2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32288

Instrumentation for Evaluating Design-learning and Instruction Within Courses and Across Programs

Steven Santana, Harvey Mudd College

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Introduction

This work-in-progress (WIP) paper communicates the initial planning and design of instrumentation, deployed through action research, to assess students' growth in design learning and their belonging and identity in engineering. The ultimate goal of the data generated through this instrumentation is to drive ongoing cycles of continuous improvement in teaching with a focus on transforming student learning. Owing to the ongoing, dynamic practices of reflective educators, pedagogy and plans iteratively evolve. These changes in practice exist in a complex environment that has the potential to profoundly impact students' ability to engage with and internalize content. Given this environment, instrumentation is deployed to collect data in a process of developmental evaluation while proactively responding to student learning and development through disaggregated data. This work equips educators with information to support the development of prototypes and innovations that strive toward providing undergraduate students with authentic, deep, and sustained learning experiences in engineering and to motivate a culture of data collection, analysis, and continuous improvement.

Design is a central component of engineering practice and offers a suite of activities through which solutions can be conceived, developed, tested, refined, and produced to "create a world that never has been" [1], [2]. Practicing engineers constantly navigate complex and ill-defined design spaces and must balance opposing tensions. A primary difficulty for novice designers is developing the experience to avoid driving toward a final deliverable at the expense of definition, ideation, fabrication, evaluation, and iteration [3]. Hence, circumventing these activities can be detrimental, if not fatal, to design work, resulting in deliverables that do not address the problem.

Design is inherently nonlinear, inefficient, and complex [4], [5]. Students often find the reality of engineering design overwhelming the first time they experience it. They begin undergraduate engineering programs learning science and math through formats steeped in a learning culture that is linear and process-oriented to identify the single answers to carefully constructed problems. Consequently, students demonstrate significant discomfort or reticence when thrust into situations in which they are expected to embrace a nonlinear, circuitous process to solve an ill-defined problem. In these circumstances students employ their practiced, linear paradigms and struggle to engage in the requisite work of inefficiently traversing the design space and to progressively iterate and improve their designs [6]–[8]. These choices result in missed opportunities for insight, creativity, and development and yield designs that do not satisfy. Students perceive this outcome and become frustrated or develop a sense that they cannot succeed as engineers.

In response, the overarching goal and mission of this work is to enhance the learning and abilities of nascent engineers while supporting the development of their engineering identity and sense of belonging in the engineering community. Engineering work is completed by teams and, therefore, is a social and collaborative enterprise. The dynamics and biases that shape and plague teams in professional, social, and academic settings are also present in undergraduate programs. Thus, educators are charged with proactively fostering students' developing engineering identities in this context while also nurturing interests and teaching core engineering concepts and mindsets. Educators who neglect to fully engage in this work risk perpetuating cycles of exclusion that predominantly burden historically underserved, underrepresented, and excluded groups, such as students of color. By focusing efforts on each of these areas, educators can engender belonging and contribute to preparing a diverse group of engineers who add necessary and varied perspectives to design [9]–[11].

As a first step toward this overarching goal, the instruments described in this work will be deployed in an early-program conceptual design course. The generated data enables instructors to gain insight into students' trajectories in design to support students' internalization and robust deployment of the design process. One critical avenue for supporting student learning is to include an intentional focus on their engineering identity. Students' performance and success in engineering are coupled with their identity as engineers and their sense of belonging in the engineering community [12]–[14]. Acknowledging this connection, this suite includes tools that assess engineering identity and belonging, confidence in design activities, and a measure of design quality, all in addition to recording design activities, to provide a window into the relationships among these factors. Together these data serve as indicators and may neither identify a problem's provenance nor dictate the requisite response but instead reveal nascent and persistent issues requiring action. Thus, reflective practitioners are equipped to engage initiate, implement, and evaluate student learning and development in response to iterative changes. Comprehensive data collection that informs instructional design and practice can transform student trajectories particularly when combined with equity-minded approaches with intentionality in disaggregating data to elucidate differential experiences and outcomes [15]. To facilitate equity-centered analysis, this work couples the instrument-generated data with demographic data. Since optimal responses and practices are context dependent, this instrumentation plan collects a holistic set of data through developmental evaluation as pedagogy and structures are deployed and refined through action research undertaken with a focus on student needs and learning.

