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Designing a Course for Peer Educators in Undergraduate Engineering Design Courses

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Designing a Course for Peer Educators in Undergraduate Engineering Design Courses

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Gina Quan is a doctoral candidate in Physics Education Research at the University of Maryland, College Park. She graduated in 2012 with a B.A. in Physics from the University of California, Berkeley. Her research interests include understanding community and identity formation, unpacking students' relationships to design, and cultivating institutional change. Ms. Quan is also a founding member of the Access Network, a research-practice community dedicated to fostering supportive communities in undergraduate physics departments.

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Chandra Turpen is a Research Assistant Professor in the Physics Education Research Group at the University of Maryland, College Park"s Department of Physics. She completed her PhD in Physics at the University of Colorado at Boulder specializing in Physics Education Research. Chandra's work involves designing and researching contexts for learning within higher education. In her research, Chandra draws from the perspectives of anthropology, cultural psychology, and the learning sciences. Through in-situ studies of classroom and institutional practice, Chandra focuses on the role of culture in science learning and educational change. Chandra pursues projects that have high potential for leveraging sustainable change in undergraduate STEM programs and makes these struggles for change a direct focus of her research efforts.

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Ayush Gupta is Assistant Research Professor in Physics and Keystone Instructor in the A. J. Clark School of Engineering at the University of Maryland. Broadly speaking he is interested in modeling learning and reasoning processes. In particular, he is attracted to fine-grained analysis of video data both from a microgenetic learning analysis methodology (drawing on knowledge in pieces) as well as interaction analysis methodology. He has been working on how learners' emotions are coupled with their conceptual and epistemological reasoning. He is also interested in developing models of the dynamics of categorizations (ontologies) underlying students' reasoning in physics. Lately, he has been interested in engineering design thinking, how engineering students come to understand and practice design.

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Emilia Tanu is a recent graduate of the Chemical and Biomolecular Engineering program at the University of Maryland, College Park. She has collaborated with members of UMD's Physics Education and Engineering Education Research Groups, and researchers at Olin College of Engineering. While at UMD, she was the co-chair of the Women in Engineering Student Advisory Board and a student ambassador for the Clark School of Engineering. Emilia is currently working in industry, and hopes to eventually pursue graduate studies in Engineering Education. Her research interests include emotion in design and empathetic classroom practices.

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Designing a Seminar for Peer Educators in Undergraduate Engineering Design Courses

Abstract
Learning Assistants (LAs) are undergraduate peer educators who participate in weekly pedagogy seminars and work alongside faculty instructors in active-learning based undergraduate courses. While LA programs were initially developed for science and math courses, many LA programs support LAs in a wide range of disciplines. This paper describes a pilot adaptation of the LA program for engineering design courses that we have developed at the University of Maryland, College Park Campus. All LAs assist in 14 separate sections of University of Maryland's engineering design course for first-year undergraduate students. Our seminar integrates topics from the discipline-general LA pedagogy seminar (cognitive science of learning, facilitation of classroom discourse, collaboration, metacognition) with topics especially relevant to engineering design (design reviews, design thinking, expert-novice practices in engineering design, engineering epistemology, teamwork and equity). While seminar goals aligned with the goals of LA programs nationally, our seminar design team also articulated several values which guided the design of our seminar: a) helping LAs reframe their role as supporting growth rather than evaluation, b) valuing a broad set of metrics of success from day one, c) celebrating that different students bring in different expertise, and disrupting overly simplistic expertise/novice dichotomies, d) acknowledging that we all have different starting points and valuing a plurality of goals, e) helping our students track their own progress through reflecting on concrete representations of their thinking, and f) supporting LAs in developing deep disciplinary knowledge of design thinking. This paper describes the embodiment of these goals by highlighting several key features of the seminar. We conduct quantitative and qualitative analysis of several data sources (surveys, instructor reflections, field notes, and coursework) to assess the extent to which the embodiment of our values helped us meet our goals. Finally, we describe challenges and identify areas where we were not meeting our goals and describe some of the aspects of the seminar that we plan to revise in the next iteration.

Introduction
Engineering education research has increasingly focused on the learning and teaching of design,[1-7] including design thinking and associated "soft" skills such as communication and teamwork. Another trend is the growing number of schools of engineering that offer early project-based engineering design courses for their first-year engineering majors. In many of these first-year engineering design courses, undergraduate teaching assistants play a significant role in implementing these courses. In many cases undergraduate teaching assistants are offered minimal training (or none at all) in pedagogy, not to mention specific training in how to support students' learning of design thinking.

In this paper, we describe our efforts to adapt the Learning Assistant (LA) program model to support first-year engineering design courses. LA programs support undergraduate peer educators, faculty, and students in transforming courses to be more closely aligned with research-based instructional practices. Learning Assistants are undergraduate peer educators who, through the guidance of weekly preparation sessions and a pedagogy course, facilitate discussions among groups of students in a variety of classroom settings that encourage active engagement.[8-10]

The LA model has been shown to be highly effective through a variety of metrics. For example, undergraduate students enrolled in LA-supported courses learn the subject matter better.[8,11-13] Research has also documented important learning outcomes for the LAs themselves. LAs learn the subject matter better through teaching it,[8,12] LAs become better teachers,[14] and LAs solidify their identities as scientists.[15] Additionally, university faculty in LA-supported courses become better teachers and begin to recognize their role in educational change.[16-18] Preliminary evidence suggests that LA programs contribute to the sustainability of course transformation efforts.[17-19]

As we know of no research or publications addressing the use of LAs within engineering design courses, we begin by describing the program adaptation we developed. Broadly, we wanted to train LAs to foster design thinking and equitable team dynamics within the first-year engineering design course. To accomplish this, we developed a carefully tailored 3-credit pedagogy seminar for these LAs. In this paper, we outline our instructional goals for the pedagogy seminar and how we embodied those goals within specific classroom activities. Then, we evaluate the effectiveness of these seminar activities through their impact on LAs. Finally, we outline areas for improvement on the pedagogy seminar and implications for instructors of similar seminars.

