



Broadening Participation in Engineering: Making in the K-12 Classroom Following an Interest-Based Framework (RTP, Strand 4)

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Broadening Participation in Engineering: *Making* in the K-12 Classroom Following an Interest-Based Framework (RTP, Strand 4)

This paper will make a **case for implementing an interest-based framework** for creating **engineering design** challenges within **Classroom Makerspaces** as a means to improve the **inclusion of women and underrepresented minorities in K-12** engineering and design learning.

Introduction:

The concern over inclusion of underrepresented groups in the engineering community is not new, and over the past few decades many attempts have been made in the form of programs to improve participation. The motivation for this study is rooted in this concern, as well as the ideas around “starting young” which have recently come to the forefront by the Next Generation Science Standards (NGSS) focusing on K-12 engineering education curriculum ¹. Another idea that has been coming to the forefront in the engineering education committee is that of Makerspaces, which is directed towards bringing the Do It Yourself (DIY) culture into the classrooms to aid teaching and learning ². However, currently there lies a gap between this idea of classroom Makerspaces and their implementation in learning environments. This paper is an attempt at filling this gap, by proposing how an interest-based framework would not only aid the implementation of classroom Makerspaces, but also serve as a means for broadening participation in engineering.

The team of researchers associated with this work have qualitatively established with one of their prior studies how school-going participants of underrepresented minority groups express an interest in making; governed either by situational or personal interests ³. Via another theoretical study, we looked at how Classroom Makerspaces can be used as means for adhering to many of the new K-12 NGSS related to engineering design practices ¹. After elaborating on the findings of these studies, and using them to situate this paper, we will present a three- fold argumentation. First, we will explore interests of students belonging to underrepresented minority groups. Second, examine the role of interests in learning and motivation. Third, to connect the previous two arguments to establish how the scope of engineering design and its learning is broad enough to cater to these various interests, hence providing motivation to engage in engineering design.

In the recommendations section, we will make a case for classroom Makerspaces as a promising environment to implement an interest-based framework for creating engineering challenges that broaden participation.

Is making interesting?

In one of our previous studies, we saw that students from underrepresented minority groups express an interest in making within the purview of engineering and science, which is governed either by their personal interests or situational interests³. In our works, we understand personal and situational interests as below: (Paraphrased from Renninger, Hidi and Krapp³)

***Personal interests** are the characteristics of a person that influence his or her engagement in interactions with the social or nonsocial environment.*

***Situational interests** refer to the interestingness of the social or nonsocial environment that evoke or encourage interactions with people or objects.*

For this work⁴ students from underrepresented minority groups were interviewed regarding their interests, and perceptions of engineering. We then identified themes and patterns within the interviews that aligned with our theoretical framework for personal and situational interests. All participants showed an interest in making, however their interests could be classified either as personal or situational. For example, where Jose was personally interested in building himself a solar powered car, Keith's interest in his science classroom was governed by the interactive nature of his class that we identify as a situational interest. This work provides meaningful and encouraging insight into the interests of students belonging to underrepresented minority groups in science and engineering.

Makerspaces and the NGSS

In another one of our studies⁵, we identified the opportunities arising from the NGSS, and proposed the idea of classroom Makerspaces as a means to meet these standards. Our vision of classroom Makerspaces is inspired by the DIY culture that has manifested into phenomena like the Maker Movement² and FabLab⁶ in the past. Classroom Makerspaces in our vision can bridge the gap between technology and learning by providing means to learn better with the aid of technology within authentic learning environments. Our earlier work explored how learning within classroom Makerspaces can help contextualize scientific principles, to solve real-world problems. We also explored how classroom Makerspaces present themselves as a good candidate to integrate STEM disciplines. Both these ideas adhere to directives mentioned in the NGSS (Appendices A, I, J & F)¹. Thus, the idea around making not just appeals to students' interests, but can also help educators in meeting learning standards.

Interests of underrepresented minority groups in engineering and science

Interests of individuals have strongly been related to self-efficacy, educational choices and career outcomes⁷⁻⁹. In this section, we present results from studies that are inspired by these ideas and identify interests of underrepresented minority groups in engineering, science and mathematics.

Byars-Winston, Estrada, Howard, Davis and Zalapa ¹⁰ studied the influence of social cognitive and ethnic variables on the academic goals of underrepresented students in science and engineering, and saw a direct relationship between students' ethnic identity, academic self-efficacy and interests. This study also quotes an earlier work by Lewis and Collins ¹¹ which established that African American students' interest in contributing to their ethnic communities influenced them to pursue majors in science.

In another study, Doughtie and Chang ¹² with the aim of understanding vocational preferences of black and white undergraduate students, reported that black students showed higher scores in social, conventional and enterprising personality types on the Vocational Preference Inventory (VPI) scale ¹³, as compared to white students. It was also established that black students choose social type of occupations more often than white students.

