# What is Making? What is Engineering?

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Dr. Jordan also founded and led teams to two collegiate National Rube Goldberg Machine Contest championships, and has 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 has appeared on many TV shows (including Modern Marvels on The History Channel and Jimmy Kimmel Live on ABC) and a movie with his Rube Goldberg machines, 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.

## Introduction

Makers are part of an emerging community of self-described tinkerers, DIY-enthusiasts and hobbyists. This work seeks to understand their activities and how informal engineering education takes place within the community. Makers exhibit characteristics of *The Engineer of 2020*[1] such as ingenuity, creativity, and lifelong learning.

As part of an NSF-sponsored project[2], we seek to understand the knowledge, skills, attitudes, and pathways that lead to making to begin understanding how making can benefit engineering education. As makers exhibit characteristics of *The Engineer of 2020*[1], learning how they attain these skills can increase the ability of engineering programs to teach these skills. To help characterize Making and its similarities to and differences from engineering, two methods were used.

The first method was convergent and based on literature review. In this method, the research team searched through articles and papers to build definitions of Making and engineering. The second method was a divergent, ad-hoc approach that took definitions from several groups in the Maker community. Respondents within these groups were asked to respond to "What is Making?" and "What is Engineering?" and record their answers. Together these approaches yielded information to help characterize making and its relationship to engineering.

## What is Making?

Previous iterations of the literature review used terms associated with making. Some of the terms used to assist the review were *maker*, *hacker*, *tinkerer*, *DIY (do-it-yourself)*, and *hobbyist*[2]. The review sought to how these terms were used and the context in which they were used.

Making takes place in collaborative environments sometimes found in libraries, schools, or businesses. These spaces often provide tools for projects such as 3D-printers or welders that may not be found in one's personal workspace. In addition, same spaces specialize in a specific area such as hackerspaces which focus on programming and electronics. As these spaces are collaborative, makers can be found working with one another or offering advice. By building upon previous knowledge, makers exhibit additive innovation. Making, according to Dale Dougherty (the founder of Maker magazine[3] and Maker Faires[4]) is "learning by doing"[5].

Tinkering appeared alongside making and describes experimentation. Kaye, Wang, and Campbell refer to tinkerers as one who makes something to fulfill a purpose[6,7]. Dale Dougherty mentions tinkering alongside making to engage kids in science and technology[5].

Some other terms were used in context with making. Honey and Siegal used the terms *personal fabrication* and *risk takers*[8] while The Economist used *enthusiasts* and *accidental entrepreneurs*[9]. These emphasize making as learning through experience while taking risks.

## What is Engineering?

Engineering is a profession involved in the application of mathematical and science for the needs of humanity[10]. Engineers may graduate from ABET accredited programs that ensure engineers

meet the standards of the profession[11]. One responsibility listed is understanding "professional, ethical and social responsibilities"[11]. Ethics for engineers deal with professionalism and understanding implications of their work[12]. The American Society for Engineering Education's ethics code appears to encourage safety by reducing conflicts of interests and partiality[12].

The disciplines of engineering can be put into 4 main groups; chemical, civil, electrical, and mechanical[13]. These groups are split into smaller concentrations with specific specialties. Despite the concentrations, engineers can become multi-disciplinary due to work involving multiple areas[13]. When examining what engineers do while working, a study found that a majority of their time was spent on technical work and a significant amount of team seeking information[14].

Students at the University of Washington describe engineering as a lifestyle with difficulty corresponding to worth[15]. In this, more work or difficulty makes something superior. This meritocracy of difficulty leads to a hierarchy forming within the engineering disciplines where some are seen as superior to the others.

## Participants

Participants were self-selected attendees at a number of Maker-related events, including a meeting of professional makers, a community faire of makers (Maker Faire), an workshop on Making organized by a funding agency, and two university classes related to Making. There were a total of 5 events during which data was collected.

