Asset-based Approaches to Engineering Design Education: A Scoping Review
of Theory and Practice

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Abstract

Asset-based practices in engineering education are intentional ways of acknowledging and leveraging strengths of students, including their everyday experiences, knowledge, and cultural practices to serve as resources for teaching and learning. Such assets or strengths, broadly, may include but not limited to mediational and navigational skills, community networks, language and communication skills, tinkering skills and knowledge, and most importantly, their lived experiences. While asset-based practices can generally foster development of engineering identities in students, there is limited work that summarizes and connects conceptual frameworks to practical pedagogical methods in engineering design courses. With a focus on Hispanic and Latinx communities, this study performs a scoping literature review to answer the following questions:

- What types of assets do students bring into engineering programs?
- What are implications of asset-based approaches to engineering, engineering design process, and design pedagogy?
- What are some pedagogical strategies for implementing asset-based practices in engineering and engineering design courses?

The review was informed by Arksey and O'Malley's five-stage methodology for conducting scoping reviews. The search was performed on several literature databases including ERIC, Engineering Village, Scopus, and the proceedings of ASEE conferences. Findings from this study demonstrate the extent and nature of asset-based practices both in theory and practice, and helped identify a variety of practical asset-based pedagogical strategies from community-inspired design projects and asset-mapping to translanguaging and cross-institutional faculty professional development initiatives. We believe that these findings will potentially motivate the engineering education community to actively implement asset-based approaches in design instruction, and further develop and test more nuanced strategies that draw upon students' funds of knowledge and cultural wealth.

Introduction

Engineering design is typically recognized and taught as a team activity, with cornerstone and capstone project-based courses requiring students to work on teams and to navigate complex social interactions [1]. Having diversity in team membership in terms of gender and cultural background has been linked to improved performance compared with homogenous teams (Page, 2008), but cultural biases and social factors can impact how certain students (e.g., women, students from traditionally underrepresented minorities, students with low socioeconomic status) engage in team projects [2]–[5]. For example, female students may be marginalized to clerical roles on design teams [3]. Instructors can play an important role in helping design teams develop effective teaming and communication practices, and can mentor teams to be more inclusive and equitable [3], [6]. However, issues of diversity may be difficult for engineering faculty to discuss, even amongst peers [6]. Faculty who teach engineering design courses need effective tools and approaches to engage on issues related to diversity and equity in team mentoring [6].

One promising equity-centered educational approach is asset-based pedagogies or practices, which are designed to acknowledge and take advantage of students' diverse strengths, experiences, and background. In contrast, deficit-based educational models of the past were built on the conceptual framework that students from marginalized groups lacked the ability or culture to succeed in certain academic contexts. Asset-based practices acknowledges students' unique identities, backgrounds, and experiences, and leverages their assets for teaching and learning. There is a large body of research focused on asset-based pedagogy that includes Funds of Knowledge (FoK) [7], Third Space [8], and Community Cultural Wealth (CCW) [9]. While these conceptual models each have their own background and unique characteristics, they all share a focus on using students' knowledge, skills, lived experiences, and cultural background in educational settings. FoK and Third Space frameworks tend to focus heavily on environments around the student (e.g., home and/or place of work), while CCW tends to be much broader in terms of student assets.

A growing body of research indicates that asset-based practices have a positive influence on students' identity and achievement (e.g., [10]–[13]), although much of this work has focused on the K-12 level. The engineering design process is an ideal environment to implement asset-based practices not only because design teams need diverse skills, competencies, and experiences in order to succeed, but also because most engineering problems are deeply embedded in sociocultural contexts. Asset-based practices allow for genuinely acknowledging students' lived experiences and their diverse assets in the design process and reducing marginalization of students from traditionally underrepresented groups on design teams. However, there is limited work that describes practical pedagogical methods built on asset-based approaches in the context of engineering design courses. We seek to evaluate existing literature to better understand asset-based practices in engineering design contexts. This study describes the results of a scoping literature review that was conducted to answer the following questions:
1. What types of assets do students bring into engineering programs?
2. What are implications of asset-based approaches to engineering, engineering design process, and design pedagogy?
3. What are some pedagogical strategies for implementing asset-based practices in engineering and engineering design courses?

