

Young Makers Becoming the Engineers of the Future and Implications

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Dr. Jordan co-developed the STEAM Labs™ program to engage middle and high school students in learning science, technology, engineering, arts, and math concepts through designing and building chain reaction machines. He founded and led teams to two collegiate Rube Goldberg Machine Contest national championships, and has appeared on many TV shows (including Modern Marvels on The History Channel and Jimmy Kimmel Live on ABC) and a movie with his chain reaction machines. He serves on the Board of the i.d.e.a. Museum in Mesa, AZ, and worked as a behind-the-scenes engineer for season 3 of the PBS engineering design reality TV show Design Squad. He also held the Guinness World Record for the largest number of steps – 125 – in a working Rube Goldberg machine.

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The purpose of this NSF-funded study “Might Young Makers Be the Engineers of the Future?” is to understand Young Makers in K-12 and how their knowledge, skills, and attitudes might prepare them to pursue advanced STEM education and careers. Makers are an emerging community of self-described DIY-enthusiasts, tinkerers and hobbyists. Makers embody characteristics from the Engineer of 2020¹ like practical ingenuity, creativity, and propensity toward lifelong learning. Making is of particular interest to the field of engineering and to engineering educators. The mission of this research is to develop a theory, inductively grounded in data and deductively built on literature, illuminating the knowledge, skills, and attitudes of Young Makers related to pathways forward to engineering and STEM-related majors and careers. By describing educational pathways to or around formal engineering education, we will better inform future innovations to improve the practical ingenuity and lifelong learning of our future engineers. The specific research questions to be answered are: (RQ 1.) *What knowledge, skills, and attitudes do Young Makers possess that could be related to engineering?* and (RQ 2.) *How do pathways of Young Makers intersect with engineering?*

Methods

Using qualitative research methods of artifact elicitation and critical incident interviews, we are developing a theory describing Young Makers and their preparation to pursue advanced STEM education and careers. The interview protocols were based on themes that emerged from our related Adult Maker study (EEC-1232772)². After interviewing our first round of participants at the Bay Area Maker Faire in May 2014, we discovered that parents and families were extremely important to supporting Young Makers. We then expanded our interviews to start looking at Maker Families, interviewing children about their experiences Making, parents about how they support their kids in Making and what they think their kids are learning, and siblings (who are often also Makers). We are continuing artifact elicitation interviews at Bay Area and World Maker Faires in 2015 and 2016, and conducting follow-up critical incident interviews. Some analysis has begun to support early publishing of conference papers, but we intend to fill out sampling gaps prior to a deeper analysis across all participants. To date, 40 Young Makers and 22 parents have been interviewed at Maker Faire events.

Maker Theory: Additive Innovation

Findings from our qualitative artifact elicitation and critical incident interviews showed that Makers demonstrate the characteristics of an *Additive Innovation*^{3,4} mindset that describes the open community of sharing and learning that is in the Maker community. Introduced in this paper as an umbrella concept, *Additive Innovation* is a mode of collaboration where participants in a community are:

- a) inspired by shared artifacts/ideas,
- b) openly share (and learn about) technology and processes used to create these, artifacts/ideas,
- c) design and prototype own modified version of the shared artifact/idea, and
- d) share their modified artifact/idea back with the community.

Learning Attributes of Making

Making is rooted in constructionism, learning by doing or Making and constructing knowledge through that doing⁵. Aspects of Making that could appear in the engineering classroom are described in the following sections. Attributes of Making come directly from themes emerging from our ongoing research^{2-4, 6-11} listed in Table 1. These learning attributes are described more fully in the authors recent work¹².

Table 1: Attributes/themes of Making and common definitions¹²

Sharing	give jointly
Practical ingenuity	of doing, quality of cleverness
Personal investment	of one, commit money
Playful invention	amusement, creative abilities
Risk taking	danger, application
Community building	group of people, constructing
Self-directed learning	initiative, knowledge to acquire

Discussion

Preliminary findings also indicate the critical and significant involvement of parents in the additive innovation networks of Young Makers are a part. Parents of Young Makers enable participation in making by supporting their children financially, technically, logistically, and emotionally. They also have strong opinions about the benefit of Making for their kids, so we plan to expand our interview strategy to include parents. This study will advance the currently limited knowledge of the Young Maker community by developing theory characterizing Young Makers and their pathways through the lens of formal engineering education. The aim is to establish evidence as to how Making benefits Young Makers and affects their pathways to STEM majors and related careers. By highlighting such connections, the results will inform subsequent planned future research on the accreditation of informal and formal Maker activities.

This study could inform future innovation in formal K-12 STEM pedagogy based on successful attributes of informal engineering education and tinkering activities. The results of this study will transform the conversation of who Young Makers could become, 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 (by age, gender, ethnicity) set of success profiles of Young Makers widely in the formal education system (to students, K-12 school administrators, university leaders, and admissions officers) and to Young Makers both online and at Young Maker community events, we aim to illuminate pathways for Young Makers to become the engineers of the future.

Future Role for Making in the Classroom

There is also an opportunity to place engineering Making and doing to into a formal classroom learning environment in K-12 and undergraduate engineering program. Making-Based Learning¹² can support students in academic Makerspaces. Making may attract and recruit a

broader base of engineering students. An inversion of the values of engineering analysis and engineering doing may be necessary to fully and authentically support the role of Making in the classroom. At the very least, it is possible to imagine engineering curricular reform and support for active and project-based learning wrapped up in Making-Based Learning. We have shared learning attributes of making; it could be a useful intellectual exercise to consider how such values are amplified or lessened within an engineering learning culture. The concept of additive innovation is mentioned above. Can that be supported in K-12 and undergraduate learning experiences? Is the current implementation more convergent and less exploratory in nature?

The study of Makers, Making and Making-Based Learning is a ripe opportunity for the engineering education community to reflect on our approach to teaching and learning. Making-Based Learning may already fit into some aspects of the engineering curriculum, such as first-year Introduction to Engineering courses and project courses in programs with a project spine (e.g., Arizona State University, Harvey Mudd College, Olin College). However, engineering faculty critics of the Maker movement argue that Makers do not actively learn and apply engineering fundamentals in their projects, thereby limiting the applicability and appropriateness of Making-Based Learning pedagogical techniques in the engineering curriculum. We seek to continue our research by better understanding the role and expectations of Making in the formal engineering setting through future case study examples and to better capture and understand perceptions of Making by engineering faculty. Making may offer new opportunities to engage young people in STEM majors and careers and stretch the bounds of how we conceive of engineering and engineering learning.

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