Methods for Examining the Educational Pathways of Adult Makers

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Abstract

This paper presents our methods for examining the educational pathways of adult Makers. Through critical incident interviews and artifact elicitation interviews of a segment of Makers collected at Maker Faire events, we seek to develop a theory based on the knowledge, skills, attitudes, and pathways of Makers to inform future innovations in formal engineering education, specifically in the areas of *practical ingenuity, creativity* and *lifelong learning* of our future engineers. Our primary research questions are: **(RQ1)** What knowledge, skills, and attitudes do Makers possess that could be related to engineering? and **(RQ2)** How do pathways of Makers intersect with engineering? The focus of this paper is to convey our methods for this work.

Introduction

We can probably all recall a friend or colleague who fits Apple's Think Different tribute to the practically ingenious. While sometimes they succeed in making big changes, they often lack requisite resources to fully realize their dreams - resources that could be facilitated by engineering training. Building on the work understanding student engineering pathways, our research seeks to examine the community of self-described Makers engaged in informal engineering education and tinkering activities. As Makers embolden characteristics from the *Engineer of 2020*, and in particular *practical ingenuity*, *creativity*, and propensity toward *lifelong learning*, we explore the question: **Should Makers be the engineers of the future?**

Using qualitative research methods of critical incident interviews, artifact and context elicitation interviews, we are developing a theory describing Makers and their engineering education pathways. Our primary research questions are: **(RQ1)** What knowledge, skills, and attitudes do Makers possess that could be related to engineering? and **(RQ2)** How do pathways of Makers intersect with engineering?

This study is grounded in the conceptual frameworks of Bloom's taxonomy and pathways theory, which provides a useful means to knowledge, skills and attitudes Makers may posses as well as engineering pathway decisions. A total of 36 participants are being sampled purposefully and equally stratified across the dimensions of age (college age and post-college age Makers) and engagement (through their formal engineering education, informal engineering education and tinkering activities). The study population is being over-sampled for underrepresented groups based on ethnicity and gender.

What is a Maker?

The Make movement is a phenomenon to describe the tinkering, hacking, re-making, and creating of technical artifacts, often done without prior expertise. Making comes from an imaginative, creative mind-space, done outside the confines of established engineering education curricular activities. Making has a do-it-yourself ethos and is historically rooted in efforts like *Popular Mechanics* magazine who demystified everyday stuff for hobbyists and the *Whole Earth Catalog: Access to Tools*[1] who surveyed everyday tools for the counterculture movement of the

1960s. Additional real-world touchstones are the growth of Radio Shack stores and the 1980s television program MacGyver where the lead character would resolve each episode's predicament by fashioning an escape plan out of found objects.[2] Technology and sharing of information via the Internet has greatly increased the ability for smaller communities with shared interests to coalesce and grow.

The label "Maker" is a self-determined one assigned by affinity or involvement in a larger Making community. Makers are do-it-yourself-minded individuals participating in informal communities (doing-it-with-others) that support and celebrate building and prototyping technical proof-of-concept exploration and ad-hoc product development. A Maker is a modern-day tinkerer and hands-on doer and fashioner of stuff. The range of expertise could be large but novices and experts alike share an enthusiasm and appreciation for building and creation. Individuals and groups embark on projects of all sorts, led primarily by their interests and curiosities, informed by their skills or the skills they want to learn. They make creative efforts like fire-breathing robots as performance art, combining contributions from community members with electrical, mechanical and embedded systems know-how[3] or construct intricate, wooden geometric puzzles CNC'd from exotic woods commissioned by patrons.[4] They show off their work readily and share their technical recipes with those interested.

Makers participate in communities of practice. They populate maker spaces and hacker spaces[5] and use commercial ventures like Tech Shop[6] to gather with other Makers. A significant part of such participation is to benefit from opportunities to continue learn from, teach and mentor other Makers.

Make magazine and the Maker Faire are champions of the Make movement and described as "a central organ of the maker movement".[7] Founded in 2006 as a quarterly publication, *Make* magazine presents "DIY Projects, Inspiration, How-tos, Hacks, Mods & More".[8] Its pages celebrate the people engaged in making and is a modern-day equivalent of the *Whole Earth Catalog* crossing technology with the category of tools covered. *Craft* and *Ambidextrous Journal of Design* have been additional efforts to capture the people and processes of crafting and design thinking respectively. Maker Faire has been an outreach effort of *Make* magazine, convening flagship, multi-day fair events in select cities and supporting smaller, regional one-day events around the country. Its credo is to "celebrate arts, crafts, engineering, science projects and the DIY mindset."[8] The first Maker Faire was in the San Francisco Bay Area in 2006, attracting 100 exhibitors and 40,000 attendees. In 2010, the Bay Area Maker Faire hosted 1,000 makers and had 80,000 in attendance.[9] Maker Faires have been held there since then, with Austin added for 2007 and 2008, and Detroit and New York in 2010 and 2011.