Thus, the immediate goal of this work in progress is to establish a suite of instruments to measure student learning, identity, and experiences in a cycle of responsive pedagogy to inform instructors as to the efficacy of their instructional methods and develop a framework for identifying issues, asking questions, prototyping solutions, and determining appropriate and beneficial instructional practices. When reflective practitioners engage in this work, student learning rightly becomes the focus. Through this instructional culture, students are increasingly well equipped to tackle complex, ill-defined problems and to develop the mindsets necessary for making meaningful contributions to society as confident engineers.

Purpose

This work communicates the contents and design of a preliminary instrument suite with a purpose of enhancing student learning and development as engineers as informed by data. The data will span student- and faculty-generated assessments with a mind toward developing a holistic view of learning, development, and performance in engineering and design. Innovation stems directly from identifying problems without known solutions and in spaces with current solutions that aren't acceptable. This is how engineers approach their work and how educators should, and often do, approach innovative instruction. In this work, developmental evaluation is embraced as a way to uncover opportunities for improvement and innovation in pedagogy through a cycle of ongoing engagement and learning with a charge to use data to learn, prototype, test and improve through action research [16]–[20]. To identify these opportunities for change, this instrumentation includes tools to collect data across a range of measures. In particular the instrumentation suite contains a design diary, a design quality assessment tool, an ability inventory, and an engineering identity and belonging inventory. Critically analyzing this data supports faculty in uncovering narratives and themes and to improve instructional practice and student outcomes. The use of developmental evaluation in this frame enables cycles of iterative question asking and answering in service to student learning. Looking forward, this toolset is being developed with a mind toward programmatic evaluation, on a departmental level, even as initial efforts are focused on an introductory engineering design course.

Methods

Context and Participants

This design course is taken by students during their first or second year and is typically their first exposure to engineering. This course situates teams as engineers contracted to work on a project provided by an external client. The instructors solicit, select, and refine projects that present engineering problems requiring conceptual design and tangible, mechanical solutions. In this course, the overarching learning outcome is to implement and practice a design process to identify, frame, and solve open-ended and ill-structured engineering problems. This outcome emphasizes the inherent complexity, ambiguity, and nonlinearity of the design process [8], [21], [22] and is, as a result, a challenge to teach and difficult to learn. A primary learning outcome of this course is for students to internalize the design process as a set of activities that engineers deploy with adaptive expertise to create high-quality deliverables that satisfy needs while developing their identity as engineers [23]–[27].

In service to this learning outcome, this introductory design course involves a mix of individual and team learning in a studio setting. Individuals taking this class typically have interest in engineering or design but have not yet declared a major. Students learn design activities through multiple design cycles throughout the academic term, including a one-day design sprint, a short-duration design project, and a long-duration team design project. While developing their knowledge and practice as designers, students learn computer-aided design, finite element analysis, and manufacturing techniques, among other skills, through hands-on activities that are included to complement and enable their design learning and efforts. The objective in this configuration is to equip students to design, prototype, and iterate to produce a solution to deliver to their client.

Instrumentation and Data Collection

This instrument suite will source data on student activities, abilities, performance, identity, and belonging to gain insight into student learning and development as engineers. Given this distribution of topics, data is primarily generated by students. Faculty provide redundant information by assessing student abilities and design quality to gain insight from the alignment or divergence of unique perspectives. Previous work has demonstrated the correlation between design quality and the sequencing and duration of design activities therefore focusing on these outcomes in concert has potential to yield high returns for student learning. It is also well documented that students' academic and professional trajectories will be significantly impacted by their learning, experiences, identity, and interest in engineering [28]–[31]. Thus, it is imperative that instructors develop pedagogy and structure content, as informed by data, such that students can experience and celebrate success in each of these areas.

In summary, this work seeks to develop a mixed-methods instrument suite to (1) assess students' implementation of design activities within authentic design projects, (2) evaluate final deliverable quality, (3) survey students' engineering design abilities, and (4) record students' evolving engineering identity and sense of belonging in the engineering community. Future work includes deploying and developing prototypes of the aforementioned instruments through on-going action research while also assessing and, as necessary, improving their validity and reliability. In their current iterations, each of these instruments exist as drafts, inspired by or adapted and adopted from previously published works. Through deployment, validation, and reflection they will evolve to better measure students' actual experiences and to drive toward improved student learning, strengthened engineering identities, and an enhanced sense of belonging.

