of the group could read to better understand how to approach informal learning. This group of students described the various roles they enacted in Hackademia (e.g., as a teacher to their fellow students, a learner, an experimenter, a researcher, a teammate, among others) and how those roles changed throughout their experience. The majority of students experienced—and enjoyed—multiple kinds of roles. One student reported that he initially thought he would not be able to be a good teacher to other students due to having limited patience, but that he actually found it enjoyable. These findings have inspired us to integrate new opportunities for peer teaching (e.g. ‘skill share presentations’ in the current model).

Students in the third focus group also described challenges they encountered throughout their experience. This group, in contrast with students from the first and second focus groups, worked on two technical projects of their own design (two different light-up jackets), which did not come from a kit. Students split into two groups to build the jackets. They reported that choosing a project to work on was very challenging because they felt compelled to make something that had not been done before. In response to this feedback, we now spend additional time and effort at the outset of each quarter helping students select an appropriate project, and emphasizing that students can build from existing work and need not be overly concerned with novelty.

This group also described some of the communication issues they encountered while working on the project. One student mentioned that she felt that at times nothing was really happening in the group. Another student reported that some of the work was occurring at an individual level and was thus invisible to the group at large. This finding underscores the importance of scaffolding better communication practices among group members, and in the design of subsequent groups we have asked participants to create a shared online schedule of when they will be in the workspace. One student in the current Hackademia group made a “status report” timeline on the whiteboard in the workspace in order to facilitate information sharing about the three separate projects members were working on.

As described in our findings section, we also found that social capital is essential to building sustainable participation in technical communities outside of institutional structures. Hackademia group members have enthusiastically embraced the learning communities outside the university, and they have established concrete pathways for lifelong learning.

Students, especially non STEM students, who want to continue to work on technical projects need to be able to identify and use the networks of people and information available. The social elements of learning communities are well documented, and for the kind of “being technical” that informal learning encourages, the ability to collaborate and seek out expert knowledge is essential (Barron, 2006; Cole, 2006). This connection is a key aspect to the maker community and the DIY movement, which are essentially distributed learning communities.
that leverage technology for effective knowledge creation, collaboration, and dissemination.

**FUTURE DIRECTIONS AND CONCLUSION**

Hackademia continues today, based on the findings presented in this paper and other lessons learned that fall outside the scope of this discussion. The group has been a pathway to more technical engagement for some students, and others have come in and out over ten weeks, bemused by the experience but not necessarily changing their life goals. Some students have changed their majors as a result and all have made a blinky LED.

Our goal is to continue leading the group. Over the coming academic quarters, we will do more systematic outreach to arts and humanities students, and we will continue to ensure there is a mix of undergraduate and graduate students in the group. In the longer term future, we hope to sponsor Hackademia reunions, bringing together students to work on specific projects, perhaps tied to competitions for innovative technologies. Also, we would like to expand the model to other universities to see how it plays out in other institutional contexts.

But in the meantime, we are gratified to realize that every student who has participated has engaged in reflection on what it means to be technical and they have interrogated the idea of a fixed technical or nontechnical identity for themselves or others. This, in turn, has forced them to interrogate notions of power and expertise in the larger culture. The eventual hope, of course, is that they carry with them a curiosity and willingness to experiment with knowledge they may have previously considered the domain of “experts.” The group is certainly a success if participants move forward with their basic functional engineering skills and feel able to engage in an ongoing conversation about technology and culture.

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