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Abstract

In our call for proposals, we argued that engineering education is in need of a paradigm shift that takes students' assets as epistemologically primary to our conception of what engineering, and engineering education, can and should be. The 12 papers collected in this special issue show how a focus on youth assets can realign engineering education to be more humane, more inclusive, and just as meaningful as that of a traditional model. The papers offer both theoretical argumentation and empirical evidence to support their answers to the question of how asset-based approaches can improve engineering education. An emergent theme in these papers is that *relationships* and *community* are central to what it means to attend to and leverage youth assets for learning. In this introduction, we reflect on the papers, their individual and collective findings, and we offer a call to action to the field of engineering education.

Keywords

asset-based, equity, community, care

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Reflections on Asset-Based Pre-College Engineering Education to Promote Equity: An Introduction to the Special Issue

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We are pleased to introduce this special issue, "Asset-Based Pre-College Engineering Education to Promote Equity," which brings together 12 research articles that expand our understanding of the theory and practice of equitable engineering education.

As we consider this collection of papers, our minds are drawn back to our first planning conversations, held in crowded corridors and coffee shops of Tampa, Florida during the 2019 American Society for Engineering Education conference. As we write now in early 2021, those bustling moments of togetherness feel a world away. In the months since that meeting, we have experienced a period of disruption and collective loss unparalleled in our lifetimes. We have seen over 2.5 million deaths globally from COVID-19, including over 500,000 in the USA alone (World Health Organization, n.d.); we have seen an eruption of grief and protest over the epidemic of anti-Black violence in the USA; we have seen extreme weather, symptomatic of climate change, disrupt the lives of millions; and we have seen white supremacists violently attack the U.S. capitol in an effort to disrupt the peaceful transfer of power. While all have suffered loss, we must acknowledge that the pain and burdens of the past year have not fallen on us all equally, but have followed the well-worn channels of inequality, exacting a particularly heavy toll in communities of color.

Amidst the darkness, there have been beacons of light. We have seen the triumph of science and medicine, producing effective vaccines with previously unthinkable speed. We have seen billions of people worldwide change their lives in profound ways to protect the vulnerable. We have seen school systems upend their routines and teachers around the world strive to meet the needs of their students in new ways, despite tremendous hardships. We have seen countless people stand up against anti-Black racism and violence.

Despite all that has changed, the issues that motivated this special issue—the systematic failures of our educational institutions to truly serve the needs of, and recognize and foster the brilliance of, diverse learners—are more salient than ever. The pervasive underrepresentation of women and people of color in engineering is well documented, and we are seeing little improvement, despite substantial investment. In our call for proposals, we argued that engineering education is in need of a paradigm shift that takes students' assets as epistemologically primary to our conception of what engineering, and engineering education, can and should be. We believe that such a paradigm shift needs not only robust theory, but also an extensive library of examples of what a commitment to students' assets looks like, and makes possible, in the concrete particularities of local contexts and participants' goals. As a field, we have much to learn, and pairing guiding principles with concrete examples is a simple but sound pedagogy (Gick & Holyoak, 1983). As such, we invited papers that "investigate the design, learning and social processes, and outcomes of asset-based engineering education" (Martin & Wendell, 2020), so as to develop a library of work that brings together theory and practice.

Collectively, these papers challenge a deep-seated but fatally flawed narrative about equity in engineering education. This narrative assumes that, even though the technical frontiers of the discipline are constantly evolving, the fundamentals of

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what engineering is and what it means to be an engineer are settled. It assumes, for example, that certain aspects of engineering competence (such as mathematical acumen) are necessary prerequisites that can and should serve as gatekeepers to limit participation. In this problematic view, advancing equity revolves around a two-step process of diversifying participation, which itself entails (a) getting diverse learners "into the room," perhaps by building excitement or by rooting out barriers to participation, and then (b) remediating their deficiencies so that they can be full participants. When we hold a narrow, idealized view of engineering in mind, it is difficult to look at young people and see anything but the ways in which they do not yet meet the purported ideal. When we value only a narrow band of assets, only certain students look like good candidates for a future in engineering, and we are oblivious to the ways in which young people can contribute to the transformation of engineering and its impact on the world.

The authors of the papers in this special issue upend this narrative. In line with the call to "question and critique the historically accepted notions" of science and engineering (Wright & Riley, 2021), they ask, can we really educate students when we ask them to leave so much of themselves at the door—their race, their gender, their ethnicity, their language, and their histories? Do we really know with such confidence which aspects of mature engineering must be in place early on—that mathematics, for example, is a more important entry point than empathy, than understanding of community, than creativity? These papers show how a focus on youth assets can realign engineering education to be more humane and more inclusive than, and just as meaningful as, a traditional model. Importantly, the papers offer both theoretical argumentation and empirical evidence to support their answers to the questions of how asset-based approaches can improve engineering education.