Avilés and Spokane ¹⁴ in their study that attempted to understand the vocational interests of Hispanic, African American and White students reported findings from 570 6th, 7th and 8th grade students in an urban middle school. They reported that Spanish primary language students expressed a higher interest in investigative and artistic themes as compared to White and Hispanic students, and a higher interest in social, enterprising and conventional themes as compared to White students. They also reported that Hispanic students showed a higher interest in conventional themes as compared to White students. Between male and female students, where male students were reported to express higher interest in realistic themes, females were reported to show a higher interest in artistic, social and conventional themes.

In a study by Swanson ¹⁵ that was aimed at examining the underlying structure of measured interests among African American college students by analyzing the Strong Interest Inventory profiles ¹⁶ of 357 subjects, male students showed higher scores on the Realistic scale as compared to female students.

Some works also tie underrepresented minority students' interest with self-efficacy. For instance in a study by Waller ⁷, it was hypothesized and proven that math self-efficacy and outcome expectations relate to math interest in African American college students. Another study by Gushue ⁸ reported findings on 9th grade Latinas/Latinos, it was established that students' ethnic identity played a role in their ability to engage in exploration of different careers mediated by their self-efficacy.

Hence, studies support that students belonging to underrepresented minority groups exhibit different personal and situational interests as compared to majority students.

Role of Interests in Learning and Motivation

Learners' interests play an important role for their learning and development ³. Our previous work that explored underrepresented minorities' interests in making, and this work are situated in Voss and Schauble's ¹⁷ general model of learning as seen in Figure 1. According to this model the process of learning not only takes place within an individual, but also in the environment that

the individual is exposed to. It is claimed that an individual has two sorts of “equipment”, the value based (i.e. goals and interests) and intellectual (i.e. knowledge and beliefs), and learning is manifested between their interplay. Personal and situational interests were introduced earlier in the present text. Research shows that learning activities associated with these interests result in higher levels of engagement, learning and achievement ¹⁸⁻²¹.

Deci ²² claimed that a person’s interest in an activity drives the motivation to engage in it. Two functions of motivation: the qualitative function of directing individuals to select activities that will satisfy their interests; and the quantitative function of energizing the individual to persist and exert the effort to accomplish the goal, were identified by Atkinson and Wickens ²³. Prenzel ²⁴ goes further to make the link between learners’ interests and their persistence in learning by writing that selective persistence “describes the content-based orientation, the intensity, and even the quality of interest ... [where] the more pronounced the interest, the more pronounced will be persistence and selectivity” .

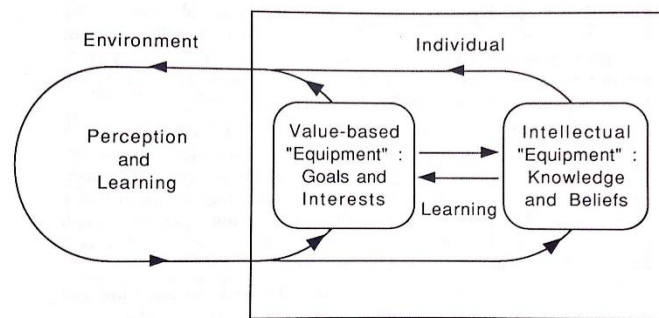


Figure 1: Sketch of general model of learning from Voss and Schauble ¹⁷

Engineering within Broad Interests

Not only is engineering broad enough to cater to the varied interests that we discussed in the prior sections, but broad and human-centered contexts also allow for a rich scope of design problems. It has been established that engineering design and the engineering design process are central to engineering education for K-12 students ²⁵⁻²⁹. Pre-college students can be introduced to engineering within the broad contexts of their interests, which would help them develop thinking and cognitive tools central to engineering design. Over time as they gain the required discipline/application specific knowledge, they can apply the process to specific problem-solving contexts.

Our claim that engineering is a humanistic or people-centered endeavor comes from the idea that engineering takes place in a society where engineers work for, or in service of, people, with people, and as individuals with their own values, beliefs, and perspectives ³⁰. The National Accreditation Board (ABET) also calls for more well-rounded engineering graduates who can navigate the global, economic, and environmental aspects of engineering problems ^{31,32}. The NGSS in Appendix J ¹ calls for making home and community connections by: “(1) increasing

parental involvement and encouraging roles as partners in science learning, (2) engaging students in defining typically engineering problems and designing solutions of community projects, and (3) focusing on science learning in informal environments”. Also, Appendix F ¹ mentions piquing students curiosity towards real-world problems (such as energy, disease, fresh water and food, climate change). Hence human-centered contexts for design activities allow for rich problem scoping and also result in more authentic learning experiences.

Making following an Interest-Based Framework

All claims made in this paper converge to the need for an interest-based framework for engineering design in the K-12 classroom. We propose using classroom Makerspaces as a means to implement this framework. Our proposition in addition to the aforementioned need is also particularly meritorious on several other grounds that we will discuss in this section.

