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What is Cool Stuff? Exploring Engineering Students' Motivation to Be Excited About Their School Activities

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Introduction

Many prospective college students see engineering as a great career choice due to the high salaries and satisfying results of their projects. All throughout childhood kids see rockets go to space, cars drive so fast you barely see them go by, and robots becoming more advanced as the years go on. Growing up with this it is no wonder the view of engineering is a sleek and cool job where it seems you can sit around and invent all day. This also demonstrates why engineering programs have such a high dropout rate as students become immersed in the curriculum. As they go along, students see less and less of the cool results and see more of the difficult and ugly computations that are hardly ever seen by outsiders. The intent of this study is to consider how we can display the results of engineering over the course of the undergraduate curriculum, in an attempt to motivate the students to continue in these career paths.

To do this we will investigate each course students in an undergraduate mechanical engineering program will take and explore how the subjects can be taught focusing on the results of the work. This will be done with the intent to provide motivation to the students to show the benefit to the hard work they're currently doing.

Motivation

The motivation for this topic of research weighed heavy on the primary author, near the end of their undergraduate career in engineering. Having been an active member of an engineering extracurricular activity for three years and leading it in the fourth, they had grown numb to the novelty of the cool aspects of the club. This was especially amplified by the difficulty of finishing the project, taking two years of slow and difficult progress. The author was working on a new component for the project, that had so far taken the better part of a week and was still not finished, and patience was wearing thin. As the part was being test fit the newest advisor to the team came in looking for something. They started talking and the advisor asked how it was all going. The author replied that it was going alright, but the defeat in his voice was clear to all parties present. After a brief pause the advisor said something that is remembered very clearly to this day, "I don't know if I've ever said this, but I think what you guys are doing is really cool." Such a simple phrase, most likely insignificant to the advisor, but it changed the perspective of the author greatly. It gave them the insight needed to take a step back and really look at all that had been done. From then on as the team prepared for competition by doing the tedious task of fine tuning the machine the words of the advisor often returned. Through this process the cool aspect of the engineering project became especially apparent. It was at this point the author saw how important it was to keep remembering the cool aspects of engineering as the computations and work get hard. So, when the opportunity of research came, this topic was on the forefront of the authors mind in hopes to help others keep motivated through the engineering process.

The purpose of this research is to find how students are motivated by what they think is cool Once this information is obtained, the motivating factors can be used to improve the

effectiveness and increase interest from the student perspective in an attempt to reduce dropout rates from engineering students.

Context in Literature

Across Activities in Curriculum, Co-curricular, and Work

Studying engineering as an undergraduate student allows for the exploration and investigation of possible interests. A program of study in a particular major may map out a balance of breadth and depth in that engineering field. There are co-curricular and extra-curricular opportunities that add to that [1, 2].

And certainly, internships bring additional context for what students may consider as the practice and activities of engineering. With all that, students' study of engineering may still be conceptualized, and presented, as an abstract endeavor. Starting with a generative question of "what is cool stuff?" (a marketing platitude being developed at our university), we seek to better understand from undergraduate engineering student what that might mean for them.
The goal is to take a general notion of being motivated to do engineering work because of "cool stuff" into more nuance about an underlying aspect of motivation. Some motivation may come from the intrinsic motivation, doing for its inherent satisfaction and impact, and other may come from an extrinsic motivation to accumulate outward rewards, such as a good paying job. We will revisit the National Academy of Engineering's Changing the Conversation project [3] to present messages about engineering in a more targeted fashion for prospective engineers. It is expected that students' stories and experiences will be placed even more concretely in their own contexts, and perhaps also in a context more directly drawn from students' experiences in their undergraduate educational experiences and its setting and programs. This will extend previous work about the engagement of students and potential students into engineering and inform local efforts to frame engineering about "cool stuff."

Previous Efforts to Define Cool Stuff

The National Academy of Engineering has undertaken a few projects to capture the attention of prospective and current engineering students. For the Changing the Conversation report, missives like "Engineers are creative problem solvers" and "Engineers design the future" are offered as effective messaging [3]. Similarly, the Grand Challenges [4] enumerated 14 grand challenges for engineering from clean water to personalized learning, giving a list of engineering problems worth solving collectively.

Research Methods

Through qualitative, semi-structured interviews that ask students to reflect on "critical incidents" [5] in their decisions to get involved in engineering and experiences along the way, we will do emergent thematic analysis of students' responses to find patterns of commonality across individual experiences. Participants are also asked to bring with them photos that depict what they think is cool [6, 7].