Background

The Learning Assistant Model

Originally developed at the University of Colorado at Boulder, the Learning Assistant model uses the transformation of STEM courses as a mechanism for achieving four goals: (a) improving the quality of university STEM education, (b) improving STEM teacher recruitment and preparation, (c) expanding discipline-based education research efforts, and (d) changing institutional culture to value research-based educational practices.[8-9] In this model, the transformation of STEM courses involves creating environments in which students can interact with one another, engage in collaborative problem solving, and articulate and defend their ideas. To accomplish this, undergraduate peer educators or Learning Assistants (LAs) are hired to facilitate small-group interactions in these LA-supported courses. As such, LAs are critical to beginning and sustaining course transformation efforts.[16,20]

As part of the LA experience, LAs participate in three coordinated activities: (1) *Practice* - LAs facilitate in-class discussion amongst students while students work through group-worthy activities, (2) *Content* - LAs have regular instructional team meetings with the STEM faculty teaching LA-supported courses where they work through upcoming in-class activities, reflect on the past week, and prepare for the coming week, (3) *Pedagogy* - LAs participate in a weekly 3-credit pedagogy seminar where LAs learn about questioning strategies, promoting discussion, formative assessment, and learning theories.[8] These three activities happen concurrently during the LAs' first semester of participation in the program.

Since the LA model was launched at CU Boulder in 2003, it has been emulated at over 88 institutions around the world.[21] Over 3,000 LAs are currently working in 190 STEM departments, impacting roughly 150,000 students.[21] At some institutions, LA programs have grown to support a wide range of disciplines beyond science and mathematics, such as education and foreign languages. There are approximately a dozen institutions in the US beginning to integrate LAs into engineering courses, some of which may include engineering design courses. However, none of these institutions (to our knowledge) have worked to tailor the training of LAs to teaching the engineering design process specifically.

Engineering design courses have some features in common with other science courses where LAs have been particularly effective. Within these courses, class time is spent working in groups on ill-structured open-ended problems for which there exist a broad set of approaches and successful outcomes, and no problem is simple enough to be solved by one person.[22] Students in these courses must work collaboratively and rely on one another's expertise. However, engineering design courses differ from interactive science and math courses in some key ways. Interactive science and math courses typically involve working through contained problems that focus on a particular content area, whereas design courses often involve extended, multi-week projects. We believe that the longer timescale nature of these projects impacts aspects of student engagement such as group dynamics and student emotion. Engineering design courses also require students to integrate knowledge from a variety of STEM disciplines and subdisciplines of engineering. Students often have to draw on content that is not centrally covered within the course, which can pose interesting challenges for educators who do not have expertise in those areas. Therefore, we chose not to simply import the canonical discipline-general LA pedagogy seminar for peer educators in design courses.

This paper describes a pilot adaptation of the LA program model to support students in learning about engineering design processes within an extended project-based engineering design course at University of Maryland, College Park Campus. In this paper, we focus on one component of this program, an LA pedagogy seminar tailored to prepare LAs to foster design thinking and equitable team dynamics. All of the LAs enrolled in this seminar were simultaneously teaching within one of 14 separate sections of University of Maryland's engineering design course for first-year undergraduate students.[23] In the next section, we describe relevant features of the LA-supported design course. (To clearly distinguish these two instructional settings, we will use the term "Pedagogy Seminar" to describe the course on engineering design pedagogy for the LAs, and the term "Design Course" to describe the first year introduction to design course for engineers.)

First-year Design Course: Course Content, Staffing, and Unique Instructional Challenges

At the University of Maryland, College Park Campus, all first-year engineering majors are required to take the Design Course. The Design Course is one of several introductory courses for engineering majors coordinated by the Keystone Program in the School of Engineering. Typically, 14 sections of the Design Course are offered each semester, with 40 students in each section. Currently, the project-based course requires students to work in 8-member teams to develop a battery-powered and microprocessor-controlled autonomous overland vehicle. The vehicle navigates a sandy terrain and performs a mission such as neutralizing a chemical spill, collecting fresh water, putting out a fire, identifying and collecting debris, or mapping the dimensions of a rock. The course requires first-year students to be able to understand and apply the basics of mechanics of motion, basic electronic circuits, microprocessor programming, 3D printing, and control theory. The students undergo an authentic engineering experience through the planning, investigation, design, manufacture, assembly, and evaluation of a fairly complex product. The project also requires students to work in teams, plan a long-term project, and communicate their product development plan, preliminary design, and final designs through a series of presentations and reports. The course has a final competition where teams demonstrate their designed products. In an earlier paper, Calabro, Gupta, and Lopez Roschwalb[23] discussed more details about the design and implementation of this Design Course.

Each section is staffed by an instructor and an undergraduate teaching assistant (UTA). Additionally, there are laboratory teaching fellows who manage the laboratory/fabrication space and assist teams in fabrication and/or programming as needed. The staffing for the Design Course is coordinated by the Keystone Program. Faculty members are selected from across the various departments in the School of Engineering, assigned titles of Keystone Professor or Keystone Instructor, given renewable three-year appointments with a base salary increase and discretionary funds to support their activities, and are assisted by additional support personnel. The faculty across all of the sections of the Design Course meet every other week during the semesters to help with coordination across sections, share new curricular materials, and share problems they might be facing in their own teaching practice. These faculty learning community meetings are coordinated by a designated course coordinator (also a Design Course instructor). In most cases, faculty instructors also have weekly lesson planning meetings with the UTA they are working with.