Design Diary

Engineering design is systematic, nonlinear, and iterative. By contrast, instructor observations indicate that students proceed through the design process in a linear fashion, spend insufficient time scoping problems, and minimally implement design activities to advance their work and learning. This trend is well documented [2], [32]–[35]. Throughout their work, novice designers often fail to iterate, whether in incremental or progressive fashions [6], to improve a design's quality. Students are encouraged to traverse the design space, but the extent to which this happens is not formally measured. This omission represents a significant opportunity for collecting data that can be used to reimagine instruction, improve design quality, and enhance student learning through reflection, discovery, and generating excitement around design. To quantify student trajectories through the design space, students will maintain design diaries. The design diary, as shown in Table 1, is a self-reported record of design phases and activities throughout a project. As a data collection tool, diaries provide a depth of information but have potential to place a high burden on participants and investigators [36]–[39]. To mitigate this burden while retaining access to students' design activities, the diary activity is used to periodically collect phase and activity engagement and sacrifices information regarding duration and frequency, within the collection period. The design diary is structured so that students can complete it quickly, in approximately two minutes, to encourage a high rate of completion. In this approach, this work gains regular data reported proximal to activity completion and minimizes student time costs but risks losing the reliability associated with expert observers. Any potential gaps between actual and reported activities must be determined through future validation efforts.

Table 1: Design Diary and Reflection

<table>
<tr><th>Design Phase</th><th>Design Activity</th><th>Optional Reflection</th></tr>
<tr><td>Empathize
Define
Ideate
Prototype
Test
Other
None</td><td>Need recognition
Problem Definition
Information Gathering
Idea Generation
Modeling
Feasibility Analysis
Evaluation
Selection/Decision
Seeking Feedback
Communication
Implementation
Management and Planning
Documentation</td><td>Possible items to comment on:
Nothing!
What’s one thing you want to share about today?
How do you feel about the work you did today?
To what extent do you enjoy or dislike these design activities?
When, if at all, did you feel stuck?
How did you overcome an obstacle?
What are the next steps in your design work?
How did you improve your design?
Or anything else!</td></tr>
<tr><th colspan="3">Required Reflection</th></tr>
<tr><td colspan="3">To what extent do you identify as an engineer?
To what extent do you feel like you are a member of an engineering community?</td></tr>
</table>

The desired outcome of the design diary is to quantify and generate visualizations of students’ paths through various design phases and activities. This tool’s design is inspired by prior work documenting students’ and professionals’ design activities in time-constrained design problems [8], [21], [39], [40] and design thinking phases [3]. The benefit of this student-produced diary is that data can be collected on an individual level throughout a team-based, design project regardless of duration. To ensure greater fidelity between actual and reported activities, students will need to be trained to use this tool and will require frequent instructor feedback throughout the process. Since the introductory design course includes a short-duration and a long-duration project, the diary entries completed during the short-duration project can serve as an initial training activity for the long-duration project. Even though students and teams are afforded freedom to navigate their design efforts, scheduled activities, such as design reviews, provide an opportunity for understanding the alignment between actual and self-reported activities.

This tool also provides students with an optional opportunity to reflect on their experience as engineers. Through this component, students can connect their design activities to future plans, accomplishments, or their sense of belonging, among other topics. The purpose of including a reflection activity is to encourage students to play an active role in their learning by considering their growth and development and to yield information that affords a frequent glimpse into students' perceptions regarding their own abilities, identity, and belonging [5], [7], [35], [41] while also affording investigators with the data to validate and question conclusions derived from the quantitative data. A required reflection is included to be completed periodically throughout the term to relate engineering identity and belonging to the various phases and activities of design. In this way, through reflection, students can develop as engineers as they consider their connection to aspects of the full range of engineering activities and not preconceived notions regarding what activities define an engineer's experience or success.

The design diary will be completed on a daily basis as part of students' assigned activities. The option of reporting no engagement in any design activities is included to minimize perceived pressure to report activities when none were undertaken. The required reflection will be completed three times over the course of the academic term, to avoid burdening students or oversampling this information, to afford students an opportunity to consistently reflect on their learning, through the lenses of identity and belong, in a sustained manner. Prior to completing the reflection activity, students will be provided with a visualization of their design activities, initially modeled on those communicated in prior works [8], [21], for consideration as they reflect. As they reflect on their record of activities, students are supported in connecting a broad range of engineering activities with their identity as engineers.

