Developing a Model to Support Collaborative Engineering Projects: Student Uncertainty as a Productive Resource for Engineering (SUPER-E)

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Collaboration | Engineering Learning | K-12 | Student Uncertainty

Engineering design in K–12 classrooms is inherently uncertain as students tackle open-ended problems and team dynamics. Building on the Student Uncertainty as a Pedagogical Resource (SUPeR) model in science, informed by engineering design education theory and teachers' design activity and discussion in a professional development, we developed the Student Uncertainty as a Productive Resource for Engineering (SUPER-E) model. SUPER-E is a four-phase framework that maps uncertainty across the engineering design process. It supports teachers to anticipate when and how uncertainties emerge across each phase and offers teachers a structured yet flexible tool for leveraging student uncertainty as a productive resource. Next steps involve classroom-based implementation with middle school students.

Introduction

Engineering design is an inherently ill-structured, uncertainty-filled activity in K–12 settings. Students must manage hesitancy, differing opinions, and conflict while collaborating in discourse-intense, argumentation-rich engineering cultures (Cunningham & Kelly, 2017; Jordan, 2015). How teachers design and facilitate engineering projects therefore shapes whether students can notice, acknowledge, and productively work with their uncertainty. Previous work has primarily examined how students navigate scientific uncertainty in science classrooms. However, because science seeks to explain how the world works, whereas engineering focuses on designing scalable solutions to real-world problems using science as one tool in that endeavor(Goodell et al., 2023), there is a clear need for a distinct model tailored to uncertainty in engineering design contexts.

Developing the SUPER-E Model

Initial Development: Theory Informed

To develop the Student Uncertainty as a Productive Resource for Engineering (SUPER-E) model, we initially identified the sources of uncertainty in collaborative engineering design projects to create an initial tentative model. This work was informed by three resources: previous research on uncertainty in engineering design, our previous work on the (Student Uncertainty as a pedagogical resource (SUPeR) model, and our own experience facilitating engineering design projects with K-12 teachers and students. Across these, we consider two aspects of uncertainty as important: the types of uncertainty that students are likely to experience (i.e., conceptual, epistemic, and relational), and (b) how teachers can help students navigate those uncertainties (e.g., Kaur & Dasgupta, 2024).

The SUPER-E model was also informed by understanding of how people navigate uncertainty, particularly how teachers can help students navigate uncertainty (Chen & Jordan., 2024). Uncertainty navigation can be understood as the process of strategically raising, maintaining, reducing, and ignoring different types of uncertainty in order to advance learning in engineering design contexts (Jordan & McDaniel, 2014; Chen et al., 2024). Raising uncertainty requires teachers to know what desirable uncertainties we need to identify or bring up so they can be addressed. Maintaining uncertainty means encouraging students to “live with” desirable uncertainties for a while because it is unproductive to reduce them too soon. Reducing uncertainty means what uncertainty we want to get rid of because it is undesirable. It is also necessary to know when and how to help students postpone or ignore uncertainties that are irrelevant to the task at hand.

Iterating the Model: Teacher Informed

After developing an initial SUPER-E model (Figure 1), we tested it with 18 in-service science teachers during a week-long PD on using uncertainty as a resource for STEM learning. Teachers worked in teams on a Solar Home Hack engineering design challenge organized around the first and second versions of the model, with their work audio–video recorded. Their activity was punctuated by periodic whole group discussion, reflection, and critique of the model.In this way, teachers stepped into the design challenge as students and stepped out as expert educators to offer critique and to reflect on their own experiences of uncertainty during the engineering design process.In a final discussion, teachers identified types and sources of uncertainty students might encounter at each phase and recommended further differentiating Phases 2 and 3 into sub-sections, leading to a revised SUPER-E model (Figure 2).

Figure 1.