UTAs are students who have taken the Design Course in the recent past. UTAs are nominated for the position by their Design Course instructor or respond to a recruitment call for the position. The selection and hiring of the UTAs is coordinated by the Keystone Program staff. UTAs are interviewed and selected on the basis of their performance in the course, passion for teaching, organizational and time management skills, commitment to spending ~10 hours per week on the job, and compatibility of their schedule.

The Design Course context offers instructional challenges that are often different from those in a typical engineering/science course where the goal is knowledge acquisition or skill development (such as solving differential equations). For example, if a student is confused about how to pursue a textbook problem from their statics course, the instructor or UTA might help the student develop conceptual understanding of relevant concepts and scaffold them into choosing the procedure to get to the correct answer. In the Design Course, if a student is stuck on how to solve a problem (for example, if their vehicle is drifting as it moves forward), the appropriate instructional move might not be to converge them to a solution, but rather to help them think divergently in order to come up with many ideas, which they would then need to weigh, prototype, and test in order to figure out their own unique path to solve the problem. Instructors and UTAs in the Design Course also need to attend to whether and how a team is organizing themselves, planning for milestones, and issues of equity in how teams go about their work. Since UTAs are closer to students' experiences (in being their campus peers and having been students in the Design Course in recent past), often they are the ones who can best help individual students and teams through the practical and emotional challenges of design thinking and maintaining equitable team dynamics.

Adapting a Program for Undergraduate Teaching Assistants
Prior to the launch of the pilot Pedagogy Seminar, UTAs were required to take a 1-credit seminar as part of their duties. The UTAs met for an hour each week to discuss the instructional logistics for the upcoming week, discuss how the past week went, and occasionally touch on problems within their own instructional practice. They were also required to submit a lesson plan for some aspect of the Design Course.

Gupta, who is also an instructor for the Design Course, in recognition of the unique instructional challenges of the Design Course, felt that the 1-credit seminar was inadequate in preparing UTAs for their instructional role. At the same time, a few other instructors in the Design Course were intrigued by the LA model and wanted to explore what that might look like in the Design Course context. This led to the pilot effort for designing and implementing the 3-credit Pedagogy Seminar for the UTAs in the Design Course in Fall 2016. In our pilot year, we enrolled 14 students. Six students (43%) identified as female and eight (57%) students identified as male. Eleven students identified as white (79%), two students identified as Asian (14%) and one student identified as white/Asian (7%).

As we transition to describing how the design and implementation of the Pedagogy Seminar was geared toward helping prepare the undergraduate peer educators in the Design Course, we will also transition to calling them Learning Assistants, instead of Undergraduate Teaching Assistants, in recognition of the alignment with the broader Learning Assistant Model.

Pedagogy Seminar: Overview
The Pedagogy Seminar was primarily developed by Turpen, Gupta, and Quan. Turpen and Gupta served as co-instructors for the seminar and led most of the lessons. Quan served as teaching assistant and occasionally led lessons but assigned no grades. All authors are part of the research team, but Quan and Tanu led the data collection at the time the seminar was running to ensure that data collected could not unintentionally impact LAs' grades.

The Pedagogy Seminar development began in Summer, 2016. We started with topics from the discipline-general LA pedagogy seminar and integrated topics especially relevant to engineering design (we elaborate on each of these topics in the next section). Our seminar development and activities were documented in an internal wiki. This wiki was updated throughout the semester as we developed weekly lesson plans and reflected on how each class went.

Figure 1 provides an overview of the connections between the Pedagogy Seminar, Instructional Prep Meetings, and the Design Course. Assignments and activities in the Pedagogy Seminar directly support LAs' instruction in the Design Course and conversations with faculty during Instructional Prep Meetings. LAs' Practice in the Design Course and LAs' experience working with faculty in Instructional Prep Meetings guide activities and discussions in the Pedagogy

Seminar. LAs' participation in the Instructional Prep Meetings supports their instruction in Design Course.

