I-Engineering:

Tools for Teaching and Learning Engineering Practices: Pathways Towards Productive Identity Work in Engineering

MICHIGAN STATE UNIVERSITY

INVINCIBILITY LAB AT MICHIGAN STATE

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Project Overview & Objectives

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I-Engineering supports identity development in engineering as a part of (not apart from) learning two core practices in engineering: 1) defining problems and 2) designing solutions. The I-*Engineering* framework and tools help teachers/students to localize the engineering design process. The process of localizing engineering design as involving iterative engagement with both the technological and social dimensions of engineering design towards refining the problem constraints/specifications while exploring possible modes of solution optimization for particular people/ contexts. We are also generating empirically based understandings of how to support identity work of middle school students engineering for sustainable communities across spaces and over time. Our framework and tools support teachers in understanding how students develop this identity work in their classrooms, when designing for community and local concerns. We are currently underway in creating curriculum and teacher tools that support teachers and students with thinking, planning and reflection around community ethnography and the design process when engineering for sustainable communities.

Practice	Technical Dimensions	Social Dimensions	Interactions
Tool Set 1 Defining problems	• What problems can technology solve? • What do I need to know about the technology to solve the problem?	• How can I identify, seek out and incorporate multiple perspectives from relevant stakeholders? • How can I translate my technical thinking into questions, ideas and concerns for outsiders?	Setting criteria & constraints: • Seeking evidence from different perspective: What perspectives matter and why? • Seeing problems as layered & complex: How do different perspectives constrain problems differently and why does this matter?
Tool Set 2 Designing solutions	• How do I decide on a design that best meets the criteria and constraints? • What do I build and how do I test it? (Modeling, prototyping) • What do I need to know to optimize my design?	• What perspectives should my design address and how do I test my design against these perspectives? • How do I communicate ongoing design/ decisions to others who may not have the same knowledge as me?	Refining specification & optimization: • Which criteria are most important? • How do I balance competing or conflicting factors? • How do I maximize trade-offs?




Conceptual Frameworks

Productive Identity Work (PIW)

I-Engineering aims to promote students' productive identity work in engineering. Productive identity requires:

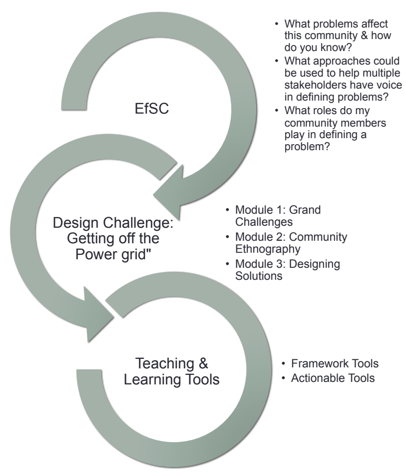
1. **Knowledge and Practice**: Students' funds of knowledge along with disciplinary knowledge are leveraged in the classroom to transform curriculum.
2. **Recognition:** Others noticing and publicly valuing the strengths that students bring to STEM, even when these are not traditional STEM resources (e.g., being funny).
3. **Agency:** Supporting students to feel engaged, capable, competent and belonging to the engineering classroom community.

Engineering for Sustainable Communities (EfSC): Core Design Principles and Educational Implications

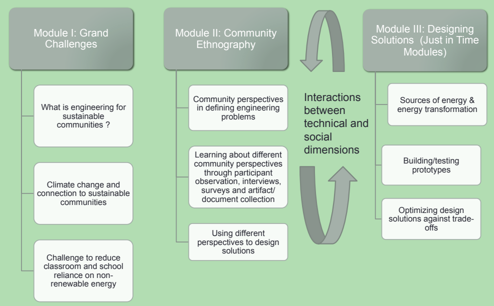
Design principles help teachers navigate from a topic to a problem space where students can develop realistic and testable tools based upon current knowledge, empirical investigation of technical & social dimensions, and operational constraints and specifications.