## Data Collection

Answers were collected for the questions "What is Making?" and "What is Engineering?" from notecards or post-it notes. Responses from groups with varying familiarity of the making community were sought. To do this, populations were asked from maker events, college classrooms, and a conference. Due to the differences in environments, methods of collection varied. Some groups were asked to include their answers on a shared "wall" of responses. Some of the groups were also self-selected.

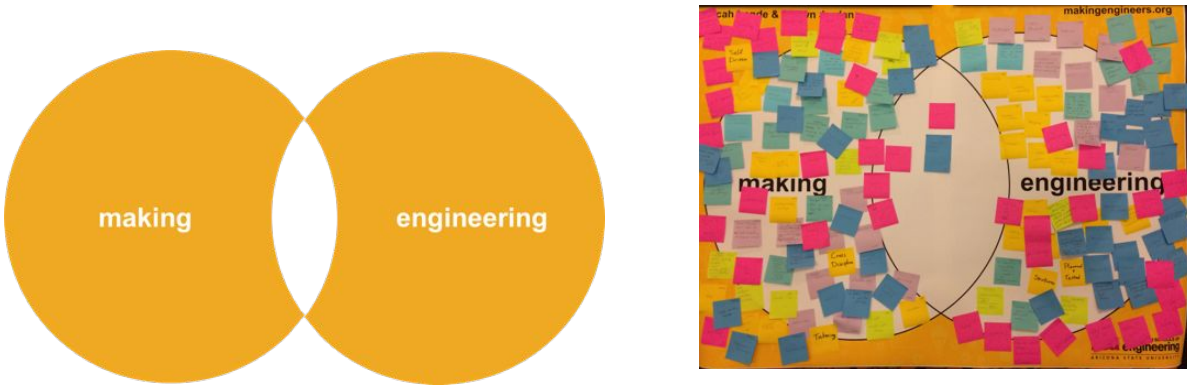


**Figure 1:** Example of a shared "wall," before (L) and after (R)

The populations at Maker Faires came from attendees of Maker Faires. In this case, respondents were self-selected and their responses were anonymous. Due to their attendance of a Maker Faire, respondents likely had some degree of familiarity with making. Attendees of a professional meeting of Makers, an event coinciding with Maker Faire, were also asked to respond to these questions. Attendees of this event consisted of thought leaders in the making movement and people interested in marketing their product towards makers. Respondents from this event were also self-selected and anonymous.

Responses were also collected at a workshop put together by a funding agency with the goal of educating professionals about the making community. After listening to a presentation on makers, attendees were asked to respond to the questions on post-its and share their answers on a shared "wall".

Finally, responses were collected from surveyed from students in two different engineering classes. The first class came from a traditional engineering experience while the other class took place in a project-based engineering curriculum. Both classes were asked to respond and submit their answers anonymously.

**Analysis**

Analysis of responses was conducted using summative content analysis[16]. This approach took the frequency in which words appeared and analyzed their usage. Words appearing often show a consensus among the group of the meaning of making or engineering. To accomplish this, responses for each sample were collated and the frequency of words were found. The responses were separated into nouns, verbs, and adjectives. This helped with analysis by putting into categories of what each involves, what is done, and a description. Words used frequently across each sample group, point to an interpretation shared by a wider group of people.

**Results**

Similarities between responses for each question were often ambiguous with broad meanings. Common responses across all samples were *making*, *building*, and *things*. The lack of specificity reflects the wide range of projects for engineers and makers. Across the responses from samples close to making, engineering is described more formally in terms of approach to projects. Engineering is *structured* while making is *trial-and-error*. **Tables 1-5** demonstrate the top responses from each group and question. When a word appeared in two forms, such as *solving* and *solve* in **Table 2**, they were placed together and the word count was separated.