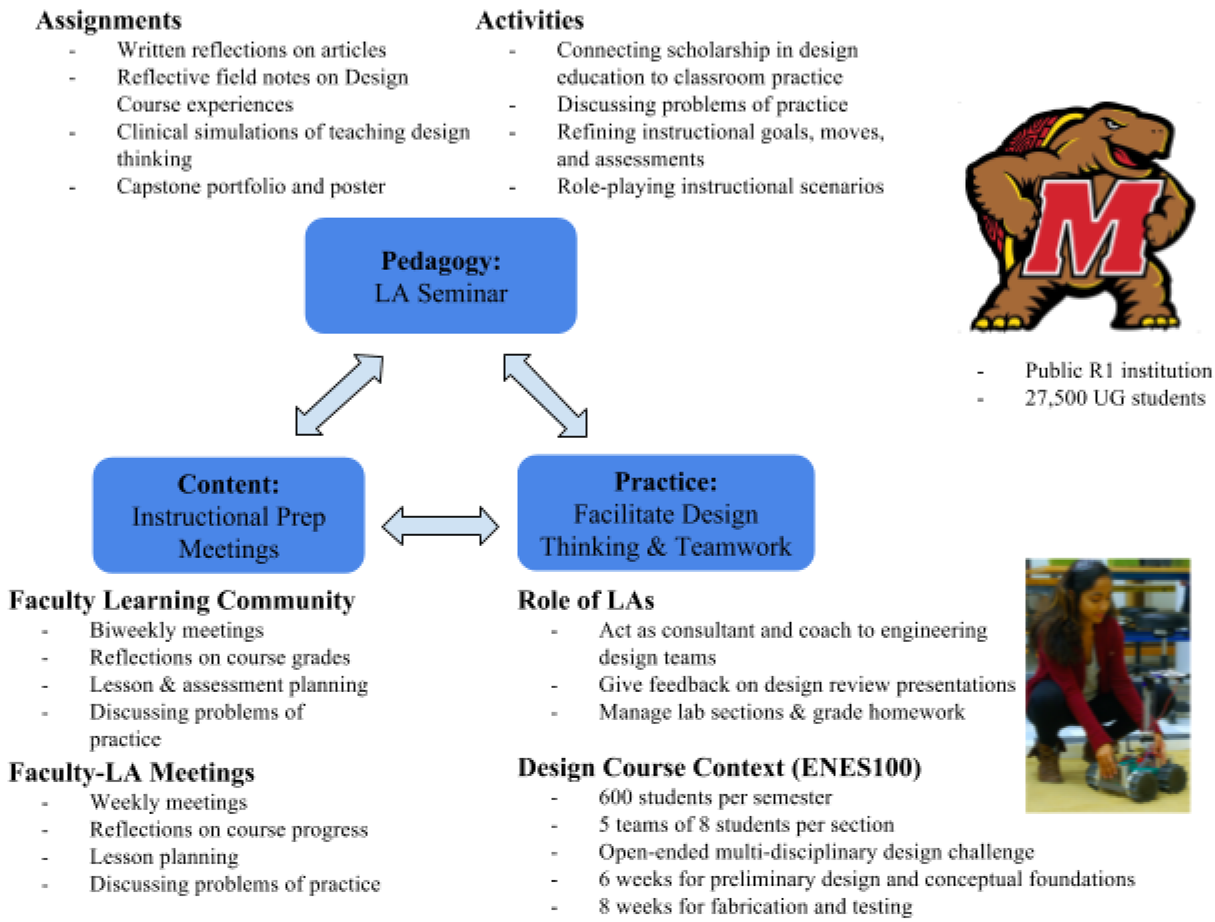

Figure 1: Overview of the LA Experience in our Engineering Design Adaptation

Central Goals, Values, and Learning Objectives

Before we talk about our classroom activities and assignments, we first describe our central goals and values that guided our work. These goals were developed during the planning of the seminar and refined throughout the semester. Several goals were rooted in Turpen & Quan's participation in the Access Network.[1]

1. *Helping LAs reframe their role as supporting growth rather than evaluation* - it is common for instructors to see their role as correcting wrong answers and affirming correct ones. Instead, we wanted LAs to think about students' progress by identifying

[1] The Access Network (http://accessnetwork.org/) is a research-practice community of eight university-based programs dedicated to improving equity in undergraduate STEM education. Core values of the network include promoting student leadership, developing supportive learning communities, and engaging students in authentic STEM practices.

areas for growth and supporting students along that growth process. Adopting a growth mindset has also been shown to improve persistence through challenges.[24]

2. *Valuing a broad set of metrics of success from day one* - often, engineering design courses overtly reward the building of a successful end product. Instead, we wanted LAs to have an expansive notion of what counts as "success" in the Design Course, including aspects such as engaging in authentic design thinking, pursuing a creative but risky idea, and having a harmonious team dynamic where everyone contributes and learns.
3. *Celebrating that different students bring in different expertise, and disrupting overly simplistic expert/novice dichotomies*- doing engineering requires more than knowing content and skills. It also requires students to have interpersonal and emotional skills for collaboration, organization, and perseverance in the face of setbacks.[25] We wanted LAs to recognize how all students can make a unique contribution to their team.[26]
4. *Acknowledging that we all have different starting points and valuing a plurality of goals* - Within Design Course, students are all starting from different places and may all want different things out of the course. We wanted LAs to be responsive to individual students' goals and prior experiences.
5. *Helping LAs track their own progress through reflecting on concrete representations of their thinking* - We draw from *constructionism*,[27] in which having concrete objects and representations of one's thinking can facilitate reflection and opportunities to feel proud of one's work.[28]
6. *Supporting LAs in developing deep disciplinary knowledge of design thinking, and pedagogical content knowledge to support the instruction of design thinking* - we wanted LAs to develop deep knowledge about the design process and the research-supported best practices for teaching design thinking.

These goals and values were enacted in the course through a variety of in-class discussions and out of class assignments. Later we describe a few of these activities in detail to give a sense for how tasks were designed to embody these values and how they were taken up by the LAs.

In addition, we specified a few learning goals toward developing the LAs' scholarship of teaching and learning:

LAs will be able to:

1. Select and critically evaluate claims from education and/or engineering education literature and judge the utility of these claims in relation to their experiences as learners and educators.

2a. Document classroom events in a scholarly way by selecting episodes of classroom events, and constructing descriptive accounts of student thinking and classroom interactions for critical examination.

2b. Recognize and practice using key concepts from education and engineering education (such as metacognition, epistemology, student collaboration, design thinking) within classroom events.

3a. Analyze classroom events in a critical and scholarly way by substantiating claims about students' understanding/participation with evidence from classroom events or student work, building higher inference interpretations of events from supporting evidence, and exploring and considering multiple plausible interpretations of events.