Methods
We adopted Arksey and O'Malley's five-stage framework (identifying research questions; identifying relevant studies; study selection; charting the data; and collating, summarizing, and reporting results) [14] for conducting scoping reviews. The search was performed on four primary literature databases: ERIC, Engineering Village, Scopus, and conference proceedings of the American Society for Engineering Education using the following keywords: "asset-based" and "engineering". Search results were then augmented using Google Scholar and two systematic reviews related to asset-based frameworks in STEM (FoK [7] and CCW [9]), respectively. Those articles that met any one of the following criteria were included in this review:
1. The study includes evidence of assets for one or more certain student population(s) or,
2. The study includes asset-based practices for teaching and learning engineering or engineering design in any educational setting or,

3. The study includes conceptual ideas or general suggestions related to asset-based practices that can be used to develop educational interventions at the course-level or program-level in engineering or,
4. The study is a systematic review related to asset-based practices in science, engineering, or mathematics education.

Studies that met criteria #1 or #2 were considered for primary analyses. Other studies were considered for secondary analyses. Two reviewers (HB and VS) independently screened articles for relevance and then resolved any conflicts by consensus.

Results

Our literature search identified a total of 288 relevant articles. Of these, 44 articles were included for analyses and reporting (see Figure 1 for more details). Twenty-four articles met the criteria for primary analyses.
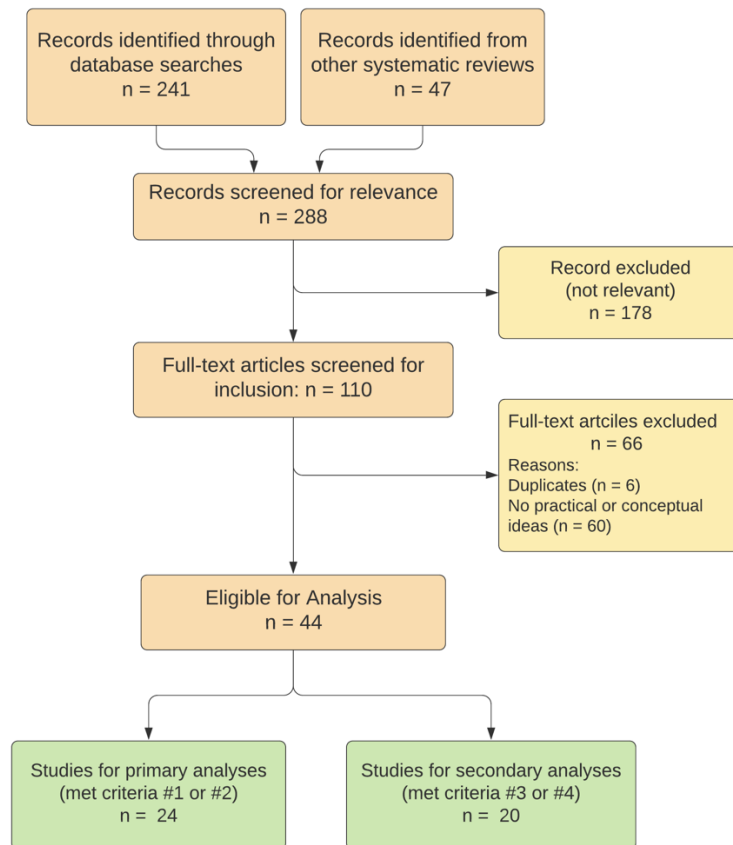

Figure 1. Flow Diagram for Study Selection

What types of assets do students bring into engineering programs? What are implications of asset-based approaches to engineering, engineering design process, and design pedagogy?

Different student groups hold different assets in the form of cultural wealth and/or funds of knowledge. Here, we summarize (see Table 1) assets by student subpopulations and their implications to engineering and engineering design education. Neither the student subgroups nor

their corresponding assets and asset categories are meant to be exhaustive in nature. The summary in Table 1 reflects evidence found in the literature and are only meant to be illustrative and of practical value to engineering educators.