Participants

We recruit student participants longitudinally from 1st year students to seniors. Participant details are listed below in Table 1, with pseudonyms used.

Table 1: Participants Demographics

	Year	**Major**	**Gender**
Adam	Freshman	Mechanical Engineering	Male
Ben	Freshman	Mechanical Engineering	Male
Craig	Senior	Mechanical Engineering	Male
Doug	Senior	Mechanical Engineering	Male

Developing Interview Protocols

To find out what interests students about the cool part of engineering we decided to look at the opinions of new college students and experienced college students. For this, two freshman and two seniors were interviewed in an attempt to find out some similarities and differences between how college will change opinions on what is cool to students. To reduce variation in answers the students selected for interviews were all active members in the same engineering centered extracurricular activity.

Interviews were conducted in rooms students were familiar with no interruptions. Interviews acted more as focused conversations while audio was being recorded. After the interview the recordings were transcribed for later analysis and use in paper.

To get a full picture of the students' motivations and experiences the questions were split into two categories. The first was *Personal Background and Inspirations* section, which asked some fairly basic questions like "What do you do for hobbies" and "why did you choose this major." The first half of this section of questions focused on pre-college experience to see if there was similar motivation amongst the participants for their goals and reasoning for selecting the educational path that they did. This way if one interviewee's answer differed significantly from the others then we could see if they had different experiences and expectations than the rest of the group. The second half of this section of questions was looking into what they have enjoyed in college so far and what they have not found satisfaction in to discern similarities between successful college classes and what they chose to do to entertain themselves in their free time. There were also questions about general aspects of common courses to see if there was any satisfaction in completion of tasks.

For the second section of questions participants were asked to bring two objects (or pictures of said objects). The first was any item they haven't made, that they think is cool. This question was intentionally left vague, and participants were asked why they thought this item/object came to their mind right away. This opened the conversation of what is cool to involve any conceivable thing, so the results were not biased to what's already been made. The second item they were asked to bring was something they made. They were then asked to describe it in their own words, so they were allowed to highlight the most important parts of the project. Then, to indirectly see

why they think it was cool they were asked why they chose this object over other ones they've made, since there was a reason, they chose to talk about that specific project. Next, they were asked if finishing it was easy and if they put more time into it than they needed to. Finally, participants were asked what the first thing they first felt when they looked at the object to see if there was satisfaction with their efforts. The full list of questions can be found in Table 2.

Table 2: Interview Questions

1. What do you do for hobbies?
    a. Why do you like to do that?
2. Why did you choose this major?
3. Why did you choose this school?
4. Besides preparing you for your career, is there anything else you hope to get out of going to school for engineering?
5. What has been your favorite college class and why?
6. What has been your least favorite college class and why?
7. Have you ever felt accomplished when you finish homework? … Why?
8. Tell me a story about something you made that left you feeling satisfied and why you think you felt that way.
    a. Did you feel accomplished when you finished it? Why or why not?
9. Will you tell me about the thing you brought today that you think is cool?
    a. Why do you think it's cool?
    b. What differentiates it from other things you find cool? (The reason this is what you thought of when I said something cool)
10. Tell me about the thing you brought today that you made.
    a. What differentiates it from other things you've made?
    b. Was it hard to finish or easy? Do you think you put more work into it than you needed?
    c. What is the first thing you feel when you look at it?

Results and Discussion

Personal Background and Inspirations

The participants in this survey all had fairly similar activities to what they do in their free time. Generally, all the answers revolved around things that kept them active, working with their hands and being creative in different ways. Similarly, all the participants chose to become mechanical engineers for the same reasons as well. Their main motivations were to be able to design and build stuff and they liked the idea of a broad field that could lead them anywhere they decide to go once they get their degree, or as freshman two said "there's just so much variety to it that, I don't know, for me I can say the sky is the limit essentially." However, when asked why they chose their school their answers began to differ. A senior and a freshman both said they chose this school mainly because it was hands on. The other freshman said his was a mix of cost, academics and locations that were his driving factors. Finally, the second senior said he chose this school because it ss where his parents attended college.

