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# Framing Engineering as Community Activism for Values-Driven Engineering: RFE Design and Development (Years 3-4)


## Virginia A. Davis (Alumni Professor)

Dr. Virginia A. Davis is the Daniel F. and Josephine Breeden Professor of chemical engineering at Auburn University (AL, USA) and a member of the Alabama STEM Council. Her research has three thrusts: 1) develop the scientific understanding required to enable the promising properties of nanomaterials to be realized in macroscopic systems (e.g. coatings, films, fibers, three-dimensional objects), 2) increase the sustainability of polymers and other materials, and 3) facilitate the development of a diverse, equitable, and inclusive STEM workforce through educational research, outreach activities, and DEI training and organization initiatives. In particular, she is interested in how science and engineering fair involvement and framing engineering as altruism affects STEM identity development.

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## Daniela Marghitu

Dr. Daniela Marghitu received her B.S. in Automation and Computing from Polytechnic University of Bucharest, and her Ph.D. degree in Automation and Computing from University of Craiova. She is a faculty member in the Computer Science and Software Engineering Department at Auburn University, where she has worked since 1996. Her teaching experience includes a variety of Information Technology and Computing courses (e.g., Object-Oriented Programming for Engineers and Scientists, Introduction to Computing for Engineers and Scientists, Network Programming with HTML and Java, Web Development and Design Foundations with HTML 5.0, CSS3.0 and JavaScript, Personal Computer Applications, Spreadsheet-Based Applications with Visual BASIC, Web Application Development). Her research areas include STEM K12 Inclusive Computing Research and Outreach; Web Applications Design and Development; Education and Assistive Technology; Software Engineering; Web and Software Engineering Usability and Accessibility. Dr. Marghitu has received funding for research and education projects from National Science Foundation (e.g.Co-PI of NSF RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics; Co-PI of NSF INCLUDES Alliance: The Alliance of Students with Disabilities for Inclusion, Networking, and Transition Opportunities in STEM (TAPDINTO-STEM); Co-PI of NSF EEC "RFE Design and Development: Framing Engineering as Community Activism for Values-Driven Engineering"; Co-PI of NSF CISE "EAGER: An Accessible Coding Curriculum for Engaging Underserved Students with Special Needs in Afterschool Programs"; co-PI of NSF INCLUDES: South East Alliance for Persons with Disabilities in STEM, Co-PI of NSF CE 21 Collaborative Research: Planning Grant: Computer Science for All (CS4ALL)). Dr. Marghitu was also PI of grants from Center for Woman in Information Technology, Daniel F. Breeden Endowment for Faculty Enhancement, AccessComputing Alliance, Computer Science Collaboration Project, Microsoft Fuse Research, Altova Co., and Pearson Education Publishing Co. Dr. Marghitu has mentored over one thousand high school, computing undergraduate, graduate students including representatives of underserved/underrepresented communities, women, and people with disabilities. Dr. Marghitu has participated in numerous administrative activities at Auburn University. Among these activities are the following: Auburn University Board of Trustee Faculty Representative; Auburn University representative for National Center for Women in Information Technology, AccessComputing, Access10K, and AccessEngineering Alliances; Auburn University Persons with Disabilities Committee chair; Founder and Director Auburn University Laboratory for Education and Assistive Technology; faculty representative Auburn University Core Curriculum Oversight committee and Multicultural Diversity Commission. Dr. Marghitu also served as World Usability Day Web Site Committee Chair; Alabama STEM Education