**Table 1.** Word frequencies collected at Professional Maker Meetup

**What is Engineering?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Problem | 11 |
| 2 | Solving | 7 |
| 3 | Design | 7 |
| 4 | Building | 5 |
| 5 | Things | 4 |

**What is Making?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Creating | 9 |
| 2 | Something | 7 |
| 3 | Problem | 5 |
| 4 | World | 4 |
| 5 | Creation | 4 |

**Table 2.** Word frequencies collected at Maker Faire

**What is Engineering?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Problem | 11 |
| 2 | Solving/Solve | 7/4 |
| 3 | Design | 7 |
| 4 | Building | 5 |
| 5 | Things | 4 |

**What is Making?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Creating | 9 |
| 2 | Something | 7 |
| 3 | Problem | 5 |
| 4 | World | 4 |
| 5 | Building | 4 |

**Table 3.** Word frequencies collected from traditional engineering class

**What is Engineering?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Problem | 16 |
| 2 | Solver | 8 |
| 3 | Math | 8 |
| 4 | Building | 8 |
| 5 | Solving | 7 |

**What is Making?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Building/Build | 6/4 |
| 2 | Creating | 4 |
| 3 | Design | 3 |
| 4 | Create | 3 |
| 5 | Food | 3 |

**Table 4.** Word frequencies collected from project-based engineering class

**What is Engineering?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Design | 12 |
| 2 | Creating | 11 |
| 3 | Problem/Problems | 10/10 |
| 4 | Making | 10 |
| 5 | Designing | 10 |

**What is Making?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Creating/Create | 25/10 |
| 2 | Something | 18 |
| 3 | Ideas | 12 |
| 4 | Making | 7 |
| 5 | New | 7 |

**Table 5.** Word frequencies collected from workshop on Making at funding agency

**What is Engineering?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Creating | 9 |
| 2 | Something | 7 |
| 3 | Problem | 5 |
| 4 | Creative | 5 |
| 5 | Design | 4 |

**What is Making?**

| *Rank* | *Word* | *Freq.* |
|---|---|---|
| 1 | Creating | 10 |
| 2 | Something | 7 |
| 3 | Problem | 7 |
| 4 | Creative | 6 |
| 5 | Building | 6 |

The responses between making and engineering were remarkably similar across all groups sampled. Both making and engineering are seen as the creation of things and are described in broad terms such as *something*, *creating*, and *making*. Many responses also suggested some form of a design process for both groups. For engineering, the design process seemed to be formal with words such as *theory* and *math*. Making however seemed to be more informal in its process. *Trial-and-error* and *hands-on* appear in responses to this question supporting the learning by doing approach expressed in the literature review. The increased exposure each group had to the making community correlated to an increase in responses including a process or goal for the "What is Making?" question. Adjectives used for making focused on the experience such as *personal*. Engineering however focused on describing the process including the words *structured* and *technical*.

The responses for the populations present engineering and making as similar with differences in their approach towards solving a problem. Engineering is described with a formal process, with

caution taken by using theory to reach a solution. Making is described as more informal where they solution is found through trial-and-error.

## Conclusions

The responses for engineering and making were similar with making described as more informal than engineering across most of the responses. Responses such as *trial-and-error* for "What is Making?" reflect learning and understanding of concepts through practice while responses for "What is Engineering?" suggest an understanding through theory and calculations. The ability to learn through practice and self-guidance show how makers exhibit traits such as lifelong learning from *The Engineer of 2020*[1].

Understanding makers' attitudes towards making and engineering can bring understanding to what brings makers to make. Knowledge from this can help bring this feeling to engineering classrooms, such as in project courses, to encourage students to exhibit traits such as *practical ingenuity*, *creativity*, and *lifelong learning*[1].

Using the characterization of making through this manner can be useful as part of the larger study investigating the educational pathways of Makers. Using qualitative research methods of critical incident and artifact and context elicitation interviews, we are developing a theory describing Makers and their engineering education pathways. Our primary research questions are: *What knowledge, skills, and attitudes to Makers possess that could be related to engineer?"* and "*How do pathways of Makers intersect with engineering?".* Responses from these respondents help to determine attitudes of makers towards making and engineering. The 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*[4] and discover additional attributes of Makers that could define the engineer of the future.

## Future Work

As the sampled populations came from engineering classes or participants who are part of the Maker community, future additions would include a sample representative of the general population and professional engineers. This could introduce additional variation into responses for engineering and making.

## Acknowledgements

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