Makers volunteer to exhibit at Maker Faire festivals. They are assigned a 4' x 10' (or larger) space inside an exhibition hall or an outdoor area to then set up their exhibits and demonstrations. There are also workshops and talks on a main stage as well as special events scheduled throughout the event. For the flagship Maker Faire events, attendees pay a nominal entry fee for a ticket ($20-28) for admittance on one of the 2-day weekend festival. It is a place where Makers come and share what they have made and learned.

In addition to studying the educational pathways of Makers, we also have additional ongoing work to explore what Making is, and what the Maker Community is. We allow Makers to self-identify through their participation in and attendance at Maker Faire events, and ask for them to define Making and Engineering. The similarities (and differences) between these areas are discussed by the authors in another paper.[10]

Research Design

This research is guided by the following research questions and research design. Our constructivist grounded theory research questions are:

RQ1. What **knowledge**, **skills**, and **attitudes** do **Makers** possess that could be related to **engineering**? *(Makers as engineers)*

RQ2. How do **pathways of Makers intersect with engineering**? *(Makers' pathways to engineering)*

Crotty's[11] four elements of a research study (epistemology, theoretical perspective, methodology, and methods) informed the research design. The elements of Crotty are particularly salient for our rigorous research design because they inform each other; epistemology informs theoretical perspective which informs methodology which informs the selection of methods. Table 1 describes the four elements, specific theories and methods selected for this study and the rationale.

Table 1: Elements of a Research Study by Crotty[11]

	Definition	**Selected**	**Rationale**
Epistemology *informs:*	Theory of knowledge	*Constructivism* Knowledge is constructed through human-world interaction[12]	To understand how and what Makers learn through their creations
Theoretical Perspective *informs:*	Philosophy that informs methodology	*Constructionism* Meaning is created through constructing & sharing artifacts[13]	To understand how Makers create meaning through the design and sharing of their creations
Methodology *informs:*	Design connecting methods to outcomes	*Constructivist Grounded Theory* Researcher is the author of participant's voice and meaning[14]	Little is known[15] about what Makers know and their pathways. Methods must be sensitive to study objectives: to understand what Makers learn and how their pathways intersect w/engineering.
Methods	Implementation of methodology	Screening questionnaire Artifact elicitation interviews Critical incident technique interviews	To screen potential participants To understand Makers' creations / knowledge / skills learned by creating To study Makers' attitudes about and pathways intersecting with engineering

Research Methods

The study will begin with administering a participant screening questionnaire to potential participants, followed by an initial stratified purposeful sampling of participants who meet criteria self-identifying as Makers and being adults (18 or older). Artifact elicitation interviews, based on the method of photo elicitation,[16] and critical incident technique interviews[17] of approximately 1 hour each will be administered to all participants. Several times throughout the study, part of the research team will conduct an inductive analysis on the transcribed interviews (generating theory from the data), which will feed back to inform questions asked in the interview protocol. Simultaneously, another part of the research team will conduct a deductive analysis (fitting data to existing theory) based on relevant theories, including Bloom's taxonomy, pathways theory, social-cognitive career theory, adult learning theory, identity theory, motivation theory, and retention theory. The results from the inductive and deductive analyses will be triangulated to generate a preliminary theory of Maker knowledge, skills, attitudes, and pathways. New theories discovered from the inductive analysis but absent in the deductive analysis will inform the theoretical sampling cycle (see Figure 1) to choose additional participants to explore the new themes in more depth. Once saturation has been reached in the theoretical categories, the final results including a theory and profiles of individual Makers will be developed. This triangulated theory, inductively grounded in data and deductively connected to literature, will describe the knowledge, skills, and attitudes of Makers, along with how their pathways intersect with formal engineering education.