Table 1. Summary of assets listed in articles included in primary analysis, stratified by various student subpopulations

Student subpopulation	Assets	Implications to engineering education
Military veteran students	Leadership skills acquired during military training	Providing leadership opportunities in academic settings (e.g., technical co-lead in a design team) may increase engagement in engineering [17], [18].
Low-socioeconomic students	• Defining and solving problems in the midst of financial and material scarcity; • Social and navigational capital	Administrative and instructional faculty involved in engineering design programs may intentionally build connections with students' community networks [19]. They may also consider projects with emphasis on design for affordability Taking solely an asset-based approach will ignore systemic issues such as inequitable access to educational opportunities (e.g., advance placement or dual-enrollment courses). A balanced perspective that both leverages assets and addresses challenges faced by these students in engineering programs is needed [20].
First generation students	• Tinkering knowledge from work or home; • Perspective taking, reading people, mediation skills; • Community networks; • Connecting to lived experiences	Assets that first generation students hold are perceived to be largely "hidden", which highlights the need for tools to elicit students' funds of knowledge [21]. Assets identified in research studies [21]–[23] suggests the importance of community-oriented projects in first-year design experiences.
*Low-income, first generation (LIFG) students	• Building, fixing, and adapting technical artifacts and systems; • Empathizing with marginalized groups and communities	Engineering science and design courses may benefit from problems that build upon funds of knowledge that LIFG students possess. For example, students can be tasked with rewriting engineering problems for scenarios and contexts that are more relevant to their backgrounds [24], [25]. Another potential strategy may be to create multiple, explicit avenues in design projects where students can make design decisions and incorporate their choices into the design process (see Table 1 in [26]).
Transfer students	• Navigational capital ("ability to move through social institutions") [9] • Experiential capital ("pre-college experiences that provide a foundation for	Students transferring from two-year colleges may be attuned to maneuvering through complex support systems and identifying the right resources needed for college success [27]. Four-year institutions should not take such capital for granted. Rather, support systems need to be

	success in college and engineering") [27]	strengthened (e.g., having dedicated faculty mentors in addition to staff advisors; better coordination of dual-enrollment courses that goes beyond articulation agreements) [28], [29]. It is noted that specific assets that transfer students bring with them may not be well-recognized [30].
Latinx students	Resistant capital ("skills that foster oppositional behavior to challenge status quo") [9]	Resistant capital is often realized by participating in student organizations that provide intentional ways to serve and give back to their community [31]. More alignment between curricular (e.g., design activities in engineering courses) and co-/extra-curricular (e.g., community-facing initiatives led by student organizations) activities may help realize students' resistant capital to persist and succeed in engineering.
	Aspirational Capital ("abilities to maintain hopes and dreams despite challenges and barriers") [9]	There is evidence that Latinx students' aspirational capital is an important factor for their persistence in engineering [32], but there are no tangible strategies on how to leverage their aspirational capital at the course or program-level. Perhaps, role playing as a professional engineer [33] or closely following end-to-end design process (including product delivery to customers) could connect to students' aspirational capital.
	Familial and Social capital (e.g., knowledge related to health, agriculture, financial management, and marketing; transnationalism) [9], [34]–[36]	There is evidence that Latinx' students' funds of knowledge acquired through household, work, and life experiences are valuable and highly relevant to engineering design processes, systems thinking, teamwork, and ethical reasoning (see Tables 3 and 4 in [35]). However, the connections between students' everyday discourses and engineering discourses may not be readily evident or accessible to educators [37].
African American students	Navigational and aspirational capital	Research on cultural wealth and engineering students of color suggests that there is a strong connection between navigational capital and ways of persisting in engineering [38]. This may imply that building and activating students' navigational capital early on (e.g., in high school) would be beneficial for their college success. It should be noted that even though the most common assets or capital across various student groups may seem similar, how a certain group

		(e.g., African American vs. Latinx students) activates their capital may be different [38].
*Intersectional identity		

What are some pedagogical strategies for implementing asset-based practices in engineering and engineering design courses?

Six studies met inclusion criteria #2 (i.e., included some form of asset-based practices for teaching and learning engineering or engineering design), with four articles sourced from ASEE conference proceedings, and the remaining two papers sourced from other databases. Here, we summarize (see Table 2) the studies based on the intervention participant population, research setting (with Hispanic-Serving Institution [HSI] status specified), specific engineering discipline for intervention (if applicable), and whether the intervention was applied at a course or program level. All studies were conducted in the United States, and most were set at a four-year institution. One study included students at a community college and at a nearby four-year institution. One article described an intervention with faculty, while the other six focused on interventions with students. The majority of the studies (5 of 6) described an intervention at an HSI. Four studies focused on an intervention in a specific engineering discipline, with three describing chemical engineering courses (all three studies involved the same two authors, Svihla and Gomez), and one describing a civil engineering course. Four articles described course-level interventions that can be adapted as general asset-based pedagogical strategies, while two articles described program-level interventions.

