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# Youth Engineering Solutions (YES) Out of School: Engineering Opportunities in Out-of-School Programs for English Learners


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# Youth Engineering Solutions (YES) Out of School: Engineering Opportunities in Out-of-School Programs for English Learners

Out-of-school (OS) programs, such as afterschool programs or summer camps, educate millions of youth, piquing their interests and developing their identities. An increasing number of OS programs are offering STEM. However, such efforts have focused primarily on mathematics and science activities [1]; only about 30% of STEM programming focuses on engineering [2]. More engineering programming is needed [1]. Because most afterschool educators do not have a background or coursework in engineering or knowledge of age-appropriate engineering activities, high-quality curricular resources can play an important role in supporting the introduction of engineering activities.

OS programs offer possibilities for addressing inequities in STEM education. Hispanic and African American youth participate in OS programs at more than twice the rate of Caucasian youth, [3]. The flexible, open-ended nature of OS programs, which feature hands-on activities in low-stakes environments, are also promising environments for supporting English learners (ELs). ELs, one of the fastest growing populations in the U.S. at the elementary level [4, 5], face the challenge of learning English and disciplinary content simultaneously. ELs are currently underrepresented in STEM fields [6]. Tapping their talents, ideas, and knowledge by providing opportunities for them to contribute to and learn about engineering and science could help foster interest in engineering and STEM and broaden participation in these fields [7–10]. Engineering activities can offer a number of benefits for ELs [11].

Youth Engineering Solutions (YES, yes.psu.edu) is developing and researching equity-oriented frameworks and curricular materials for use nationwide. *Youth Engineering Solutions Out of School (YES OS): Engineering Opportunities in Out-of-School Programs for English Learners*, funded by the NSF Broadening Participation in Engineering Division, is investigating ways that equity-oriented OS engineering curricula provide opportunities for ELs to learn knowledge, discourses, and practices; bring their cultures, experiences, and ideas to engineering projects; expand their repertoire of identities and interests; and enhance membership in learning communities. Our first year of this grant-funded project focused on:

(a) developing a Model for Equity-Oriented Engineering Learning and
(b) applying these principles to the design of two engineering units for upper elementary out-of-school settings.

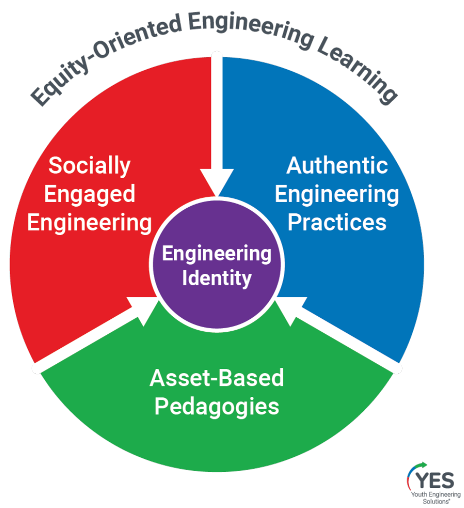
## Theoretical Frameworks

YES rests in a sociocultural learning theory. That is, we consider youth in their cultural, social, linguistic, and institutional contexts. As youth interact with peers, learning communities, and more-knowledgeable others to engage in authentic engineering work and discourse, they develop disciplinary knowledge and practices [12–14]. Engaging in engineering design activities including brainstorming, planning, constructing, testing, analyzing, and iterating affords youth opportunities to develop facility with the types of activity and discourse (speaking, gesturing, writing, representing) that constitute engineering [15, 16]. Youth also negotiate roles, establish norms and cultural practices, and figure out what it means to be a member of the knowledge-creating community [17]. Such social and discourse processes foster relationships and identities among youth and result in conceptual understandings of the discipline.

**YES Model for Equity-Oriented Engineering Learning**

Educational environments in which *all* youth flourish are designed intentionally. The YES team began its work by articulating a set of equity-oriented design principles. We drew from our previous, proven, equity-oriented curricular principles [18–20]. Additional literature review and consultation with experts informed an update the principles. We paid particular attention to theories and best practices related to English language development for ELs, especially related to STEM [6, 21–23]. We also reviewed literature related to social justice and engineering [24–27]. From this we identified a YES Model for K-12 Equity-Oriented Engineering Learning (see Figure 1). This model and its components are described in more detail in our ASEE 2022 Conference Paper "*Design Principles for Equity in Engineering*" [28].

Figure 1: YES Model for Equity-Oriented Engineering Learning




We are pressure testing and refining these principles as we develop two curricular units for youth in upper elementary school (ages 9–12).