3b. Re-envision or imagine future classroom interactions through considering how multiple features of the educational setting could be changed, considering a range of possible educator moves or actions, hypothesizing how changes to the educational setting and/or the educator's actions may influence shifts in the students' engagement/learning and developing intentions and associated plans-of-action for when similar situations arise in the future (in light of salient learning goals).

4. Communicate effectively about their scholarly practice in written, oral and visual forms through a capstone project by writing a synthesis paper, building a visual poster representation of their argument, and presenting their poster publically.

We prepared rubrics to track the progress of the LAs along these dimensions of learning. (We provide the current version of the rubric in Appendix A)

Pedagogy Seminar Activities

Course Readings
Every week, students were required to come to class having read one or two articles that we assigned. We integrated topics from the discipline-general LA pedagogy seminar (cognitive science of learning, facilitation of classroom discourse, collaboration, metacognition) with topics especially relevant to engineering design (design reviews, design thinking, expert-novice practices in engineering design, engineering epistemology, teamwork and equity). Our themes and readings are in Appendix B. Before coming to class, students were asked to write a reflection paper on that week's readings. In-class discussions on the readings were structured to help students make sense of specific claims made in the reading or connect the reading to themes within their own teaching practice within the Design Course.

Field Notes
Over the semester, LAs wrote 4 field notes on their experiences as a Learning Assistant in the Design Course, focusing on their interactions with individual students or teams. The purpose here was to scaffold LAs in noticing and describing students actions and their own responses in descriptive and interpretive ways rather than evaluative ways.

Clinical Simulations of Teaching
Twice during the semester, LAs invited their students in the Design Course for a session in which LAs recorded and analyzed themselves facilitating teams/individuals doing design tasks. In the first simulation, LAs engaged the student group in a short design thinking task and in the second, the LAs engaged a student group over an issue that their team was facing in the Design Course. LAs transcribed the recordings (audio or video) from the meeting, and wrote reflection papers emphasizing the creation of multiple interpretations of events and analyzing their own instructional responses through considering multiple possible instructional moves.

Capstone Poster and Portfolio
The seminar culminated in a poster session to the broader STEM education community at the University of Maryland and a capstone portfolio where LAs used artifacts from their teaching to depict their growth trajectory through their LA experience.

Other in-class activities
In-class discussions supported the synthesis of readings, reflection on teaching experiences, and analysis of video episodes of students engaging in design thinking. An example of one such classroom activity is watching video clips of the clinical simulations of teaching. As a class, we would discuss the forms of design thinking present and analyze the impact of instructional moves. We also provided space for LAs to share and discuss their teaching in the Design Course, which helped them empathize and share common struggles with one another, as well as brainstorm possible solutions forward.

Analytical Approach
Our data collection served two purposes: 1) ongoing assessment of the seminar in order to inform improvements to future iterations of the seminar, and 2) research on the seminar investigating the resources LAs draw on in their teaching, and how they make progress toward supporting students' design thinking. The first of those purposes is discussed in this paper.

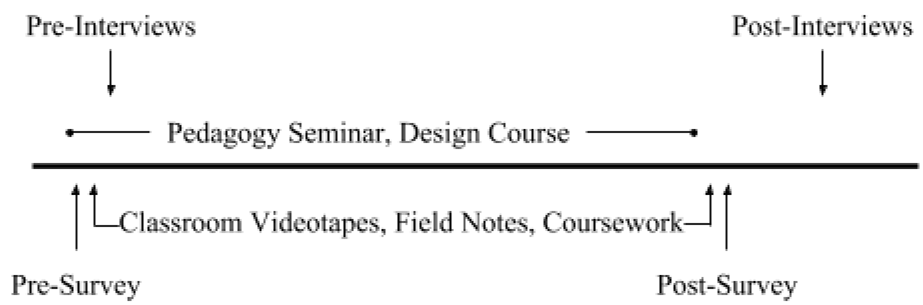

Figure 2: Timeline of data collection relative to Pedagogy Seminar

Quan and Tanu collected written surveys, interviews, videotapes of the Pedagogy Seminar, and student coursework (see Figure 2). Pre- and post- surveys focused on what students hoped to get out of (or got out of) the seminar, their attitudes toward teaching engineering, and their goals for the future. During each seminar, Quan and Tanu collected videotapes and wrote field notes of what was happening during the seminar. We also collected seminar materials and planning documents from our internal wiki.

In our assessment of this seminar, we sought to describe how our activities embodied our teaching goals and supported LAs' instruction. In this paper, we focus on the embodiment and evaluation of our progress toward three teaching goals: 1) for LAs to develop deep disciplinary knowledge of the engineering design process and design thinking, 2) for LAs to recognize and value a breadth of positive outcomes beyond content learning and 3) to create space for LAs to be able to share and process problems of practice that educators encounter, for the purpose of honing their skills in noticing and attending to student ideas.[29]

We describe our implementation of seminar activities that supported these goals, and then use LAs' written responses and videotapes of the seminar to analyze how these activities impacted LAs' recounted instructional practices. One limitation of this work is that we primarily draw on data from written work and Pedagogy Seminar interactions, rather than actual observations of LAs' instruction. To fully understand how the seminar supported LAs' instruction, we would need to include more data, such as videotapes of LAs teaching in the Design Course.

Designing Activities Rooted in our Goals
In this section, we present illustrative examples of how the design and implementation of activities in the Pedagogy Seminar connected to our goals and values. We discuss how the LAs participation in these activities in the Pedagogy Seminar connected (or could connect) to their instructional practice in the Design Course. In this paper, we highlight the implementation of three key goals of our Pedagogy Seminar:

1. Refining LAs' understanding of the design process,
2. Valuing outcomes beyond content learning, and
3. Providing opportunities for reflecting on concrete teaching scenarios.