Table 2. Summary of articles included in our primary analysis

First author (year)	Participant population	HSI	Engineering discipline	Intervention level
Svihla (2017) [39]	First-year undergraduate engineering students	Yes	Chemical	Course-level
Gomez (2018) [40]	Second- and fourth-year undergraduate engineering students	Yes	Chemical	Course-level
Battistini (2020) [41]	Third-year undergraduate engineering students	Yes	Civil	Course-level
Galvan (2020) [42]	Tenure-track and career-track instructors	Yes	Not specified	Program-level
[a]Smith (2016) [43]	[b]Low income, first generation engineering students	No	Not specified	Program-level
[a]Gomez (2018) [44]	First-year and second-year undergraduate engineering students	Yes	Chemical	Course-level
[a]Journal publications; [b]Includes students from both 4-year institution and community college HSI: Hispanic Serving Institution				

Asset-based Strategies at Course-level
Culturally-responsive or Community-inspired design projects: A course-level pedagogical strategy described in two articles was choosing design project topics that engaged students and drew from students' assets. Hands on, ill-structured course projects give students an opportunity

to "try on" an engineering identity, while focusing on project topics that are relevant to students helps students to become more engaged [39]. Svihla et al. [39] described creating design challenges that were community-, industry-, research-and entrepreneurially-inspired, drawing on related work on service-learning and community-engaged learning. In another work, Gomez and Svihla [44] incorporated several small community-inspired design challenges that drew upon students' knowledge of local rural communities. This strategy can be adapted for a wide variety of engineering design courses by choosing design project topics related to problems that impact local communities and make use of students' knowledge of a local region or community. To activate students' assets (funds of knowledge (FoK), cultural wealth), instructors can explicitly call out a relevant FoK or background as a strength that students should identify and leverage on their team [44]. A related pedagogical strategy, described by Battistini [41], is to choose examples drawn from students' communities and cultures to introduce the engineering design process. For example, Battistini asked students to identify and analyze buildings or structures from a country of their choice [41]. Culturally-relevant examples can serve as an opportunity for students to reflect on how culture influences design outcomes [41]. This course-level strategy could be applied in engineering design courses by using examples and problems that are authentically drawn from cultures relevant to students

Asset-mapping: Another course-level strategy involves asset-mapping. Gomez and Svihla [40] describe a two-step asset mapping activity that was implemented in two chemical engineering courses. In the first step, students identified their own assets and the assets of their teammates, and in the second step, students mapped team assets to critically evaluate areas of strength and weakness, using a list of engineering-relevant skills (e.g., communication, project management) provided by their instructor. The authors note that asset mapping in context of engineering design projects helps students to develop stronger teams and grow in awareness of the importance of professional skills for engineers [40].

In addition to strategies identified in our primary analyses, we extended conceptual ideas and suggestions in studies that met inclusion criteria #3 and #4 (i.e., early-stage studies or other systematic reviews) and provide the following practical ways of applying asset-based approaches in engineering courses.

- Design instructors may co-design course content and project topics with students such that the topics are aligned with extra-curricular activities (e.g., membership in student organizations with a design emphasis) and/or connects to their community funds of knowledge [49], [50], [51]. Tailoring course content to students' assets and interest is a common recommendation in several studies. To do so, engineering instructors may elicit asset information from students through asset maps discussed earlier [40], pre-class survey, brief interviews with students [52] (if the class size in small), and written memoirs.
- Engineering design projects may include detailed vignettes as a way to situate the problem (and the overall design project) in different social, historic, and cultural contexts [48]. Such vignettes should ideally bring together technical concepts in engineering, students' lived experiences, and the societal context. An example vignette for energy-related design projects can be found in [48].
- Technical terms in design and engineering science courses can be dissected and systematically developed and shared among students [45]. This may involve allowing

students to develop metaphors and/or analogies from their lived experiences for common and important engineering vocabulary.

- Bilingual students and English as a second language students tend to use more verbal and visual sources than written sources for information gathering phases in the engineering design process [46]. Design instructors and students can jointly curate a variety of visual, oral, and written sources of information for design activities. Instructors can also encourage students to use their home languages in addition to English (i.e., translanguaging), as appropriate, in the design process, especially when working with linguistically diverse customers [46]. Translanguaging offers an intentional approach to recognize bilingual students' ways of knowing, doing, and being and eventually, create engineering knowledge in multiple languages [47]. Unfortunately, translanguaging is almost non-existent in postsecondary engineering education.