**Research Methods and Questions**

YES materials are developed using iterative, user-focused, design-based research (DBR) that closely mirrors the engineering design process. We systematically design curriculum while simultaneously researching it [29, 30]. An iterative cycle of design and test/research underlies our efforts to understand how to design curricula for OS programs that support ELs and their educators [31, 32].

Cycles of research, design, review, testing, data collection, analysis, and redesign probe users' needs and constraints, how the materials work with the intended audience, and what can be changed to further strengthen the resources. We recognize the importance of close collaboration with diverse programs, educators, and youth to shape the products. Observations, surveys, and focus groups provide valuable feedback that inform subsequent iterations. Educators are an important source of expertise and ideas—we often fold their modifications into the curricula. Educators also often spark the development of new curricular supports as they request additional products that will improve their experience or that of their youth.

Adhering to principles of DBR allows YES to contribute to the growing body of research and knowledge about preK-8 engineering as well as create resources that meet the needs of diverse stakeholders that can be used at scale. The research questions we seek to address include:

**RQ1**: In what ways do equity-oriented, socially engaged OS engineering curricula afford opportunities for ELs to:

- Develop engineering knowledge and practices?
- Engage in authentic discourse?
- Broaden their participation in engineering and learning communities?
- Develop engineering interest and identities?

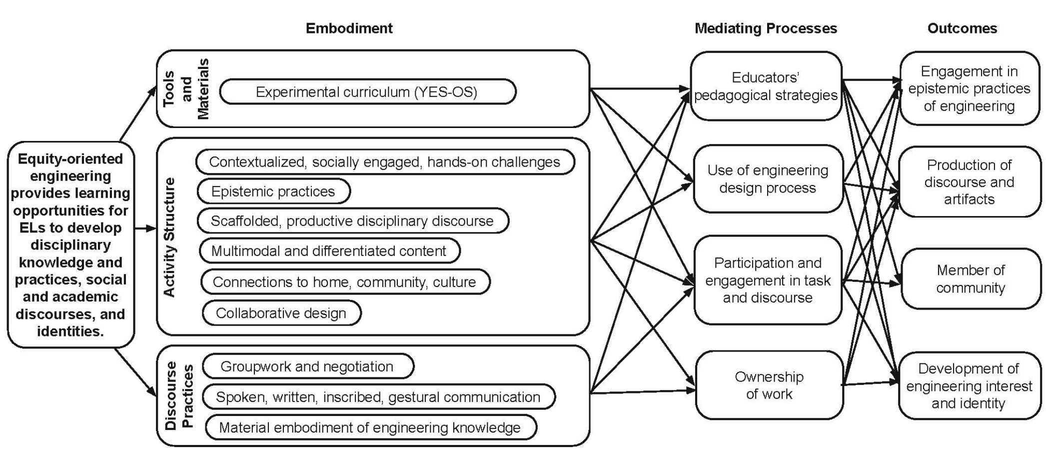
**RQ2**: How can educative, equity-oriented engineering curricula support OS educators as they:

- Build their knowledge of engineering, especially engineering practices?
- Enhance their understandings of ELs' strengths and challenges during engineering activities?
- Increase their confidence to lead engineering activities and to lead such activities with ELs?
- Create asset-based educational environments that invite ELs to draw upon their experiences, language, and culture?
- Recognize and support the development of engineering practices and identities for *all* youth?

**RQ3**: Which curricular design features and scaffolds are most valued and effective in supporting these outcomes for *all* youth (including ELs) and educators?

We conceptualize our research with a conjecture map [33] (see Figure 2). This illustrates the aim of the design, distills particular features of the design and what they are expected to do, and specifies what they should produce. As we engage in the research, we will modify and revise our conjecture map to reflect our learning.

Figure 2: Conjecture map for supporting equity-oriented engineering for ELs in OS programs



These frameworks, principles, maps, and questions guided the development of our YES Out of School curricular units.

**YES Out of School Curriculum Development**

Our development efforts focused on conceptualizing and drafting two curricular units that featured a socially engaged, real-world design challenge. Through extensive research, consultation, and experimentation, we generated curricular structures, formats, features, and resources that traverse all units.

Engineering Units: Design Challenges
YES OS engages youth in an engineering design challenge. The curriculum uses an age-appropriate engineering design process as the unit backbone (see Figure 3). Youth engage in the phases of the process as they iteratively design, evaluate, and redesign possible solutions.

Figure 3: YES Elementary Engineering Design Process


We are developing two YES OS units:

- **Engineering Sock Assistive Devices**: Youth design an assistive device that helps a person with limited mobility put on socks.
- **Engineering Rescue Rope Shuttles**: Youth design a rescue rope shuttle that lands near a person who needs a water rescue.