board chair, Panel member for the National Science Foundation; member of the congressionally mandated Committee on Equal Opportunities in Science and Engineering; member of the Committee on the Future of NSF EPSCoR; and member of the Computer Science for All (CSforAll) Accessibility Board. Dr. Marghitu published seven Information Technology books at Pearson Publishing Co., articles at International Journal On Advances in Software, International Journal On Advances in Internet Technology, Journal of Women and Minorities in Science and Engineering, National Science Teaching Association Journals, Journal of Computer Science Education,International Journal on Advances in Internet Technology Transactions of the SDPS: Journal of Integrated Design and Process Science, User Experience Magazine, Journal of Computing Sciences in Colleges, International Journal for Virtual Reality, Journal of SMET Education and Research. Dr. Marghitu has published peer reviewed papers and gave presentations at numerous international conferences(e.g. ACM Special Interest Group on Computer Science Education Technical Symposium, International Technology and Persons with Disabilities Conference, International Conference on Software Engineering Advances, EDUCAUSE, Association for Advancement of Computing in Education, International Society for Technology in Education, Society for Design and Process Science, American Society for Engineering Education, Human Computer Interaction International Conference, and International Academy, Research, and Industry Association) in USA, Canada, England, France, Germany, Spain, Italy, Portugal and Romania. Her work was also presented by co-authors at conferences in Brazil, Taiwan and S. Korea. Among Dr. Marghitu's honors and awards are the following: 2011 AccessComputing Capacity Building Award, the 2012 Auburn University Access award, the 2012 Society for Design and Process Science Outstanding Achievement Award, the 2013 Microsoft Fuse Research award, the 2015 DO-IT Trailblazer award, the 2017 International Academy, Research, and Industry Association Fellowship, the 2017 Society for Design and Process Science Fellowship, and the 2019 Samuel Ginn College of Engineering 100+ Women Strong Leadership in Diversity Faculty Award.

## Edward Davis

Edward W. Davis received his Ph.D. from the University of Akron in 1996. He worked in the commercial plastics industry for 11 years, including at Shell Chemicals in Louvain-la-Nueve, Belgium and EVALCA in Houston, TX. He joined the faculty at Auburn University in 2007, where he regularly taught courses in three different engineering departments: Chemical Engineering, Civil Engineering, and Polymer and Fiber Engineering. In 2014 he was promoted to Senior Lecturer, and in 2015 he moved to the Materials Engineering program as an Assistant professor. Currently an Associate professor, his research focus is environmental and biological applications of polymeric nanomaterials. He is also very interested in improving STEM education. He is presently serving as a PI or co-PI on several STEM education improvement grants, including an NSF-funded S-STEM, an NSF-funded REU, and two DON-funded Workforce Education Grants.

# Framing Engineering as Community Activism for Values-Driven Engineering: RFE Design and Development (Years 3-4)

## Abstract

This research used a mixed-methods approach to understand how framing engineering as an altruistic, or prosocial, profession affected the engineering identity development of students from underrepresented minorities in STEM. The research was conducted through a theoretical lens encompassing the Goal Congruity Framework and Social Congruity Theory. To better understand the impacts of altruistic framing, a traditional Saturday STEM program with participants from the same demographics were studied for comparison. Through interviews and surveys, we found that altruistic framing led to meaningful changes in students' appreciation of engineering and, in some cases, new interests in pursuing engineering as a career. Students also increased their interest in engineering, but their definitions of the field did not broaden appreciably. Some found new interests, but they did not have the same type of transformative experience as the altruism-focused interventions. This research has shown that framing engineering as an altruistic career path can lead to meaningful changes in students' definitions of engineering and their connection of engineering to their career interests.

## Introduction

The Goal Congruity Framework (GCF)[1, 2] predicts that students will experience greater commitment to a career when there is alignment of their career values and their *perceptions* of the field in terms of what values it can align with. Similarly, Social Cognitive Career Theory (SCCT) explains how students' learning experiences can inform their career identity development through their self-efficacy, outcomes expectations (perceptions in GCF), and values for their career.[3] Historical engineering stereotypes suggest that engineering is a career for loners who only care about high salaries. These misconceptions are in conflict with the altruistic values that tend to be embodied by GenZ students, particularly those from underrepresented groups in STEM. Therefore, it was hypothesized that interventions that emphasized engineering as a pro-social, altruistic career would enhance engineering identity development. This hypothesis was tested by comparing how a traditional STEM content-focused program and a new altruism-focused program called *Tomorrow's Community Innovators* [TCI] impacted students' attitudes towards engineering and perceptions of the field. The content-focused program was a pre-existing 10-week Saturday program run by Alabama STEM Education (Bessemer, AL). It covered various subjects related to engineering but did not highlight engineering's' societal impacts. In contrast, TCI highlighted the positive impacts engineering has on individuals and society through activities related to the National Academy of Engineering's *Grand Challenges of Engineering*. The participants in both programs were primarily low socioeconomic status (SES) $8^{th}$ - $10^{th}$ grade Black students from the Birmingham-Hoover, AL Metropolitan Statistical Area, an urban area in the Southern United States. Additional groups of students were also included in the research as the scope of work and ability to conduct meaningful interventions varied during the course of the pandemic.