Design Quality Evaluation

To assess the quality of final designs, this suite includes a rubric to uncover the link between design processes and outcomes. Engineering design is a purpose-driven and constrained endeavor involving an intricate set of considerations, tradeoffs, and limitations with a project goal of providing a functional design that satisfies the requirements and objectives while pleasing the client, users, and stakeholders. Consequently, students direct their efforts toward producing a final product of an initially conceived idea and spend little time engaging in requisite design activities. This approach results in designs that may not effectively address the central need or fail to satisfy the objectives in a pleasing manner. The purpose of a design process is to produce a high-quality design. To this end, a reliable tool for evaluating design quality is necessary. Since the connection between design process and design quality is well established, this work seeks to provide data that elucidates this connection for students, through considering historical data around this connection, and as a forum for reflection on their own practice. These data also provide feedback to instructors regarding the direct consequences of instructional decisions and student evaluations.

Evaluating a design's quality is difficult. Many tools assess the quality of a design process or link quality to process [42]–[44]. These frameworks serve to ensure thoroughness and to organize, challenge, and clarify thinking [45]. Often these tools recommend an approach for evaluating a design and rely on teams of expert reviewers to invest substantial effort to understand the problem, process, and outcomes. These comprehensive considerations are valuable but infeasible given their expense. To evaluate design quality, this instrument suite includes the Design Quality Rubric developed by D.K. Sobek II and V.K. Jain [46], as shown in Table 2. This tool directly scores the quality of a deliverable in a process- and project-independent fashion. These features are important both because of the feasibility and applicability to any design. Designs will be evaluated on a five-point scale ranging from (1) poor to outstanding in the basic and advanced categories and (2) far below professional expectations to outstanding by professional expectations in the overall category. This instructor-completed rubric will be applied to the final design submitted for both the short- and long-term design projects. Rater reliability must be established amongst the instructors who deploy this previously validated tool [46].

Table 2: Design Quality Rubric

	Metric	Definition
Basic	Requirements	The design meets the technical criteria and the customer/client requirements.
	Feasibility	The design is feasible in its application and fabrication/assembly.
Advanced	Creativity	The design incorporates original and novel ideas, non-intuitive approaches or innovative solutions.
	Simplicity	The design is simple, avoiding any unnecessary complexity, and hence is practical, usable, reliable, serviceable, and safe.
Overall	Overall impression of the design solution.	

Student Ability, Identity, and Belonging Surveys

To measure students' perceptions of their abilities, engineering identity, and sense of belonging within engineering this work includes surveys to capture development, on an individual level, in each of these areas. To complement student self-assessments, faculty evaluate students using the student learning outcome-aligned ability assessment tool to identify potential mismatches in students' self-image and those held by instructors. This data can inform both instruction decisions and climate setting efforts.

Engineering design is social, collaborative, and community-based [47]. It benefits from a diversity of ideas, including diversity in knowledge, experience, and perspective. Engineered deliverables are improved by successfully equipping cohorts of engineers that comprehensively integrate humanity's diversity of identities, perspectives, and experiences and are prepared to empathize with and work for and alongside those from communities in need of solutions. As such it is an engineering educator's goal to teach the core skills, mindsets, and knowledge of the discipline while fostering students' development of their engineering identity and sense of belonging to the engineering community. For many educators, this goal becomes a mission as identity can be predictive of persistence in engineering [48]–[50]. Engineering identity is coupled with both an individual's perception of their own abilities and their sense of belonging in the community of engineers [51]–[54]. Important influencers of these self-assessments include students' ideas of others' perceptions about themselves. These factors work together to provide cyclic feedback that influences performance [50], [55]–[57].

Thus, considering these sets of information, as a group, supports efforts to improve outcomes amongst them all. To this end, this instrumentation plan includes student self-reported engineering abilities, through the Engineering Design Ability survey included in Table 3, and identity and belonging, through the Engineering Identity and Belonging survey, as shown in Table 4. The items included in the Design Ability Survey are derived from course-specific student learning outcomes and linked to the Design Diary [3], [8], [21], [40], previous work [58], and novel items. The Identity and Belonging instrument is based on previously published surveys [48], [49], [59], [60]. The ability survey collects quantitative data, along with optional reflections, whereas the identity and belonging survey collects both quantitative and qualitative data. All quantitative items are scored on a five-point scale ranging from strongly disagree to strongly agree. For early-career undergraduates, the qualitative data from the written responses are especially important as they provide investigators with knowledge regarding their evolving concept of what engineering is and what engineers are and do. This information is vital for interpreting students' self-evaluations and bolstering the validity of any insights or conclusions.