The team committed to creating curricular materials that reflected a suite of other elements, including socially engaged engineering, engineering practices, scaffolds for language development, and family resources. We also wanted the materials to be educative—helping OS educators develop knowledge about engineering and pedagogies as they used them.

Socially Engaged Engineering
The YES team distilled three principles related to socially engaged engineering to guide our curriculum. These we also share with the educators in the YES-OS Educator Guide as seen in Figure 4.

Figure 4: YES Out of School Curriculum Design Principles for Equity, Socially Engaged Engineering [34].

| Category | Design Principles for Equity | Youth Activity |
|---|---|---|
| Socially Engaged Engineering | Situate engineering in real-world contexts | Youth engage in real-world engineering challenges that expand their horizons while connecting to their home, communities, and cultures. Activities begin with narratives that engage youth' imagination and demonstrate how engineers design and shape our world by solving problems. |
| | Introduce multiple perspectives and possible impacts of technology | Youth consider stakeholders and possible impacts of the technologies they design. Each unit situates engineering in local, community, and global contexts. |
| | Connect engineering to youth' family, community, and cultures | Youth explore cultural and family connections to design solutions that are relevant to their everyday lives. |

As we develop units and activities, we ensure that they encompass these principles.

Engineering Practices

Engineers approach their work using common engineering practices. Research conducted by the YES team that drew from studies of engineering in professional and school settings identified 16 fundamental engineering practices for preK-12 engineering [35] outlined in Table 1. YES engineering practices align with the NGSS practices and describe more specific, engineering-focused behaviors.

YES curricula build youth's facility with engineering practices. These practices are often captured in an activity's learning objectives. Each YES OS activity highlights one practice, describes how youth engage with it, and signals where in the activity it occurs with an icon in the Educator Guide.

Table 1: YES Engineering Practices

| **Engineering Practices** | |
|---|---|
| Consider problems in context | Use systems thinking |
| Use processes to solve problems | Construct models and prototypes |
| Investigate properties and uses of materials | Make evidence-based decisions |
| Balance tradeoffs between criteria and constraints | Persist and learn from failure |
| Innovate processes, methods, and designs | Assess implications of solutions |
| Apply science knowledge to problem-solving | Work effectively in teams |
| Apply math knowledge to problem-solving | Communicate effectively |
| Envision multiple solutions | Identify themselves as engineers |

Language Scaffolds
Many youth, including ELs, are developing language proficiency. Few STEM and engineering curricula have been designed to scaffold participation and language development. The YES team reviewed research and best practices and consulted with experts to generate a set of research-based approaches that invite meaningful participation by ELs. The embedded scaffolds and strategies are designed to support language development across reading, writing, listening, and speaking domains and include:

- Discussion strategies
- Content presented multimodally
- Encouragement of home language(s)
- Vocabulary presented in context
- Strategic groups
- Scaffolded writing
- Hands-on exploration
- Key sentence frames
- Multimodal communication [34].

Engaging Families
YES recognizes that the support of youth's families and broader communities are critical to fostering youth's positive identity development and confidence. A review of the literature and work with experts helped the team to identify promising goals and practices for working with families. These include:

1. Help families understand that engineering is all around them.
2. Honor families' knowledge and experiences.
3. Engage families as co-creators and problem solvers.
4. Provide support for families to advocate for their children's STEM learning and possible careers in STEM. [34]

These goals drove the creation of a set of family-facing resources and strategies. Throughout the unit, educators are encouraged to use these resources and strategies to actively communicate with families and connect children's home lives with their schooling and other experiences.
Current family-facing YES OS resources include:

- A family letter that is sent home at the beginning of unit. It describes the unit and provides discussion prompts that can spur related conversations.
- A family activity, designed for families, siblings, and community members to engage in, which is related to the engineering OS unit.
- Prompts that remind educators to share photos or videos with families to encourage conversations at home.
- A showcase event at the end of each unit where youth can share their engineering work with family and community members.

Educative Curricula
Engineering is still a new discipline for many educators, particularly elementary educators. Many educators may not be familiar with teaching ELs. Some out-of-school educators may need

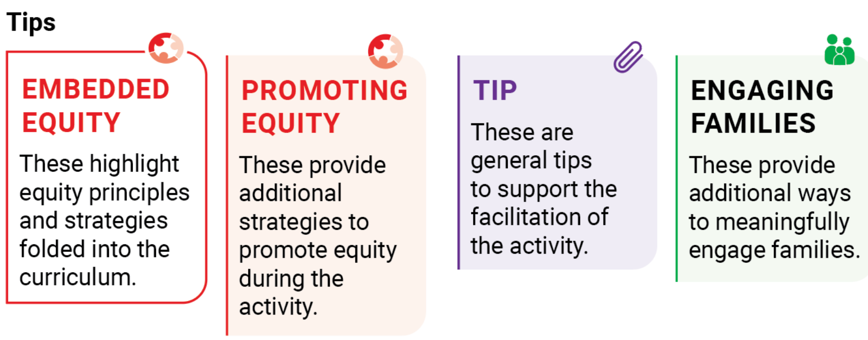
support in offering age-appropriate engineering experiences. Helping educators develop their knowledge about engineering and instructional practices that support participation by all youth is also a goal of YES.