The TCI program has included university-run summer camps, events for parents and students coordinated with a regional STEM Education nonprofit, and attending university engineering open houses. Activities have included thought exercises, laboratory experiments, app development, robotics, and meetings with groups such as Engineers Without Borders. In 2019, all students came from one low-income urban community. In 2020, virtual participants came from rural areas in addition to the urban community. In 2021, we returned to our original community, but our participants were attending campus with students from any background. Through interviews and surveys, we found that TCI camps led to meaningful changes in students' appreciation of engineering and, in some cases, new interests in pursuing engineering as a career. Impacts were more pronounced when the camp theme was powerfully related to altruism. Many students noted how broadly engineering affects our everyday lives and how it helps others. Students in the traditional STEM program also increased their interest in engineering, but their definitions of the field did not broaden appreciably. Some found new interests, but they did not have the same type of transformative experience as the altruistic-focused camps. Overall, framing engineering as an altruistic career path led to meaningful changes in students' definitions of engineering and their connection of engineering to their career interests.

## Grant Activities

In the first year of the grant, we refined and tested tools for assessing how various interventions affected students' engineering identity. To look at the impact of altruistic framing we compared two distinct programs. The first program was a ten-week Saturday STEM program run by Alabama STEM Education (ASE), a nonprofit in Bessemer, AL. The program predominantly served Black youth from an urban area in Alabama. This program included hands on STEM activities, guest lectures and museum visits, but did not include an altruism component. In parallel, we designed a program that used *Grand Challenges of Engineering [4, 5]* to highlight the impacts of engineering on society and our everyday lives ("altruistic framing"). Students from the same demographic as the traditional STEM program were recruited for this program, titled *Tomorrow's Community Innovators* (TCI). From Summer 2019 to February of 2020, the TCI program consisted of a week-long residential program, a local event for parents and students co-hosted by Alabama STEM Education (ASE), the Auburn faculty, graduate students, and undergraduate mentors, and bringing students to Auburn University for their annual engineering open house. The plan was to continue similar activities for the three years of the award. However, limitations on in-person activities resulting from the COVID-19 pandemic necessitated altering the original plan. The team provided students access to activities that highlighted engineering as an altruistic career through a series of virtual activities in 2020 and 2021. A few students were also able to attend an in-person camp in the Summer of 2021. At all of the camps, as well as the Saturday program, students completed pre- and post-camp interviews and surveys about their experiences and how they perceive or define engineering. A summary of activities is provided in **Table 1.** In addition, one of the authors, Dr. Lakin, assisted with capacity building by assisting the leader of ASE with facilitator training and grantsmanship skills. This training facilitated ASE's ability to expand their offerings. For example, ASE was able to host children during virtual school while their parents work and providing other types of needed support to the community.

**Table 1.** Annual Activities (T) indicates traditional framing (A) indicates altruistic framing

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| **Parent and student engagement** | • A: Recruitment via ASE program (A) | • A: Lunch and learn event with parents and students in Bessemer, AL | • A: Lunch and learn event with parents and students in Birmingham, AL (with masks and social distancing) |
| **Extended STEM learning opportunities** | Traditional STEM:<br>• T: Saturday Academy program<br>• A: On-campus TCI camp | • A: Virtual, week-long TCI camp<br>• A: Virtual computing camps (weekend) | Altruistic framing:<br>• On-campus week-long STEM camps<br>• Virtual Reality Camp (weekend) |
| **Engineering open house, other engagement** | -- | • E-Day at Auburn University<br>• Interviews of 2019 undergraduate mentors and STEM for All video<br>• ASE capacity building | • Virtual E-Day |