Each paper in this collection answers these questions in a different way.

Lottero-Perdue and Settlage consider data from a study where kindergarteners designed an enclosure for a robotic creature, representing a farm animal. Their paper demonstrates the authors' own processes of learning and growth as they reexamined and reinterpreted their data to more broadly consider the epistemic practices of engineering that kindergarteners brought to this task. Their findings argue strongly that empathy and care are central practices of engineering. Furthermore, their approach provides a model for how researchers can and should continually attend to and learn from students' ideas.

Carlone, Mercier, and Metzger investigated the ways in which a first-grade teacher created and held open space for students to take on the role of epistemic agents within an engineering design unit. The paper attends to the multiple, interwoven epistemic practices that unfolded throughout the unit, and its analysis provides a taxonomy of the teacher's key epistemic commitments, including attentive love and epistemological heterogeneity. As such, it provides us with both an existence proof and a model of elementary engineering education that nurtures meaningful student agency.

Chiu, Fick, McElhaney, Alozie, and Fujii also highlight the important role of the teacher in making progress toward equity in elementary engineering education. Through a case study of fifth grade teachers and students enacting an integrated unit on water runoff reduction, they show how teachers' curriculum adaptation choices and moment-to-moment moves made the curriculum more connected to students' real lives and experiences. These customizations were vitally important to making the NGSS-based engineering instruction more centered on student assets.

Calabrese Barton, Schenkel, and Tan present rich narratives of the design work of middle-grade youth who challenge what counts as engineering problems worth solving. They show how these youth centered empathy and care as they applied both everyday ingenuity and technical expertise for social change making in their school community. These authors lift up the youths' own accounts of 13 different design projects to reveal how school community development and youth identity development can co-occur within justice-focused engineering.

Gravel, Tucker-Raymond, Wagh, Klimczak, and Wilson argue for the importance of a learning space's engineering ideology in supporting the participation of youth of color. Taking an ethnographic lens, they describe a technology center committed to antiracist and liberatory practices in its centering of collaborative making and tinkering. Within this special space, one young Black student found his relationship to conventional engineering representations transformed. He could then use his care for, and knowledge of, his community and the Black Lives Matter movement to connect these engineering representations to broader issues of importance to him, strengthening both in the process.

Holly provides an autoethnographic account of his experience teaching an engineering course as a Black male engineer teaching young Black male students. He centers his experiences within the context of the anti-Black racism endemic to America and the engineering profession, drawing from his own experience and from anti-Racist theoretical lenses. His paper offers a grounded set of pedagogical principles that offers new perspectives and guidance to all those who wish to teach engineering to and for young Black men.

Jordan, Zuiker, Wakefield, and DeLaRosa report on a study of youth participation in a real-world community solar energy design project across 15 months of project work. They found that youth leveraged their community and engineering knowledge to propose innovative solutions to meaningful and consequential problems. Community and care were interwoven on multiple levels, as the project designs showed knowledgeable care for the broader community, and as the

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project group (as a community) cared for one another through successes and failures. The paper emphasizes the pedagogical principles of consequential work within a community where everyone learns and everyone contributes.

Nixon, Stoiber, Halverson, and Dando study a maker-mentor program for high school youth in a rural community and reveal a collection of factors that support some youth in taking an inbound trajectory toward the maker community while other youth remain on the periphery. They show the importance of youth having opportunities to apply their assets to relationship-building and community-oriented tasks. All five youth participating in their study brought material, relational, and ideational resources to the maker-mentor program, but the students who had the most opportunity to foster other community members' engineering experiences were those who ended up identifying most strongly with the maker community in the end.

Spruill, Elliott, Volpe, and Alcantara analyze the experiences of two young women of color who were programmers in a high school robotics club. The paper details how these women's identities and positions within the club were negotiated and constructed across multiple contexts and multiple participants. Their ability to persist, learn, and contribute their expertise to the team's effort were, in part, due to the relational work they did in collaboratively constructing comfort spaces for themselves. The authors argue that progress toward our equity goals will require us to carefully examine relationships and how they function within learning environments.