(1) The idea of making and digital fabrication labs has **strong historical and theoretical roots**. Stager ³³ writes about the implications of the Constructionist Learning Laboratory (CLL) that emerged a decade before the present interest in the Maker Movement and DIY culture ². Work in the domain of the CLL established treating students as individuals, quality work utilizing time, giving importance to students working themselves over instruction, diverse learning environments and their favorable outcomes, and collaboration as productive for learners. Also, Ackermann ³⁴ wrote about Papert’s theory ³⁵ which with the goals of self-directed learning and feeling like a part of people and situations, propagated the idea of using tools, media and context of making things in learning environments. In the same text by Ackermann ³⁴, Vygotsky’s ideas of cultural artifacts, language and people forming the crux for cognition are also highlighted. All these themes, resonate very well with the underlying ideas of classroom Makerspaces.

(2) Classroom Makerspaces also address the need for **moving from a skill-based to a fluency-based approach** in the purview of design and engineering, that was raised by Paulo Bilkstein, the creator of the FabLab at school ⁶ and Dennis Krannich ³⁶. This idea is in alignment with digital fabrication labs engaging students to develop diverse solutions for ill-defined problems that belong in the engineering and design space. Bilkstein and Krannich ³⁶ also acknowledged the impending need for digital fabrication labs to prove themselves as viable options as more technology is brought in to schools. Classroom Makerspaces are a meritorious step in the direction of satiating this need.

(3) Classroom Makerspaces can potentially fill in the **gap between technologies that target education, and learning that goes on in classrooms**. The Maker movement is a popular topic that has emerged over the last few years. Its initiation dates back to 2005 when Dale Dougherty founded the *Make Magazine* ². However, dialogues around the space alone will not ensure its inclusion in making learning better. *Making* in classrooms following an interest-based framework is a step in the direction of filling the aforementioned gap.

Implementation

This section looks at the implementation of the proposed framework in the future. We will first present examples of what design activities within this framework would look like in our targeted grade levels, and then discuss potential constraints and problems associated with the implementation.

Even though the theoretical premise behind the arguments that support the framework proposed in this text can be extended to engineering design practices at all grade levels from K-college, this research is situated in middle and high school classrooms. The learning activities can be contextualized by any theme that the students are interested in. For example:

- (1) If the students are interested in sports and identify scorekeeping as a problem:
 - They can design an electronic scoreboard, or a sturdy stand to hold the scoreboard at a place that is visible to everyone on the field.
- (2) If the students are interested in listening to music, and identify their earphones getting tangled up as a problem:
 - They can design a portable case for their phones/portable music devices that lets them wind up their earphones to prevent them from getting tangled up.

In our earlier study that identified how classroom Makerspaces can help adhere to many of the NGSS, we also reported four themes of challenges, that concerned the main identified stakeholders (teachers, students, school administrators and parents)⁵:

- No Child Left Behind, along with its high-stakes system of reward, that leaves little to no time for individualized assignments.
- Preparing teachers to fill in the role of facilitators required in an engineering classroom or a Makerspace, requires a different set of skills as compared to mathematics and science teachers.
- Since Classroom Makerspaces are usually rich in technology, technology and resource management brings up concerns related to funding, administration, use and repair.
- With students in a classroom having diverse interests, backgrounds and prior knowledge, it becomes essential to strike a balance between individualized learning experiences and meeting curricular priorities for the class.

Broad concerns regarding the transfer of knowledge and skills from highly contextualized classroom environments to real-world problems have also been raised in other literature. Bruner³⁷, while elucidating upon the different kinds of transfer involved with learning (that of training, principles and attitudes), emphasizes on how transfer is central to most learning exercises. Bransford, Brown & Cocking³⁸ take from Byrnes³⁹ and define transfer as “the ability to extend what has been learned in one context to new contexts”. As learning in our proposed framework will be situated in contextual environments, the broader problem of transfer also applies to these students who will be learning design thinking. Representing problems at a higher level of

abstraction, relating learning and transfer conditions, viewing transfer as an active rather than a passive process, and relating transfer and metacognition are some of the important factors that influence this transfer³⁸. Thus even though transfer has been identified as a challenge for learning systems, it is essential for students, and means to do so have been researched and reported.

Conclusion

Over the course of this paper, we made a case for implementing an interest-based framework for creating engineering design challenges within classroom Makerspaces as a means to improve the inclusion of women and underrepresented minorities in K-12 engineering and design learning. We did so by scaffolding on our previous work that addresses how *making* is interesting for students of underrepresented minority groups, and how classroom Makerspaces address the opportunities brought forth by the K-12 NGSS. In this paper we started by identifying different interests prevalent in underrepresented minority groups in engineering and science. We then explored the role that interests of learners play in learning and motivation. Then we established how engineering caters to broad interests, and also how broad and human-centered contexts allow for a rich scope of design problems. Finally, we recommended classroom Makerspaces as a meritorious means for the implementation of the interest-based framework for creating engineering challenges.

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