***Fall 2018 – Fall 2020 Activities***

Previous years activities and findings are described in detail in previous proceedings and publications.[6-11] An abbreviated summary is included herein. The TCI camp activities included thought exercises, laboratory experiments, app development, and robotics. Both of our samples were in grade 8-10 and Black students. In 2019, twenty students from one low-income urban community participated in a residential camp featuring labs and app development related to three Grand Challenges: provide access to clean water, make solar energy economical, and restore and improve urban infrastructure. In 2020, thirteen virtual participants came from rural areas in addition to the urban community. For one camp, we shipped materials for activities around water filtration and testing the quality of water and some of the activities were led by some of previous year's mentors. These mentors were Black engineering undergraduates from the same geographical area as the participants. In 2021, the pandemic was still constraining the ability to provide in person activities and affecting student and parent interest in residential camps. We returned to our original community for the activities we offered and students from any background were also included. Findings were limited due to the small sample size, but we achieved the primary goal of maintaining student engagement.

***2021- 2022 Activities, Virtual Computer Science Camp***

In Spring 2021, a four-day (9:00 am to 3:00 pm) virtual computer science camp for nine high school students was developed by the project team members specializing in computer science and software engineering. Topics included basic computer science and programming topics related to the solar and water engineering grand challenges. The camp focused on state-of-the-art technology to boost students' interest and engagement in Computer Science and Software Engineering career. Students were introduced to the use of augmented reality and virtual reality in everyday life, robotics, and designing and coding a functional application. **Table 2** briefly describes the curriculum; additional details are available in Bhattarai and Marghitu, 2021. [12]

**Table 2:** Spring 2021 Virtual Computer Science Camp.

| Day | |
|---|---|
| **1** | This unit introduced the foundational concepts of computer programming, which unlocks the ability to make rich, interactive apps. In this unit, students learned Block programming language, and Scratch as the programming environments to make an animation in respect to solar and water energy.[13] They learned basic CS concepts including variables, conditional statements, loops, and algorithms using CS-4ALL junior and other resources. |
| **2** | Students were asked to go through the activities based on the concepts taught in the first day. The first part of the day took place in the Main Camp Cabin studio. Students were introduced to different projects done to save the oceans. In the second, part students were asked to discuss their scenarios (storyboard) and suggest different components they can use in their ocean saving project. |
| **3** | Day 3 focused on filtering water. Students created stories in which they defined an application or a game for filtering water. Their applications could be educational, gaming, or any other kind of application or game. At the end of day, students were asked to present their storyboards with their classmates and discuss the possibilities of making their thoughts practical. |
| **4** | Day 4 focused on solar energy. Students were asked to create stories in which they defined an application, or a game related to solar energy. Their applications could be educational, gaming, or any other kind of application or game. Storytelling: Students made an adventure game explaining about solar energy and its benefits. Before starting with their stories, students were introduced to different techniques to implement an adventure story game in scratch [14] and a questionnaire solar game.[15] Students also learned how to simulate ideas for solar energy that may or may not be feasible to invest money in. [16] |

**Virtual Computer Science Camp Findings:** Pre- and post- surveys were used to evaluate the effects of the camp on students' knowledge and attitudes. Key findings were that: 1. None of the students were familiar with the concept of AR/VR applications. 2. Many students indicated that the use of AR/VR functionalities helped them in better understanding of subject topics. 3. Students agreed that the apps were easy to use and that they were able to effortlessly determine drinking water sources and sun location. Overall, students developed a greater understanding of AR/VR and Robotics technology by using and implementing different applications. According to the post-survey findings, 50 % of the students strongly agreed, and the other 50 % agreed that using such technologies can be practical in their everyday lives and they are interested in pursuing computer science to enhance their understanding and implementing such applications. The Drinking Water AR app made it easy to find drinking water places, according to 50 % who agreed somewhat, 25 % who agreed, and the remaining 25 % who strongly agreed. Similarly, 50 % strongly agreed, 25 % agreed, and 25 % slightly agreed that determining the sun's location using the Sun Path AR app was simpler. Therefore, based on the result of the camp, after the camp students became more interested in applying computer science in their daily tasks. They learned problem solving skills given 14 engineering challenges. Students think that computer science and AR/VR can be applied in other fields and are willing to invest their time further in CS, Robotics, and AR/VR.