Initial SUPER-E Model

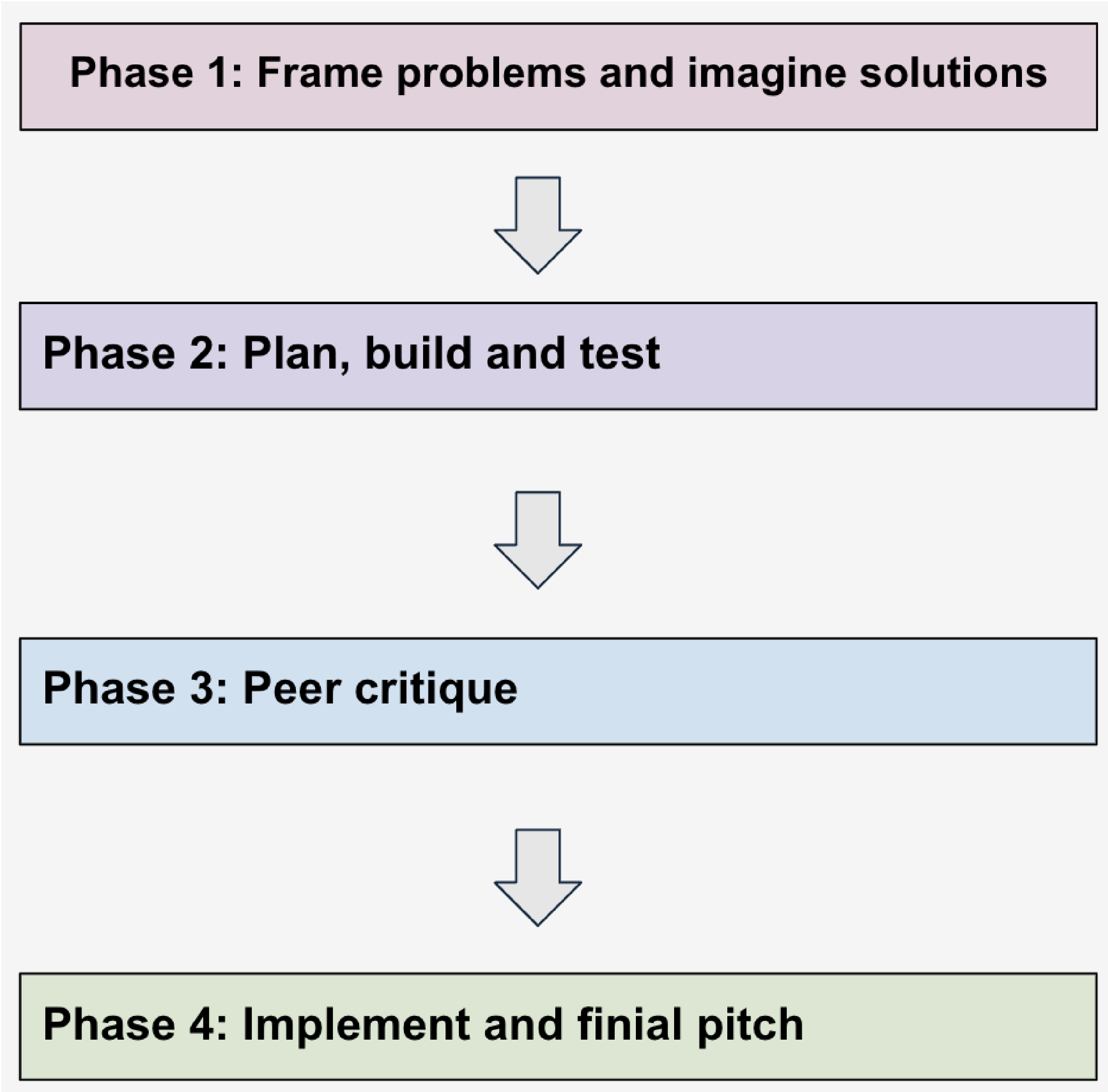
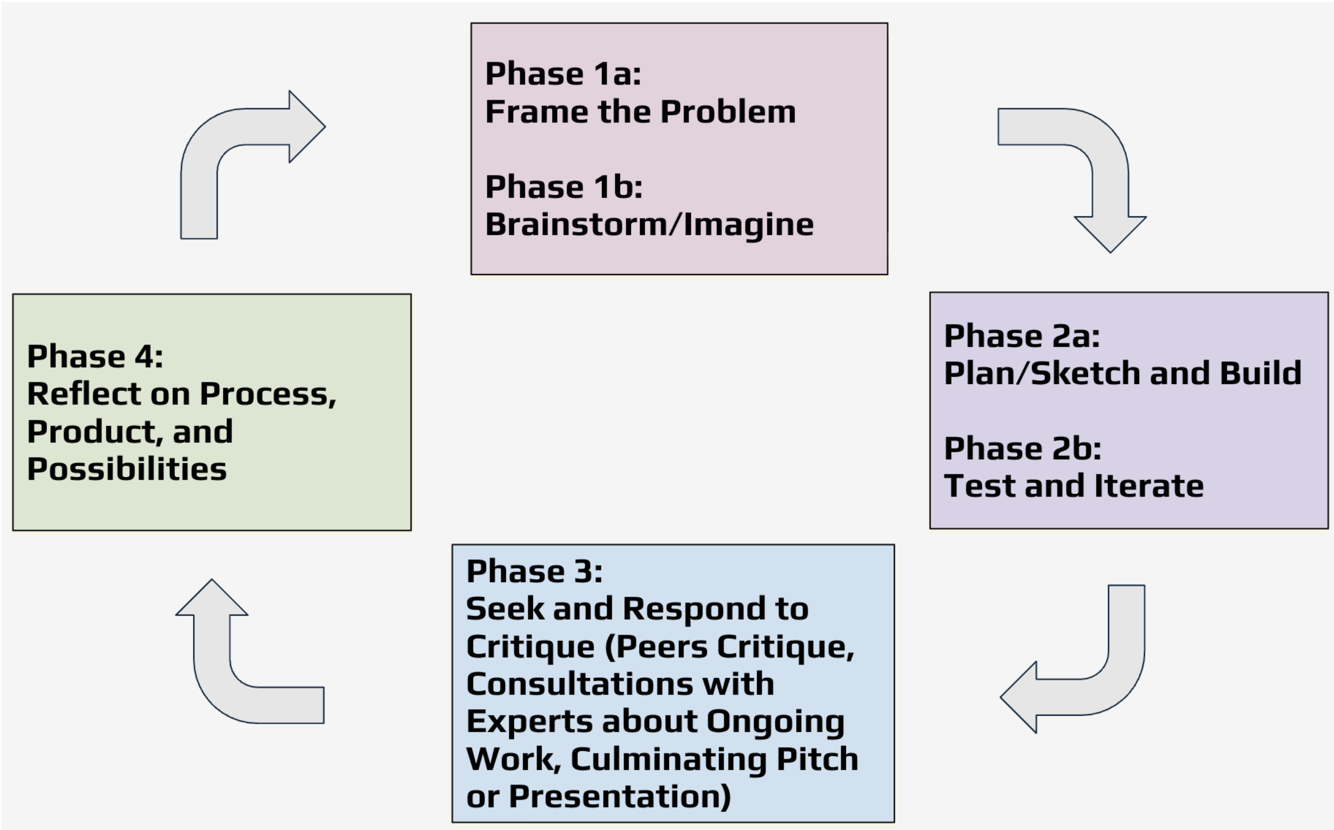