Students will complete each survey through a pre- and post-term assignment to afford investigators insight as to growth in students' self-conceptions of their abilities, identity, and belonging as well as their evolving understanding what engineering is and what engineers do. These quantitative and qualitative components will support efforts to inform and validate conclusions through triangulation. The pre-course assessment will serve as the baseline data to ascertain students' self-reported abilities and identities and to evaluate their growth and development throughout the semester. To address concerns regarding test-retest reliability and to support students in evaluating their current state and growth, when completing the survey at the end of the term, students will evaluate their current state as well as their current estimation of their state at the beginning of the academic term. These data will be compared to the pre- and post-data from prior semesters, in a disaggregated fashion, to gain insight into the efficacy of pedagogical shifts, content substitutions, and other deployed changes.

Table 3: Engineering Design Ability Survey

Category	**Survey Items**
Overall Design Process	• I can implement a design process to solve engineering problems. • I can solve open-ended and ill-structured engineering problems. • I can assess design decisions according to a code of ethics. • I can recognize when it is necessary to revisit design activities to improve a solution.
Design Phases	• Empathize: ○ I can develop a deep understanding of a problem through empathy. • Define ○ I can define a problem. • Ideate ○ I can ideate a set of potential solutions to a problem or need. ○ I can ideate a set of creative solutions. • Prototype ○ I can ask questions that improve a design. ○ I can select and develop a prototype to answer questions. • Test ○ I can design an experiment to assess the performance of a prototype. ○ I can plan next steps based on prototype evaluation results. ○ I can determine the feasibility of a design.
Design Activities	• Information Gathering ○ I can identify the knowledge and resources needed to develop a solution. ○ I can ask probing questions to clarify facts, concepts, or relationships. • Selection/Decision ○ I can select a solution that best satisfies the problem objectives and constraints. ○ I can defend and justify selection of the solution that best satisfies the problem objectives and constraints • Manufacturing/Fabrication ○ I can interpret engineering drawings. ○ I can build a design according to drawings or instructions that someone else has created. ○ I can construct a prototype at an appropriate resolution. ○ I can build a design that I have created.

Team and Project Management	● Teamwork ○ I can function effectively on a team. ○ I can give and receive professional feedback. ○ I can resolve conflict on a team. ● Communication ○ I can communicate design work in writing. ○ I can communicate design work verbally. ○ I can communicate design work graphically. ● Management and Planning ○ I can monitor progress toward team goals. ○ I can divide a project into manageable components or tasks.

Table 4: Engineering Identity and Belonging Survey

Category	**Survey Item**
Definition	● I understand what it means to be an engineer.
Interest	● I enjoy learning engineering. ● I am interested in learning more about engineering. ● I find fulfillment in doing engineering.
Recognition	● My instructors see me as an engineer. ● My peers see me as an engineer. ● My family sees me as an engineer. ● I see myself as an engineer.
Belonging	● I feel a sense of belonging to the engineering community. ● I can see myself becoming an engineer when I am done with school.
Performance	● I am confident that I can understand engineering in class. ● I am confident that I can understand engineering outside of class. ● I understand concepts I have studied in engineering. ● I can do well on projects/assignments in engineering. ● I can do well on exams in engineering. ● Others ask me for help in engineering.
Qualitative	● Complete the following statements: ○ Engineering is ○ An engineer is ○ I DO/DO NOT see myself as an engineer because ○ Others DO/DO NOT see me as an engineer because

Methodology

As previously mentioned, this work seeks to employ action research through continuous improvement in a process of developmental evaluation. In this way investigators, instructors, and students reflectively engage with the data together to critically explore and respond to the effectiveness current practices. Together the community will make plans for improving practice to enhance learning. This is appropriate as action research is consistent with engineering design. As with design, action research is a nonlinear, systematic process that requires reflection [20]. Involving students as participants and by engaging in transparent communication with them regarding the process and goals will serve to enhance student learning. By undertaking this work through action research investigators and participants engage in opportunities for discernment and discovery through a shared set of experiences and goals [19]. Since action research is undertaken in an atheoretical framework, making sense of results may require subsequent work and question-specific theoretical frames. This process, when appropriately approached and considered, engenders a process of inquiry, supporting participants in cycles of question asking and knowledge generation. Through strategic planning, centered in data, values, and goals, these questions can be prioritized and investigated through immediate action or through planned work in future academic terms.