***2021- 2022 Activities, Incorporating Participants into Pre-existing Residential Summer Camps***

For summer camps, we worked with ASE to connect to families with eligible students and place them in camps organized by other Auburn faculty, but with a congruent focus on STEM and community-focused solutions. In total, 27 students applied to participate in the summer camps. Due to restricted camp size, due to COVID, we were register 15 students for three camps that were held. All of these students were Black students from our focal community. Many attended low-performing schools, including Bessemer City and Jefferson County school districts. For various reasons, only about one half of the students participated.

**Table 3.** 2021 Camp Participation

| **Camp** | **Participation** |
|---|---|
| Senior E.A.G.L.E. (June 6-11) | 8 students registered |
| Industrial Design Camp 1 (June 20 – 25) | 4 students registered |
| Industrial Design Camp 2 (July 11-16) | 3 students registered |

The Exploring Agriculture & Gaining Leadership Experience (E.A.G.L.E.) Camp, hosted by the College of Agriculture, is designed to expose high school students to a wide variety of STEM fields within agriculture. They visit many different research programs at the university, including animal sciences, horticulture, turfgrass, and biosystems engineering and engage in hands-on activities at each. We attempted to collect data according to our evaluation plan, but coordination with the camp counselors was indirect and difficult. We obtained survey data from three of our participants at the start of camp and evaluations from two days of camp, indicating that students enjoyed camp activities, but not allowing us to address our hypotheses about the focus of sessions on altruistic or community-focused STEM, although the camp clearly aligned to that focus.

The Industrial Design camps, hosted by the School of Industrial and Graphic Design, were held in a residential format at Auburn University. They are designed to be flexible and responsive to student interests and include a week-long design challenge. The camps had a significant focus on both engineering and altruistic concepts. They included defining and caring about others' needs, the engineering design process, creative problem solving, communication, and drawing and modeling skills. The directors of the Industrial Design Camps were able to provide opportunities for data collection and observations during the programs. In 2021, the camp focused on designing bicycles for specific avatars (archetypal end users) with different needs such as electrical assistance, speed, durability. All students in the camp (whether recruited by TCI or not) participated in our project-related activities and data collection in addition to camp activities. We were able to observe the camp activities which are summarized in **Table 4**.

**Table 4.** Summary of Auburn Industrial Design Camp Activities.

| | |
|---|---|
| Monday morning | • Archetypes or avatars for consumers and their needs<br>• Bicycle designs |
| Monday afternoon | • Opportunity Research & Recognition<br>• Team building |
| Tuesday morning | • Engineering as a prosocial career path<br>• Design challenges with designer/engineer from Trek<br>• Discussed roles of designers and engineers |
| Tuesday afternoon | • Games designed to enhance story telling and creativity |
| Wednesday morning | • Solution Exploration<br>• Prototyping—started making computer mouse models, |
| Wednesday afternoon | • VR as a quicker means to prototype<br>• Continuing to shape and primer-coat computer mouse model |
| Thursday morning | • Ideation game (Designing Under Influence, Need and Context)<br>• Shark Tank—two sides of group given challenge and 30 minutes to define idea subject to constraints |
| Thursday afternoon | • Continued work on mouse model<br>• Paired off for additional ideation and prototyping |
| Friday morning | • Camp wrap-up and departure |

**Data Collection from Industrial Design Camps:** Data collection activities were based on our evaluation of previous iterations of camps, with adjustments to be less intrusive in the camp experience. The quantitative surveys included measures of science and engineering interest as well as a measure of perceptions of engineering.[8, 9, 11, 17] Example items are provided in **Table 5**. The scale for each ranged from 1 (not at all true) to 3 (somewhat true) to 5 (very true). Rather than a more formal measure of STEM interests and attitudes, we chose a measure of STEM interest that was more concrete, to better align with the interests of students attending camps without an explicit STEM focus. We used the interest ("enjoyment") scale developed by the Engineering is Elementary program. [18, 19]

**Table 5.** Survey scales and sources

| **Scale** | **Primary source** | **Example items** |
|---|---|---|
| Altruistic beliefs about engineering (n=7) | Litzler & Lorah (2013) | Engineers help to make the world a better place. |

| Scale | Primary source | Example items |
|---|---|---|
| Individualistic beliefs about engineering (n=7) | Litzler & Lorah (2013) | Society values the work engineers do. |
| Interest in STEM careers (n=12) | Lachapelle & Brennan, 2018 | I would like to help plan bridges, skyscrapers, and tunnels.<br>I like thinking of new and better ways of doing things. |