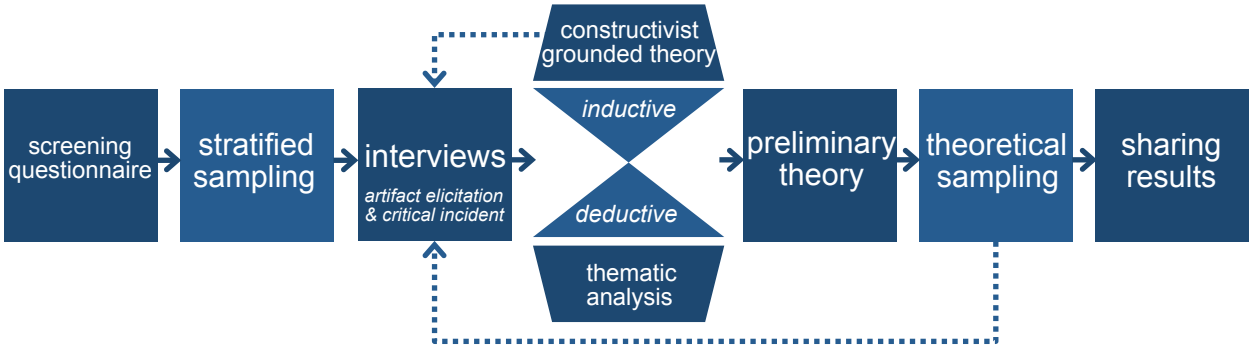

Figure 1: Research process (adapted from Martin[18] which also uses constructivist grounded theory to study the educational experiences of engineering students)

Population and Sampling

This study will sample the population of adult Makers (see Figure 2) in order to understand how their paths intersect with formal engineering education. The results from this study will inform a future pipeline study of young Makers and their consideration of careers in engineering. We will seek out Makers who participate in Maker Faires around the country, in addition to Makers who publish articles in *MAKE* magazine. Exhibitors at two flagship Maker Faires will be recruited (see Table 2) to create a pool of potential participants (the Bay Area Maker Faire draws over 500 exhibitors).

Table 2: Participant recruitment and interview opportunities (potential participant pool, location, date)

1500 Makers* at New York Maker Faire September 2012	1000 Makers* at Bay Area Maker Faire May 2013	1500 Makers* at New York Maker Faire September 2013	1000 Makers* at Bay Area Maker Faire May 2014

*number of Makers exhibiting at 2010 events[9]

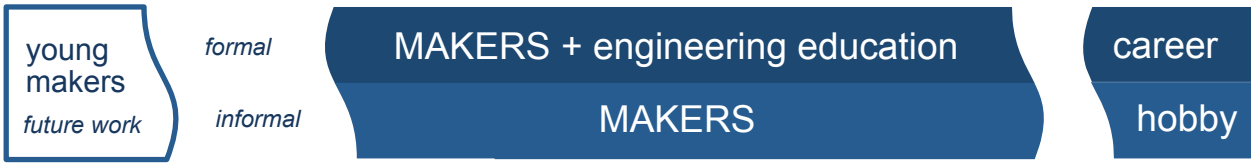

Figure 2: Target population for this proposal (N = 36)

In order to answer the research questions about Makers, a stratified purposeful sampling strategy[19] will be used for initial selection of the participants. Participants will be selected to maximize variation across the strata described in Table 3, while oversampling for underrepresented groups and ensuring that all participants self-identify as Makers. This sampling strategy is appropriate to target the Maker population relevant to the research questions, whereas representative sampling may not provide a complete picture of knowledge, skills, attitudes, and pathways of Makers necessary to inform theory generation. Each participant will receive a monetary incentive for their time.

Table 3: Stratifications for purposeful sampling

Primary Strata	Secondary Strata
▪ Self-identified Maker ▪ With/without formal engineering education experience (e.g., engineering degree) ▪ With/without informal engineering education experience (e.g., robotics team, hacker space) ▪ Member of an underrepresented group based on ethnicity and gender	▪ With/without an engineering-related career ▪ With/without an engineering-related hobby ▪ Years of experience as a Maker ▪ Range of ages

Makers who have a formal engineering education degree will provide insight into how formal engineering education has helped them in their who have chosen pathway. Makers who have informal engineering education experience (e.g., robotics team) will provide breadth to the study and illuminate how informal education experiences influence engineering pathways and career choices.

Following analysis of data from an initial group of participants, a Preliminary Theory will be developed and theoretical sampling done "on the basis of the emerging concepts, with the aim being to explore the dimensional range or varied conditions along which the properties of concepts vary".[15] Theoretical sampling will strengthen the theory through purposeful selection of

participants who address weaknesses in the emergent theory, which is a key feedback element to a strong parallel inductive-deductive research design. Additional participants will be sampled until theoretical saturation in the model is reached.