Instrument deployment in the pilot study is undertaken in three phases. Phase I includes a plan to collect baseline data through the Design Ability (Table 3) and the Identity and Belonging (Table 4) surveys, respectively. Each survey will be deployed in a pre-post format. Phase I also includes design deliverable evaluation using the Design Quality Rubric (Table 2). Phase II continues the deployment of all instruments used in Phase I and integrates the Design Diary and Reflection (Table 1). The goal of this tiered approach is to understand the impact of the design diary activity on student learning. During this phase, no substantive curricular innovations will be implemented. In Phase III, all instruments will be deployed in concert, as described in the Methods section, to inform students, instructors, and investigators as to the impact of changes in practice on student learning, performance, belonging, and identity. In addition to affording insight into the impact of these curricular innovations, ongoing work through each phase includes efforts to improve and validate each instrument.

Instrument Development and Data Analysis

The Design Diary and Reflection (Table 1) and Design Ability Survey (Table 3) are structured to align with course content, student activities, and learning outcomes. The ability survey will evolve with changes in the content and outcomes of the course. Upon adopting these instruments in other settings, these tools should be modified to include the context-specific content, outcomes, and competencies. In the context of this work, the diary's format will develop in response to instructional needs, student learning, and student engagement with a focus on data quality and user experience as informed through human-centered design. For each of the items and constructs considered in the Identity and Belonging Survey (Table 4), internal reliability amongst the quantitative elements will be established through Cronbach's alpha. This analysis may dictate iterative improvements for this instrument in Phase I activities and beyond. Responses to qualitative items will be encoded through a process of inductive thematic analysis. Any emergent themes will be used to validate and question conclusions derived from the quantitative analysis. This approach is likely to be particularly helpful as these combined efforts may uncover confounding conclusions resulting from the pre-post configuration. Together these efforts serve to gather the requisite data for monitoring student learning and development and for generating questions in this exploratory work executed through a transferable action research paradigm.

Discussion

The objective of this instrument suite is to generate a dataset that equips investigators, faculty, and leaders to evaluate students' products, activities, and experiences from multiple sources to develop a dashboard indicating student learning and development as engineers in courses and academic programs through context-specific action research. With this data, educators and leaders are equipped to proactively prototype and deploy innovations, while supplementing this structured dataset with additional data derived from new instruments and data collection efforts pertinent to the questions at hand. By engaging in these efforts, educators can work toward continuously improving practices; enhancing student learning; and encouraging, inspiring, and equipping engineers. In this way, educators are prepared to uncover needs, ask questions, generate ideas, and design a future of improved student experience, learning, and persistence in engineering. These outcomes are particularly crucial in early-career engineering courses while also being important across engineering programs. Although these measures may not dictate the optimal or requisite responses, constant analysis of and reflection on data by educators establishes the foundation for effecting positive change. Engaging in this work has the potential to enhance outcomes for students and can prove to be particularly transformative when combined with equity-minded analysis involving intentionality in disaggregating data [15]. Such an approach also provides a lens for understanding how students' learning experiences inform their decisions to pursue engineering. Shifting outcomes in this area is vital as a diverse group of engineers is needed to solve the problems of a heterogeneous society [9]. Since data are generated throughout the term, faculty are equipped to create opportunities for students to engage in forward-looking activities of reflection as they learn, to facilitate meaningful dialog regarding the equity and dynamics within teams, and to develop as engineering leaders.

The first goal of this work in progress is to use, test, and refine this suite of instruments through a phased deployment, in a process of developmental evaluation enacted through action research, to uncover the context specific impacts of pedagogy and structures on student learning, belonging, success, and persistence in engineering. These combined measures will be deployed to understand students' learning as a function of course pedagogy, activities, structures, and climate and to iteratively improve instruction. A future goal is to apply this instrument suite and analysis framework to improve instruction across courses and programs all in service to equipping engineering graduates with expertise, fluency, and with the capacity to lead.

Acknowledgements

This work is made possible through the generous grant from the Carl F. Braun Residuary Trust. The author extends special thanks to Leah Mendelson and Laura Palucki Blake for their critical feedback and contributions. The author also thanks Gordon Krauss, Nancy Lape, Drew Price, and Qimin Yang for their thought partnership. The opinions expressed in this work are those of the author and do not necessarily reflect the views of the acknowledged organization or individuals.

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