**Results of 2021 Industrial Design Camp:** In each camp, we provided a brief activity introducing engineering as a pro-social career path. This included conducting the previously developed what's the challenge activity where students brainstorm challenges in their communities and then as a group rank challenges that someone should solve. As in previous offerings, these resulted in students describing several of the NAE Grand Challenges for Engineering but also items relating to reducing violence. This activity was used as an introduction to what engineers do and was followed by a Zoom discussion with a designer and engineer working with Trek Bikes that connected all the concepts and related them back to the bicycle activity. Afterward, during a meal break, students were asked to fill in a Venn diagram of how they perceived engineering and industrial design as related and distinct fields. The condensed results are provided in **Table 6.** Most students listed only two to three characteristics per region of the diagram, so the table provides combination of many responses into thematic bands. Both industrial design and engineering definitions appeared accurate and students emphasized their commonality as involving design or problem solving, using creativity, and focusing on advancing products that address community needs.

**Table 6.** Student conceptions of industrial design and engineering

| Industrial Design | Both | Engineering |
|---|---|---|
| Prototyping<br>Brand identity<br>Production support<br>Packaging | Help the community<br>Advanced | Build/branch of science, technology<br>Engines<br>Machines<br>structures |
| Tech based art<br>Aesthetic | Creation<br>Product | Art based technology<br>Technical |
| Marketing | Designing | Coding<br>logistics |
| Creative | Analytical | (None) |
| Working more with drawings/models | Creativity needed<br>Problem solving | Working more with physical objects |

We also collected attitude and interest survey data at the start and end of the one-week camp. Although twelve students complete the pre-camp survey, just seven provided data at the post-camp survey. There was a clear increasing trend in their endorsement of STEM career interest and altruistic beliefs about engineering. There was no change in individualistic beliefs about engineering, which is consistent with our expectations.

**Table 7.** Survey results of pre/post camp interests and beliefs about engineering

| Scale | Pre-camp | Post-camp | Cohen's d |
|---|---|---|---|
| STEM career interest | 3.3 (0.2) | 3.5 (0.4) | 0.59* |
| Altruistic beliefs | 3.6 (0.3) | 3.8 (0.4) | 0.74* |
| Individualistic beliefs | 3.1(0.3) | 3.2 (0.6) | 0.21 |

* Significant, $p < .05$, n=7

***Planned Activities for 2022***

Alabama STEM Education in Bessemer, AL offered its Raise the Bar Camp in Spring 2022; this was the first offering since the beginning of the COVD-19 pandemic. To formalize our findings from the grant, we trained faciliators for the ASE the Raise the Bar Saturday in altruism-focused activities developed as part of this award. The impact of these activies was assessed for a new cohort of students participating in the ASE program. Since ASE originally provided the traditional STEM programming treated as a “control” program measuring the impacts of the new activities will provide a way to directly compare changes in program content. Our refined data collection process will be used to collect pre- and post-program data on students STEM career identity and interests.

**Conclusion**

Across the various camp configurations, through interviews and surveys, we found that experiences framing engineering as altruism can led to meaningful changes in students' appreciation of engineering and, in some cases, new interests in pursuing engineering as a career.[10] Impacts were more pronounced when the entire program theme was strongly related to altruistic engineering, although the Industrial Design camp demonstrated that even brief interventions could have important impacts on perceptions of engineering. For students in the traditional STEM program and virtual camps, students also increased their interest in engineering, but their definitions of the field did not broaden appreciably. Some found new interests, but they did not have the same type of transformative experience as the altruistic-focused and on-campus experiences. Through each of these learning experiences, many students noted how broadly engineering affects our everyday lives and how it helps others. Overall, framing engineering as an altruistic career path led to meaningful changes in students' definitions of engineering and their connection of engineering to their career interests. We plan to continue to share the activities and findings from this research with informal STEM educators through internet portals, conferences, and training for educators seeking teaching certification under the new Alabama Teacher Excellence and Accountability for Mathematics and Science (TEAMS) alternative certification program.

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