To this end, we create educative curricular materials [36–38]. YES educator guides are written to build educators' understanding of high-quality engineering education. They also point out instructional strategies than can create equitable learning environments. Embedded supports offer background information, highlight asset-based strategies, and explain curricular elements so educators can use these frameworks to critically evaluate other engineering activities or develop their own challenges.

YES educative components include:

- A featured engineering practice for each activity. We indicate when this practice is introduced and when youth are actively engaged in this practice.
- Additional science and engineering background information for teachers related to the activities.
- Educative tips anchored to text throughout the activity draw attention to strategies in use or suggest additional ideas and connections. We offer four types of tips in our educator guides as seen in Figure 5 [34].

Figure 5: Explanation of Tips in YES Educator Guide Overview




<u>Out-of-School Programming Considerations</u>
As we developed the units, we also considered characteristics of OS programs and educators. These informed design features of the YES materials as outlined in Table 2.

Table 2: Considerations for OS programming and YES Design Features

| Considerations | YES Design Features |
|---|---|
| OS educators have limited time to review activities before implementation. | - All YES units and activities have a common structure, features, and format.<br>- Activity instructions are short (2-3 pages) and designed so educators can quickly implement them. For example, sample questions educators might pose are bolded. |

| | |
|---|---|
| OS educators often do not have a dedicated space. They must set up and break down materials each day. | - Activities have limited, easy-to-set up materials that can be stored between sessions. |
| Attendance in OS programs can be sporadic. | - While activities build, each is also self-contained and can be fully accessed without prior experience. |
| OS environments are “not school”. | - Activities actively engage youth and involve choice and movement.<br>- Reading, writing, and sitting quietly are not central to the experience. |
| Youth often have choice about which OS activities they participate in. Engineering needs to be engaging. | - Activities are fun and dynamic. |
| OS programming is variable in length. | - A unit includes core activities (about 5 sessions) and 3–5 optional activities that accommodate a variety of schedules. |
| OS educators can be new to teaching engineering, engineering practices, youth, and/or ELs. | - An overview explains features of the curriculum and strategic grouping for language development.<br>- Materials are designed to be educative, providing embedded scaffolds that communicate why design choices were made and highlighting critical features. For example, one engineering practice is highlighted in each activity to help both educators and youth develop familiarity with practices. Tips in the margins call out facilitation strategies and equity-oriented actions (see below). |
| Youth benefit from tools that structure their efforts. | - An engineering notebook helps organize and focus youth’s work, drawing attention to important elements and recording ideas or results that will inform subsequent activities. |
| Youth want to connect activities to their lives and world. | - Youth situate the problem in a real-world context<br>- Activities are introduced with narratives featuring diverse role models.<br>- Prompts invite youth to talk with family members and others in their community. |
| Families are critical to youth’s development. | - Family-facing resources invite them to share their knowledge and experiences and celebrate their child’s engineering accomplishments. |
| Youth should explore a range of possible futures and careers. | - Youth develop engineering identities by engaging in authentic engineering work.<br>- Activities ask youth to reflect on the engineering skills they have developed.<br>- Youth learn about a range of careers related to the challenge from people in their community. |

During our first year, we have applied these curricular frameworks, strategies, and tools to the design of two units. For each of the units we have written:

- An Educator Guide with overview pages, materials and preparation background, assessment tools, and activity instructions including discussion questions and tips.
- An Engineering Notebook that organizes and collects youthwork.
- Duplication Masters for other youth-facing handouts such as cards, signs, or visual vocabulary glossaries that are used by groups.

We have recruited a set of out-of-school educators who teach ELs in programs in Massachusetts, Pennsylvania, and Tennessee who are collaborating as pilot testers. During spring of 2022, they will implement the resources in the programs and provide us feedback about the materials. We will also collect information that help address our research questions. This testing and these data will inform revisions of the materials during summer 2022.

The productive first year of our YES Out of School grant resulted in a Model for Equity-Oriented Engineering Learning and the articulation of a set of commitments and frameworks. These have guided the development of two engineering units for out-of-school programs. We look forward to pressure testing and refining the models, frameworks, and curricular units with our research data.

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