Refining LAs' understanding of the design process
A central goal of the seminar was for LAs to develop deep disciplinary knowledge of the engineering design process and design thinking. Within our seminar, we supported LAs' learning of the design process through assigned readings on design thinking, guided written reflections, and class discussions. In this subsection, we discuss how we elevated the design process in our curriculum and scaffolded LAs' learning about the design process and how to teach the design process.

We draw from existing literature on design thinking to inform our conceptualization of design thinking. We see engineering design as the process for solving an ill-structured problem, in which the solution and problem definition co-evolve to produce a solution that meets the problem constraints.[30-31] Design thinking is an orientation that allows the designer to work in an iterative, non-linear manner through cycles of divergent and convergent thinking.[4,31]

In the Pedagogy Seminar, our goal was to create contexts in which LAs can practice noticing and attending to students' design thinking rather than focus solely on students' content knowledge or conceptual difficulties. Emphasizing design thinking in the LA seminar was important because a central learning objective of the Design Course is the design process. Developing an understanding of design thinking is also valued within the field of engineering education because it is aligned with the activities of practicing engineers.[30-31]

Implementation
Seminar readings were chosen to touch on accounts of design thinking written by design experts as well as accounts from the teaching/learning of design thinking by engineering education scholars. The first reading that explicitly took on design thinking was Brown's overview of the

design process in week four.[31] We then focused on several components of the design thinking process including: Daly & Yilmaz's article on instructor moves that support convergent or divergent thinking,[32] Wendell et al.'s discussion of how children do reflective decision making during the design process,[33] and Watkins et al.'s article on problem scoping.[34]

For each of these readings, LAs wrote weekly guided reading reflections that responded to the following prompts:

> What is the main argument(s) of the reading?
> What parts of the reading were confusing or unclear? What questions do you have after this reading?
> In what kinds of situations do you think the claims developed in the paper will apply or be useful? Discuss how the issues or arguments presented in the reading relate to your experiences (as a Learning Assistant and/or as a student). Use specific examples whenever possible.

In the first seven weeks, these reading responses were roughly two pages long. During our mid-semester feedback, LAs reported that the reading reflections were too long, so we shortened the assignment to two paragraphs.

Using LAs' reading reflections, including students' suggestions for in-class discussion questions, we generated discussion questions and activities for class. Our in-class discussions were open-ended and focused on the comprehension of articles, evaluation of claims made by authors, and the article's connection back to the Design Course. For example, when discussing the Brown design thinking article,[31] we asked "What bits of the article align with or don't align with the Design Course? Are there bits of design thinking that you think are not currently instantiated in the Design Course but could potentially be useful to fit in in some way? How would you find the space for that?" An example of a discussion question about the Daly and Yilmaz article[32] on divergent and convergent thinking is, "As an instructor, what purposes do each of these kinds of prompts (divergent/convergent/neutral) serve? When would you employ each of these prompts?"

In a typical discussion focusing on the assigned readings, LAs worked in groups of 3-4. Each group was given a whiteboard to write down their collective thoughts. Then, each group would informally present their ideas using whiteboards to the whole class, and we would discuss common themes or ideas in a whole-class discussion.

Outcomes
At the end of the semester, we asked the LAs to rate each assigned reading topic for how productive it was for them (See Figure 3). The most favorably rated topic was convergent/divergent thinking (average rating 4.84/5, with 5 corresponding to "very productive"), and design thinking was also rated highly (average rating 4/5).