Figure 2.

Iterated SUPER-E Mode



The SUPER-E Model

The iterated SUPER-E model consists of four phases as described below. During each phase, particular types and sources of uncertainty are likely to arise for students, which we categorize as conceptual, epistemic, and relational. Teachers need to be aware of and plan for uncertainties likely to arise at each phase so they can support students' uncertainty navigation in how they create engineering design challenges and respond to student uncertainties throughout the engineering design process.

Phase 1 consists of two sub-stages. In 1a–Frame the Problem, students identify initial criteria and constraints while the teacher contextualizes the challenge, and students' uncertainties and curiosities emerge. In 1b–Brainstorm/Imagine, students generate and evaluate multiple ideas and consider integration with existing systems, deliberately raising conceptual and epistemic uncertainty to clarify the problem space, goals, and constraints, justify why ideas might work, compare competing approaches, and sustain multiple possibilities for deeper reasoning and richer idea generation—even if the group's thinking is temporarily incoherent. Making trade-offs between criteria and constraints (Kelly & Cunningham, 2019) helps reduce relational uncertainty by establishing shared criteria for evaluating, refining, and integrating solutions.

Phase 2 has two sub-stages: 2a–Plan/Sketch and Build and 2b–Test and Iterate, where students turn plans into tangible products and collect, interpret, and curate results. In this hands-on "conversation with materials" (Bamberger & Schön, 1983), conceptual uncertainty is common and sometimes must be reduced (e.g., confusion about essential requirements) to keep work moving, while epistemic uncertainty is best maintained to support iterative reasoning about design decisions and outcomes. Clarifying team roles helps reduce relational uncertainty, promote equitable participation, and minimize unproductive tensions during building.

Phase 3-Seek and Respond to Critique involves peer critique, expert consultation, and a culminating pitch or presentation, with students deliberately seeking and responding to feedback on their ongoing work. Some epistemic and relational uncertainties are intentionally maintained—for example, “living with” conflicting critiques or differing perspectives within teams or with experts. Ultimately, students' uncertainty will be reduced by reconciling critique, converging on feasible solutions, and presenting a defensible design in a final pitch that establishes accountability and justification to peers, clients, or community stakeholders.

Phase 4-Reflecting on Product, Process, and Possibilities engages students in structured reflection to consolidate what they learned and extend their thinking. They identify what remains uncertain about their designs, consider future iterations, and recognize design as ongoing and iterative. Students explore new uncertainties (e.g., installation, usability, social embeddedness), reflect on how they collaborated and responded to uncertainty, and examine broader social, economic, and environmental implications, including tradeoffs and ambiguities. Because engineering design always entails tradeoffs (Kelly & Cunningham, 2019), this phase offers space to grapple with ambiguity tied to multiple, or conflicting values and to reframe uncertainty as a productive driver of deeper reasoning, and systems-level thinking.

Conclusion

The SUPER-E model offers a structured yet flexible framework for helping K–12 students use uncertainty as a productive resource in engineering design. By addressing conceptual, epistemic, and relational uncertainties across four phases and clarifying how teachers can support students, it shows how collaboration, critique, and reflection deepen engagement and make design work more authentic. The model not only maps the iterative nature of engineering but also foregrounds often overlooked affective and social dimensions of learning.

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