By way of our qualitative study research design, we estimate that 36 participants is a responsible number for our proposed study of Makers. We seek to identify factors and see this as a first step to explore our research questions; we do not claim to generalize or predict, so a smaller N is appropriate for our study aims. With our qualitative research approach, the exploratory nature of our research questions and theory-building efforts, we do expect that our number of interviews will produce more than enough "thick description" for the study's purpose to discern a pattern about participants' knowledge, skills, attitudes and pathways through artifact elicitation and critical incident technique interviews.

We acknowledge that there are limitations to our qualitative approach but also opportunities in the short and longer term to address them. Chief among limitations are that these findings will not be generalizable. Planned future work surveying Young Makers, however, may address this and concerns about sample size. With qualitative data, our primary limitations are resources. We target Maker Faire community events as the best opportunity to both recruit and interview possible participants. We expect to exceed 2X-6X the expected 36 participants in these recruiting and screening questionnaire efforts as to do be able to use strategic maximum purposeful sampling strategy to select at least 5 self-identified Makers from each of our primary sampling strata: 1) with formal engineering education experience 2) without formal, 3) with informal engineering education experience, 4) without informal. We propose to begin with an initial stratified purposeful sampling strategy to reach *saturation* around a pattern for participants by our primary (those listed above plus by underrepresented group based on ethnicity and gender) and secondary strata criteria (with or without engineering-related career or hobby, years of experience as a Maker and range of ages), as highlighted in Table 3 of the proposal. We will supplement by additional theoretical sampling for participants as needed in phases 2, 3, and 4 of data collection and allow for at least 10 additional participants in these phases.

As a benchmark, the April 2012 issue of the *Journal of Engineering Education* featured a number of qualitative studies with similar or smaller Ns of 20[20] and 14.[21] We are beyond the size of a typical qualitative study and feel confident that our research design population and sampling approach is sufficient. Future work, particularly with the Young Maker population may extend this work in a larger N study by using quantitative methods.

Data Collection

Screening Questionnaire

Potential participants will be asked to complete a short online screening questionnaire, and the results will be collected in a database. The questionnaire will consist of multiple choice and short answer questions check for self-identification as a maker, collect age, demographic, and years as a Maker data, determine if potential participants have formal or informal engineering education experience, and determine if potential participants have an engineering-related career or hobby. Results from the questionnaire will be used to select initial participants using the stratified

purposeful sampling strategy described above, and also used to contextualize the critical incident technique interview questions.

Artifact Elicitation Interviews

A semi-structured artifact elicitation interview are conducted in person (or via Skype if necessary) to examine the knowledge and skills a Maker develops as a result of making creations, and the attitudes they have about making, engineering, and their careers. The interview will rely on a physical artifact/creation that the Maker has created, and begin with asking him or her to describe the artifact. Further questions (see Table 4) will also rely on references to the artifact to elicit "thick description",[22] and questions in later interviews will evolve based on emergent themes discovered during early analysis. Data collection will occur primarily at Maker Faires, which are a pragmatic choice because a large number of Makers will attend with their creations.

Artifact elicitation interviews extend the qualitative inquiry approach of photo elicitation,[23, 24, 25, 26] where interviews that rely on photos "evoke information, feelings, and memories that are due to the photograph's particular form of representation"[24] and stimulate "latent memory, reducing areas of misunderstanding, eliciting longer and more comprehensive accounts of ideas... eliciting values and beliefs, and connecting to core definitions of the self to society, culture, and history".[27] In addition, photo elicitation method has been used successfully in engineering education,[27, 28, 29] science,[30] and math[31] as both a research and pedagogical method. Artifacts created by Makers are similar to photos in the sense that they embody the knowledge, skills, and attitudes that Makers hold, making artifact elicitation an appropriate choice to study the concepts in RQ1.

Constructivist Critical Incident Technique Interviews

A semi-structured constructivist critical incident technique interview[32, 33, 34] are conducted in person (or via Skype if necessary) to examine the educational and career pathways of Makers and how they intersect with formal engineering education and careers in engineering. The interview will consist of questions (see examples, Table 4) designed to examine college and career decision points and how they relate to engineering. Interview questions in later interviews will evolve to address emergent themes discovered in interviews with earlier participants. Klein[34] used critical incident technique interviews to study decision making in a variety of fields, and the method have been used very successfully in engineering education research.[35-40] This technique aligns well with RQ2 to understand decision points contributing to pathways intersecting with engineering.