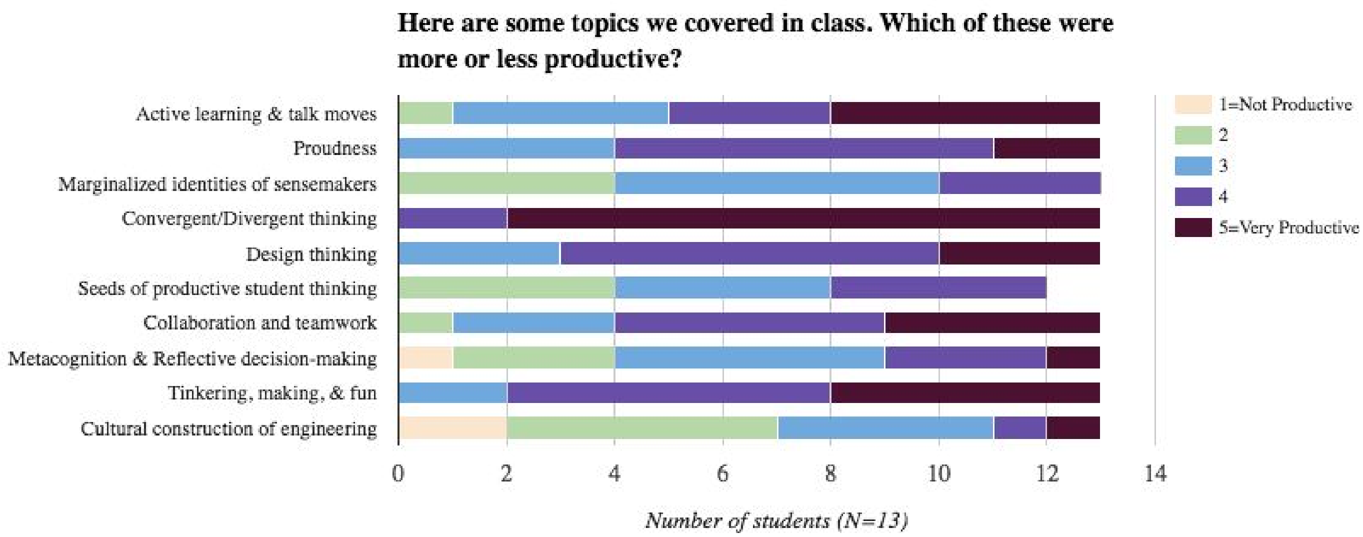

Figure 3: Productivity Rating for Topics in Assigned Course Readings

In students' written reflections, we also saw evidence that their ideas about design process were refined through the seminar. The following excerpt from Vincent's[2] portfolio describes how readings on design thinking influenced his capstone project in the Pedagogy Seminar. The focus of his capstone project was to redesign a Design Course activity called the *3D Printed Car Challenge*. In the original *3D Printed Car Challenge*, students in Design Course were tasked to assemble 3D printed parts into a battery operated toy car and race it on sand. Vincent proposed several modifications that would incorporate more design thinking.

> "Putting a name to the concepts that I had been working with previously allowed for me to try to think of ways we can improve the course that I had not thought about previously, as evident in my redesign of the 3D printed car challenge... In that redesign, I took on the ideas of tinkering, divergent thinking and reflective decision making applied to the 3D printed car challenge. I planned to have it be so that the 3D car would serve as more of a test platform for gears, motors, and wheels that the students can use to their advantage, rather than a side project that they just have to deal with."

Vincent highlights features of design thinking—tinkering, divergent thinking, and reflective decision making—that he incorporated into his final project. He describes covering these ideas in class as "putting a name to the concepts I had been working with," suggesting that he already had some intuition for these ideas. Discussing design thinking in-depth supported him in identifying an area for improvement in Design Course, and developing a proposal to address that.

As another example, in Molly's final field note, she describes a situation where a student (in the section of Design Course in which she was the LA) finds out that sand is stuck in a motor. Molly reflected on how she noticed features of design thinking while facilitating the troubleshooting process,

[2] All student names are pseudonyms

> "… My favorite part of this interaction was when he moved on to the 'now what?' thinking of the situation. His thought process showed a lot of concepts we had in the readings. His many different approaches showed divergent thinking. His idea to use string showed the concept of rapid prototyping. The description of his ideas showed a mastery of mechanical concepts such as gearing. When he referred to his idea of using a 'belt' he showed the ability to adapt information he had prior knowledge of to his current situation."

Molly noticed some of the features of design thinking in the student's activity, such as divergent thinking, rapid prototyping, and adapting prior knowledge, and she explicitly connects these to class readings. It is unclear whether or how the readings about design thinking might have influenced Molly's instructional moves during this episode. However, we believe that the process of noticing is an important teaching skill that is necessary for effective teaching.[35]

Our end-of-semester survey data shows that most LAs found topics related to design thinking as particularly productive for their teaching. For example, Vincent reported that he drew on readings about design thinking to propose an improvement to a Design Course activity; Molly noted that she used design thinking concepts to help her notice and reflect on productive aspects of students' design activities. These two examples are not intended to be exhaustive, but rather, to illustrate that the focus on design thinking impacted LAs' teaching practice in a variety of ways.

Valuing outcomes beyond content learning

As members of the engineering education community, it is not only important to us that engineering students learn content and skills. We also want students to have a sense of engineering identity, to have positive emotions such as proudness to their work, and for students of diverse backgrounds to contribute meaningfully to an engineering team. A central goal of our seminar was for LAs to recognize and value a breadth of positive outcomes beyond content learning. In this section, we describe how we supported LAs in thinking about non-content learning goals and how this impacted their teaching practice.

Implementation

We assigned and discussed several readings related to non-content learning outcomes. The development and implementation of reading reflections and discussion activities is discussed above. Topics covered included Danielak, Gupta & Elby's paper on how engineering departments support specific ways of knowing and doing engineering; students who see themselves as other kinds of "knowers" may be alienated.[36] We also discussed Little's article on the importance of proudness and how educators can design for it.[28] Finally, we read several articles about group work and equity within groups;[37-40] these articles ranged from highlighting inequities and marginalization within groups to articulating features of good group work.

In the rest of this section, we focus in on one non-content learning outcome, proudness. We choose to focus on proudness because it was taken up by LAs as a "sticky" concept; it spontaneously re-emerged several times in class discussions and written work. Little describes proudness as resulting from a period of frustration leading to a sense of accomplishment. She offers several ways that educators can design for proudness, such as helping people track their work to make the frustration period more bearable, and amplifying the sense of accomplishment through reflection.

One student's written reflection helped us generate the following in-class discussion question, "How can we support or amplify proudness in the Design Course? Think about concrete actions you can take now to aim for the 'proudness' endgame?" LAs brainstormed strategies such as developing visual, shareable representations of students' work in-progress, pointing out the ways that students have improved on various skills, and designing for mini "a-ha" moments throughout the course. They also drew on their own personal experiences to suggest proudness strategies; one LA reflected on how keeping a journal in his undergraduate research helped him track his progress and feel proud of how he overcame challenges.

Outcomes

After the initial class discussion on proudness, the idea reemerged in several class discussions and written reflections. Several weeks after the initial proudness reading, we were discussing teaching challenges in small groups. One LA brought up the challenge of how to engage a Design Course student who was "checked out" and not contributing to his group. Another LA, Mason, had faced a similar experience in his own teaching, which he addressed by teaching that student to solder. Mason described how teaching the student this new skill reengaged the student, who "now offers to, like, solder everything," by creating moments for proudness.