The next question asked if there was anything the participant hoped to get out of going to school for engineering besides career preparation. Once again, the answers differed fairly significantly, the first freshman wanted to be able to know about engineering for his personal projects and that it is important "knowing what forces are going into each component." The second freshman said "Like friendships and teamwork as well. That's one of the reasons I'm involved in Baja [engineering competition team] is because it provides just a great atmosphere to meet new people and work with them, and work towards a common goal." The first senior was interested in being exposed to many different fields and possibilities of things. "When you think of mechanical engineers you think engines, but there is also thermo, and heat transfer. There's mechatronic systems, all super cool fields." (Senior 1) Finally, the second senior was looking at "being challenged a little bit is something that I was really hoping to get at college and definitely something that has met me with"

Similarities did start to appear between the classes once college experiences came up. When asked what their favorite class was it seemed the freshman chose classes that had them doing hands on activities like working in labs. They also enjoyed these classes because "It kind of introduced me to a bunch of different stuff" (Freshman one) and all the possibilities associated with it. The seniors, however, chose classes they said are very applicable in the real world. As Senior two said,

> *That's one of the first classes I took that was actually an application of all... The first couple years are learning all that background stuff. So, [machine design course] is one of those first classes I took where like you have all this background and it's like, here you actually use it, and you could see physical, real-world products I've worked with and understand why all that background that I've spent two years learning is important for that class.*

Likewise, when asked about least favorite classes the grades were split again. Freshmen chose classes they claimed, "it didn't seem terribly applicable to the engineering, the mechanical engineering side of things" (Freshman one). The seniors chose classes they had problems understanding, either due to teaching issues or complexity of subject. For the final question in this section the participants were asked if they had ever felt accomplished when they completed some homework. All of the participants answered yes, with senior one summarizing it best by saying:

> *Where you have these 14-page homework assignments. But they're all super neat. They're clean, they're laid out, and when you staple it, when you're very done, you're just like, "It's cool to have this giant stack done."*

Completed Work and Accomplishment

To start off talking about their building experiences the participants were asked to tell of something they did that left them feeling satisfied. For this the grades had once again split. The Freshman discussed projects like a homemade dresser/closet combo and projects made from Legos that they enjoyed that they had "felt accomplished in it because it was something useful and my own and not from a box" (Freshman One). The Seniors discussed projects they had

completed for school like an industrial robotics rube Goldberg machine and a custom machined and anodized Chinese checker's board. Both seniors said they felt satisfaction when it was complete, but also emphasized the group work portion, stating that excitement and satisfaction was a key role to the importance of the project for them. Senior Two said; "they all were excited for most of it, and it turned out well. That's one of the coolest things I built." When discussing the Chinese checkers boards made with freshman who had never done a project like that before.

Figure 1: A Suzuki GSX-R1000, which was chosen by Freshman 1 the general project he though was cool.

Figure 2: A SpaceX rocket that represents the growing push to dive into uncharted territory, chosen by Freshman 2 as what he thinks is cool.

Figure 3: A Supersonic Baseball cannon made by the YouTube channel smarter every day, which is what Senior 1 thinks is cool

Figure 4: A Rivian electric pickup truck which is what Senior 2 thinks is cool

Cool Stuff Shared

The next topic of discussion was the thing the participant didn't make, but thought was cool. From these images the participant was asked to describe the thing they brough and talk a little bit about why they thought it was cool. Freshman one had a unique answer that the cool parts of the Suzuki GSX-R1000 (Figure 1)." The physical design of it is cool. I've always liked the crotch rocket look. From everything I've heard and seen about it, it handles really well. So that just makes it an all-around cool bike." On a slightly different note, Senior one brought an image of a

supersonic baseball cannon (Figure 3) built on the YouTube channel Smarter Every Day. He said the cool part of this for him was the fact that the creator one day just said "Oh, I'm an engineer. I'm going to use the resources and tools and training I have at my disposal to just do cool stuff." And the result was a supersonic baseball cannon. He also found it cool that he is running tests with it to plot usable data about the cannon for fun and educational purposes. An interesting observation was made that Freshman two and Senior Two chose very different objects for the same reason. Freshman two brought an image of a SpaceX rocket (Figure 2) to represent the advances being made in the space exploration industry. Senior two brought an image of a Rivian Electric Pickup truck (Figure 4) which he said he'd been following for around 7 years, and he's thought it was cool the entire time. Both had similar statements but along the lines of, "I really think it's cool because there's so much innovation in it." (Senior Two) and "It's pushing our limits. It's fundamentally challenging how we live our lives." (Freshman Two)

Figure 5: A homemade electric motorcycle made by Freshman 1 is used as an example of something he made that he thinks is cool