Wilson-Lopez and Acosta-Feliz detail how the workplace experiences of 20 Latinx youth provided opportunities to develop rich forms of engineering-relevant knowledge and skill. Within sometimes exploitative conditions, youth developed "counter-spaces" that emphasized care and compassion for the people and animals with whom they worked. The paper argues that, if the field wants to make good on its commitment to serving Latinx youth, it must recognize and understand the rich funds of knowledge these work experiences provide for engineering learning.

Verdín, Smith, and Lucena show how high school youth's everyday household knowledge and competencies, including not only tinkering skills but also relationship mediational skills, were predictive of trajectories toward greater participation in engineering. Their survey analysis also reveals that when minoritized students can meaningfully connect their wealth of pre-college home experiences to their college engineering experiences, they are more likely to feel confident and certain about studying engineering. By conceptualizing mediational skills as belonging to funds of knowledge for engineering, these authors make an important contribution toward transforming the discipline.

Lee, Knight, and Cardella identify and illustrate the trade-offs required in achieving the goals of a geographically distributed, asset-based, out-of-school program that seeks both to affirm cultural background as well as to broaden access to engineering. They show us how to acknowledge and analyze the ways in which an engineering learning experience may be leveraging, nurturing, or disregarding the cultural capital that students bring to it. As they apply this approach to NSBE's Summer Engineering Experiences for Kids, they help us come to terms with the tensions at the heart of any effort to "scale up" while remaining an asset-based program with a core mission of promoting equity.

Collectively, these papers provide an opportunity to consider asset-based engineering education across contexts, demographics, and methodologies. The theme we see emerging in this collection—one we did not explicitly anticipate in our call for papers—is that *relationships* and *community* are central to what it means to attend to and leverage youth assets for learning. This theme takes different forms across the special issue. One form emerged in several papers where researchers focused on discovering and understanding youth assets. In contexts ranging from a kindergarten classroom to after-school jobs, assets showed up most clearly when researchers examined youth relationships within community contexts. A second form of the theme appeared when researchers writing for this issue explored how assets could be *leveraged* in the small communities of classrooms and clubs. The nurturing of relationships and contexts of care and support was a key mechanism enabling youth to bring their assets to bear for engineering work. Finally, other researchers in this issue looked at how groups of students (small communities themselves) connected with broader community engineering issues. They revealed that youth experience within communities (local and broad) was central to their ingenuity as engineers. As a whole, the papers of this special issue suggest a guiding principle: asset-based engineering education must attend deeply to young people's relationships within and across the multiple communities they inhabit.

The theme of community as central to equitable engineering education brings us back to our reflections on this past year, for growing out of the tremendous grief and loss we have witnessed, there is a collective longing—longing for togetherness, for community, and for justice. In the wake of the murder of George Floyd, Na'ilah Nasir wrote, "As a community of educational researchers, we have the responsibility to work to improve our educational system, and to create the systems we need to disrupt inequality and injustice, and to educate all children to reach their full potential, and we must do so with deep respect for their humanity, and a profound understanding that we can only get there together" (Nasir, 2020). To carry out this responsibility, the engineering education community must also recognize the role that learning designers have played in creating and reinforcing inequalities. Keeping in mind Ruha Benjamin's image of the "spikes" that are designed into technologies to exclude particular bodies (Benjamin, 2021), we must identify and dismantle the metaphorical spikes that extract an immeasurably higher cost from some learners than from others for their participation in engineering education.

This work must include redesigning engineering learning tasks, environments, and communities so that by design, they recognize and leverage the assets of learners who care, of learners who empathize, and of learners who build community, rather than simply those who can do the math.

We believe that the 12 papers in this special issue offer a substantive response to this call to action, offering visions of how learning environments can center students' assets in pursuit of equity, and the necessity of attending to community, large and small, in our designs. We see these visions not as endpoints, but as setting-off points for multiple trajectories toward the new systems we need to construct to fulfill the promise of equitable education for all. We hope that these papers will provide our field with inspiration and concrete tools to take up these ideas and further this essential work.

We close by thanking our reviewers for this special issue, whose wisdom and labor made this collection possible.

Author Bios

Lee Martin is an Associate Professor in the School of Education at the University of California, Davis. His research is concerned with the design of equitable learning environments that foster the development of adaptive expertise and identity in STEM fields, with a particular focus on youth participation in making and the maker movement.

Kristen Wendell is an Associate Professor of Mechanical Engineering and Education at Tufts University. With the Center for Engineering Education and Outreach and the Institute for Research on Learning and Instruction, she conducts research to investigate curriculum and instructional supports for deeper and more inclusive knowledge construction by engineering learners.

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