1. The problems identified by engineers and community members are those that improve the daily lives of people with special attention to issues of injustice.
2. Designing solutions that positively affect sustainable communities requires multiple perspectives, including local perspectives.
3. Sustainable community members are empowered to design & maintain long-term solutions to problems that affect them directly.
4. The design process equitably balances political, environmental, and social effects of decisions

I-Engineering Framework



I- Engineering Design: Classrooms and Communities "Off the Power Grid"



Curriculum Modules
Engineering has played a significant role in the advancement of civilization while also contributing to the ways in which our global society is not sustainable. Our design challenges focus the relationship between the electrical production & consumption system and climate change as one critical grand challenge of engineering that demands solutions at both the global and local community level.

Our challenges are designed to cover:
- Engineering practices of defining problems and designing solutions;
- Big ideas related to energy transformations, energy production, and large scale energy systems;
- Community perspectives.

By integrating community ethnography with the technical dimensions of engineering, students will experience what it means to become an engineer for sustainable communities. Our student engineers will ask questions around: Who is the project for? Whose knowledge counts? Who takes part in the data collection and analysis and who takes action?

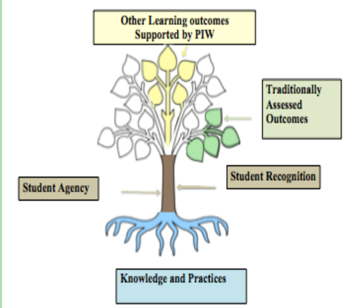
I-Engineering Tools

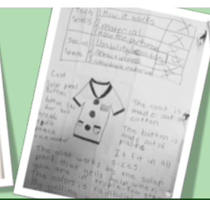
Framework Tools
Framework tools help students and teachers to engage in EfSC by integrating knowledge, practices and identity work. Tools orient teachers to the big ideas of the unit (e.g., identity, sustainable communities, engineering practices) while supporting specific planning, teaching and reflection. Attention to equity is embedded in each tool with teacher-moves that focus on inclusion and validation of student ideas and resources. Example Framework Tools include:
- Productive identity work (PIW) Tree
- Engineering for Sustainable Community Guiding Principles & Reflection Questions
- Vignettes of practice

Action Tools
Action tools support students and teachers in enacting the big ideas of Engineering for Sustainable Communities into strategies and practices to be utilized throughout the units.
- **Promoting Productive Identity Work:** Specific action tools are designed specifically to help teachers embed strategies into their practices to help their students be able to take part in productive identity work. e.g., The (RAP) Identity Work Planning Brainstorm Tool, Teacher RAP Exit Card Tool

- **Engineering Practices of Defining Problems and Designing Solutions:** These are designed to help students apply the principles of engineering for sustainable communities. These action tools will allow students to engage in community ethnography to optimize their solution to the design challenge of taking their classroom off of the power grid. E.g., Sustainable Community Engineering Solution Designing Tool, Problem Data Organizer Tool

PIW Framework Tree




Examples of Youth Engaging in EfSC

Youth maker	Bio	Invention	Types of Tech	Communities benefits
William Kamkwamba	• Masitala, Malawi (Africa) • 14 • Kicked out of school because couldn't pay fee	Windmill	High technology Wooden polls Bicycle frame Pulley Plastic pipes	His community was suffering a drought and had no access to electricity He later installed more windmills in other sectors
Lalita Prasida Sripada Srisai	• Odisha, India • 13	Water Filter System	Low technology Sand Discarded corncobs Plastic bottles Metal rod	She hope to help with the limited access to clean water that farmers have in her village
Stephen	• Michigan • 12 • Making 4 Change afterschool program	Light up football & Phantom Jacket	Lights rope Batteries Football	Security concerns led Samuel to design a football for children to play in dark areas and an alarm jacket.

Teacher's Thinking on PIW

- **Teachers focused on their role recognizing students.** The teachers shared more stories about them recognizing students than of students recognizing each other.
- **Positive recognition may impact how teachers position students.** Stories showed when a student was recognized for something positive, they were often recognized for many other things very quickly later. (e.g. Devin was recognized for a high test score, positioned as an academic leader, then recognized as a helper & positive participant in class that week)
- **One-on-one interactions led to opportunities for recognition.** Teachers identified experiences when students who did not receive recognition from teachers during class time thrived during one-on-one interactions.
- **Some teachers struggled to connect students' community experience with an energy curriculum.** Teachers were able to connect energy units to coal plants and cell phones, but had a harder time thinking about other knowledge students might have that could enhance an energy unit.