Figure 6: A dodgeball launching robot Freshman 2 made for his first robotics project in high school that he finds cool

Figure 7: A Push button help caller Senior 1 made for a project at work to help elderly people call their helpers easier

Figure 8: A Pinewood derby car Senior 2 made for a Pinewood Derby race

The last question participants were asked was to tell us about something they made that they thought was cool. This time the two freshman and a senior felt similar about their projects with one senior having a slightly different answer than the others. Freshman one and two, as well as

Senior two, all said the big impact of this project on them was the fact it was something they designed, built, and made themselves. For example, Freshman one said he thinks fondly of his project because," That's the only ground up usable machine I've built." They really enjoyed the satisfaction of looking at the final product and seeing the culmination of all their hard work had paid off and that it was almost all their work that led to the final product. Senior one also had a similar answer but with a slightly different reason for being satisfied. For his push button caller project, he mentioned that he also enjoyed the fact that he designed, built, and made the product, but he felt satisfied because of the fact that it was helpful for the elderly people he designed it for. He had this final comment about the project to say, "but when you directly see how it can make an impact, engineering itself can make an impact bettering people's life, it's super cool." When asked if they ended up putting more time into the project than they probably needed, all participants had a resounding yes! The fact that it was not necessarily easy to finish added to the satisfaction of the final product for the participants. The final question asked was how the participants felt when they looked at their final product and all the responses were very positive. The main answer (Freshman one and Senior one) said they felt pride when they looked at their end result while Senior two said joy from the very memorable time with the product. Freshman two however had a great response stating "it's kinda indescribable really" and that seeing his dodgeball shooting robot filled him with "an overwhelming sense of triumph".

Key Results

From these critical incident interviews, it can be seen that the participants have all had different experiences and motivations for their work. One finding from this group is that Senior two and freshman two both chose South Dakota Mines for intrinsic reasons, academically challenging and more hands on. While Freshman one and Senior one chose their school for extrinsic reasons, mainly cost and scholarships. There are commonalities in some things, like how all the participants felt personally rewarded to have turned in difficult homework assignments. Overall, however, a clear trend among all the participants was the willingness to put in more effort than they felt was necessary to complete their project to their desired standard. This shows a trend of intrinsic motivation to see how good the final product could be, for no other reason than the satisfaction of a good final product that reflects the creators' abilities.

As far as what is cool, for these participants it can be broken down into three main categories:

1. The first would just be the technological aspect of cool, which revolves around what is possible for human capabilities. The appealing aspect of this is how technological and engineering limits are approached, and then pushed past what is considered feasible. This ability to innovate and create attracts all sorts of attention, but especially from engineers.

2. The second type of cool that was recognized were intriguing applications of engineering. Not only is it beneficial to have advanced technology but being able to apply it to areas it was not intended for is especially appealing. This method can be a simple and effective way to solve a problem because it's easier than starting from the ground up.

3. The final thing that was found to be cool was the experiences in building that the participants had. Many of the projects that stood out had some sort of connection to a group. While all the

participants mainly focused on describing the product made, they also mentioned the group they did it with and how the members felt about that project. This is a subtle, but influential part of creating, but is also a big factor in what was found to be considered cool.

Discussion, Implications and Future Work

From this investigation it was found that the main forms of "cool" to mechanical engineers in college has turned out to be cool technologies, cool applications, and cool experiences in creating.

This information could be useful to colleges reaching out to prospective students, by getting them engaged with hands on creating activities. The students could also be shown things that have been created at the college and how those technologies have since then been applied. Finally, and more importantly, then the students can be told how they can become a part of making similar things and grow their knowledge and experiences that way.

Another way these findings may be applied would be to classroom setting. An effective way to do this would be to base more courses around project-based learning. This way intrinsically and extrinsically motivated students will both have something to gain and keep them working toward their goal. Having a project-based course allows students to learn while they are making which benefits the intrinsic students and a physical thing to keep afterwards for the extrinsic students. From these interviews it can be seen that students are willing to put in more time, effort and work than necessary for a project if they find what they are doing to be cool. An interesting observation made is that the freshman generally found pride in more complex projects they completed by themselves while the seniors found the smaller groups projects to be fulfilling. One problem with this research was how narrow of a group the participants polled were primarily white males. This was primarily due to what members were available in the extracurricular activity. However, this can act as a good start to developing a view of what is cool and in future work will be extended to incorporate female, people of colors and even different majors' perspective.

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