Asset-based Strategies at Program-level

Among studies identified for primary analyses, two studies were focused on strategies at a programmatic-level. As described in Galvan et al. [42], professional development can be used to increase awareness of educators about asset-based practices and provide them with practical strategies that can be incorporated into their courses. Galvan et al. [42] held a teaching and learning academy workshop, grounded in CCW, where the participants were asked to: (1) reflect on their own educational experience; (2) discuss their student's cultural wealth and learning characteristics; and (3) become familiar with some pedagogical techniques to draw on students' assets. Given instructors' agency in designing course content, faculty development can be an effective way to educate instructors and help them to adapt effective asset-based approaches.

The second study that described a program-level intervention focused on a cohort-based program to help students with similar backgrounds identify and draw upon their unique FoK, using out-of-class workshops and one-on-one discussions. Smith and Lucena described a program that recruited students who self-identified as low income and first generation to participate in a workshop and to take part in a series of one-on-one interviews with the researchers [43]. The interactive workshop gave students an opportunity to work together to "redefine and solve" engineering problems using their unique FoK, while the interviews enabled students to connect their FoK to engineering concepts with the researchers' help [43]. This program could be implemented in other contexts by recruiting students with similar backgrounds and providing them with opportunities to participate in out-of-class design sprints and targeted mentoring focused on students' FoK.

Designing and implementing asset-based strategies at the program-level often require a shared understanding of the value that students' assets can bring to bear on engineering programs. Few additional extended examples include:
- Providing and promoting shared physical and virtual spaces for students to interact with faculty, build professional relationships, and more effectively seek help and/or access information [57], [58].
- Expanding the criteria and metrics for admission into engineering programs that go beyond standardized test scores (e.g., semi-structured interviews to better understand prospective students' strengths and characteristics [53]), coupled with rigorous cohort-

based curricular and co-curricular activities during the first year in the program [53], [54], [55].

- Transformative faculty professional development initiatives (e.g., incentivized cross-institutional faculty communities of practice) to equip engineering educators with tools to identify, appreciate, and integrate students' cultural wealth and funds of knowledge in engineering design education [56].

Discussion

Our review showed that there is substantial research around identifying assets that different student groups may bring into the discipline of engineering. However, there is limited work on how to activate those assets and use them meaningfully in engineering design education. Of particular note is that the majority of applied work in this area were implemented in minority-serving institutions such as HSIs, suggesting that institutional identities and mission may play role in adopting asset-based practices to best serve students from nondominant groups. Gaps in implementation of asset-based approaches in engineering design could be attributed to lack of awareness of practical pedagogical strategies, which this review addresses to some extent. Additionally, there may be misconceptions or skepticism around whether an asset-based approach will be beneficial to all students and whether it will improve or hinder engineering design instruction. While assets may vary from one student group to another, we believe that taking an asset-based approach to engineering education, including design courses and activities, is essential, ethical, and will not only benefit *all* students, but also help create equitable engineering programs. Another common misconception is that students' assets are same as their prior knowledge. It is noteworthy that students' assets are much more broader, and includes social and cultural capital of their communities as well as historical and communal knowledge [59].

Limitations: Our search was exclusively focused on work that called out "asset-based" theories and practices in science and engineering, recognizing that we may have missed relevant work that were not explicitly referred to as asset-based. Further, characterizing whether a certain strategy is truly asset-based or not may need further investigation. Last, our analysis was based on assets described in existing research literature and was not meant to be exhaustive. Assets of student groups at the intersection of gender and race/ethnicity and other intersectional identities are beyond the scope of this review.

Conclusion

In this scoping review, we identified a range of assets that different student groups possess and their implication to engineering and engineering design education. We also provide a detailed account of variety of practical asset-based pedagogical strategies from community-inspired design projects and asset-mapping to translanguaging and cross-institutional faculty professional development initiatives. The assets and pedagogical strategies we identified demonstrate different ways in which predominant frameworks of asset-based approaches (e.g., community cultural wealth, funds of knowledge) apply to engineering and engineering design. These findings will potentially motivate the engineering education community to actively implement asset-based approaches in design instruction, and further develop and test more nuanced strategies that draw upon students' funds of knowledge and cultural wealth.

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