Table 4: Sample interview questions

Instrument	Sample Questions	Research Question
Artifact elicitation interview	What skills did you have to learn to build [*project*]? How does your passion for [*project*] relate to your job?	RQ1: Maker knowledge, skills, and attitudes
Critical incident technique interview	Tell me about a time when you decided what to study in college. Tell me about a time when you decided not to pursue a career in engineering.	RQ2: Maker pathways

Data Analysis

Interview transcriptions will be analyzed in parallel both inductively and deductively to generate a theory. One part of the research team will use open coding[15] and theoretical memoing[41] to conduct the constructivist grounded theory[14] inductive analysis. Sorting and theoretical coding[41] will be used to connect the resultant themes into a theory. Simultaneously, other members of the research team will deductively analyze the data using thematic analysis[42] based on a coding scheme derived from the relevant conceptual frameworks described in Table 5. Once complete, the deductive analysis will be used in a confirmatory and triangulatory capacity for the inductive analysis and uncover theoretical "holes" that will inform the next round of theoretical sampling for new participants.

Data will be collected through qualitative interviews of Makers using the described methods of artifact elicitation and critical incident interviews. In the *deductive* phase 1 of data analysis, we will create coding schemes theoretically based on Bloom's Taxonomy (RQ1) and Pathways Theory (RQ2). One member of the research team will lead a thematic analysis of the interview transcripts using these coding schemes. In a parallel and independent process, another member of the research team will lead an initial, *inductive* phase 1 of data analysis using constructivist grounded theory methodology by open coding, memoing and sorting to find patterns of the phenomena and build theory around both RQ1 and RQ2. At the end of phase 1 (Fall 2012), and again by subsequent phase 2 (Spring 2013), phase 3 (Fall 2013), and phase 4 (Spring 2014), the findings from the deductive approach and the inductive approach will be triangulated to ensure coverage and strengthen the resultant theory. This schedule allows for iterative analysis cycles through the development of a preliminary theory, refinement of the data collection instruments, and collection and analysis of additional data. It will also inform the questions asked in the subsequent interview protocols and allow for flexibility to explore areas of curiosity. We describe this as a parallel inductive-deductive theory-generating design approach.

Bloom's Taxonomy and Pathways Theory are our primary theoretical frameworks and basis for our coding scheme for the initial phase of deductive data analysis (see Table 5).

Table 5: Theories informing theoretical coding for deductive analysis

Conceptual Framework	**Relevance**
Bloom's Taxonomy[43]	*RQ1*: *knowledge* (cognitive), *skills* (psychomotor), and *attitudes* (affective)
Pathways Theory[44]	*RQ2*: multiplicity of *pathways* (rather than pipeline) into and out of formal engineering education

Expected Results: Maker Theory

The synthesized theory will identify knowledge and skills of Makers that relate to engineering, in addition to their attitudes about engineering and how their pathways have (or have not) intersected with formal engineering education. This theory will be of particular use to the engineering education community aspiring for the engineer of 2020 and beyond. It will also be useful to researchers studying pathways, student attraction and retention, and informal science and engineering education. The theory will also be transferable to other disciplines interested in attracting Makers.

Future Work

Our future planned research will use the Maker Theory to inform the study of young Makers and their STEM pathways to college and career success (see Figure 3).

Figure 3: Future work to inform study of young Makers with Maker Theory

This study will advance the currently limited knowledge of the Maker community by developing theory characterizing Makers and their pathways through the lens of formal engineering education. The aim is to establish evidence as to how Makers embody specific attributes of the *Engineer of 2020* and discover additional attributes of Makers that could define the engineer of the future. By highlighting such connections to engineering, the results will inform subsequent planned research of "early makers" (pre-college age) and their pathways to successful engagement in engineering.

The results of this study can transform the conversation of who the engineer of the future could be, linking "making" with engineering in the same way that students who excel in science and math are pointed toward engineering by parents and career counselors. By sharing a diverse (gender and ethnicity) set of success profiles of engineering Makers widely in the formal education system (students, K-12 school administrators, university leaders, and admissions officers) and to Makers both online and at Maker community events, we aim to illuminate pathways for Makers to become the engineers of the future. In addition, this study could inform future innovation in formal engineering education pedagogy based on successful attributes of

informal engineering education and tinkering activities. By characterizing the engineering activities of Makers, this study will provide a scholarly foundation to awarding academic credit to both students and lifelong learners for their informal engineering education experiences.

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