In addition to proudness reemerging in class discussions, we also have evidence that it impacted LAs' teaching practice. In Diane's capstone portfolio she reflected on how she sought to facilitate "proudness moments," which supported students in sustaining their motivation through the challenging parts of Design Course.

> "These readings inspired my interactions with my students almost immediately after I read them. For example, after reading Little's piece, I made it my goal to amplify any 'proudness moment' that my students encountered, and to help students find these proudness moments in their work themselves. I feel that this endeavor as a quasi-cheerleader was successful, as I noticed a certain resurgence of energy and motivation as I helped students realize these proudness moments… There are too many moments where students can feel beaten down by the overwhelming challenges they face in their design task, and lose sight and motivation. Incorporating and highlighting moments of proudness is key to encouraging students in those moments, and giving them new momentum to move forward in their design."

Diane describes how after reading Little's article on proudness, she created her own teaching goal to "amplify any proudness moment" and to support students in identifying these proudness moments. She also describes how she assessed the impact of these teaching moments, and noticed a "resurgence of energy."

In Molly's Capstone Portfolio, she described how the class helped her attend to a wide range of student emotions in her teaching, including proudness, frustration, and stress.

> "Another takeaway I got was the necessity for empathy as an educator... Giving attention to their accomplishments allows them to establish a feeling of proudness, which will motivate them rather than discourage...I tried to take on this role by helping students with emotional rigors of the course. Some students brought up their stress for the project and I tried to help them through that... Sometimes the issue was just frustration that nothing was working, and in that case I tried to emphasize what they had accomplished and reassured them that we would make it work." -Molly

Molly describes how the seminar helped her rethink her role as an educator to include attention to students' emotion. She valued "helping students with the emotional rigors" of Design Course by supporting them through stressful moments and amplifying their accomplishments. She saw the act of amplifying proudness as a mechanism for increasing students' motivation.

Providing opportunities for reflecting on concrete teaching scenarios

A third goal of the Pedagogy Seminar was to create space for LAs to be able to share and process problems of practice that educators encounter, for the purpose of honing their skills in noticing and attending to student ideas. We describe our embodiment of these goals and how they supported LAs' teaching practice.

Implementation

We designed several classroom activities with the goal of providing opportunities for LAs to share and discuss challenging teaching situations that occurred in the Design Course. We had regular "roses and thorns" discussions where the class broke into two groups and each person described one positive teaching moment and one negative teaching moment. In these discussions, LAs would often empathize and share common struggles with one another, as well as brainstorm possible solutions forward. We also had several classroom roleplays in which some LAs (and occasionally seminar instructors) would act out scenarios involving LAs and Design Course students. This gave LAs the opportunity to try out different teaching moves. Other LAs would watch on, and make note of how these moves played out. This would then be followed by a class discussion. We now present a vignette of one roleplay, which is based on instructors' written reflections and researcher field notes:

> *In the previous class, LAs wrote down teaching challenges they had encountered. One teaching challenge described a Design Course student with little Arduino experience, "She was having trouble with making an LED blink 30 times in 15 seconds. I had trouble explaining to her what she could do to change the blink rate without outright telling her."*
>
> *We broke students into groups of three, asked them to read the scenario, and assign two people to be the "students" and one "LA." In the first group, Peter plays the LA, while Thomas and Emily play students. Peter first asks them if they know about the polarity of LED's, and then explains how the polarity works. Emily and Thomas check the polarity and the LED still won't blink. Peter then asks them what they've done in the code so far.*

Emily explains that they copied and pasted the code but didn't know how it works. Peter reminds them that they have a set of resources for their code, so they should check that next time. Peter then begins a line-by-line analysis of the code with the students. He leads them through each line of code, inviting them to figure out what each of line means, and correcting them when they're incorrect. After they move through the code, Peter asks them how to modify the code to blink 30 times in 15 seconds, and the students suggest a change to the code that would complete this task. Ayush ends the roleplay and invites everyone else to discuss what happened.

Molly says that Peter did a good job figuring out what the students already know. Maria points out that it was productive for Peter to point out references and model the line-by-line troubleshooting so that they would be able to solve the problem themselves next time. Christian agrees that it was productive for Peter to point out resources at the beginning, but wonders whether it would have been more productive for Peter to just tell them the answer. Emily builds off of Christian's statement by pointing out that some points of confusion (such as understanding what a time delay function does) might not be worth the LA's time to explain compared to more challenging problems. Maria suggests that since this is a common problem, an LA could pull a few students together to figure it out.

Within the seminar, we used these roleplay activities for LAs to discuss problems that emerge in their teaching. This allows LAs to try out teaching moves and reflect on them. Some LAs also described how playing the student role helped them empathize with their students better. In this case, we see how the activity allowed us to have class discussions about the pros and cons of certain teaching moves in a given scenario. At the end of the vignette, Christian initiated a conversation about how LAs have to make trade-offs when their time is limited; an LA might have greater impact by spending time with students who are stuck on more challenging problems. The roleplay allowed for a discussion on this common, messy teaching challenge, and LAs generated suggestions for how to approach it.

Outcomes

Classroom roleplay was rated as one of the most helpful activities we covered in class, whereas the "roses and thorns" discussion was described as moderately helpful. On a scale from 1 to 5 (1=Not very productive; 5=Very productive), Classroom roleplay had an average rating of 4.04 (standard deviation of 0.88) and roses and thorns had an average rating of 3.46 (standard deviation of 0.97). Figure 4 shows how students rated these activities compared to other classroom activities.

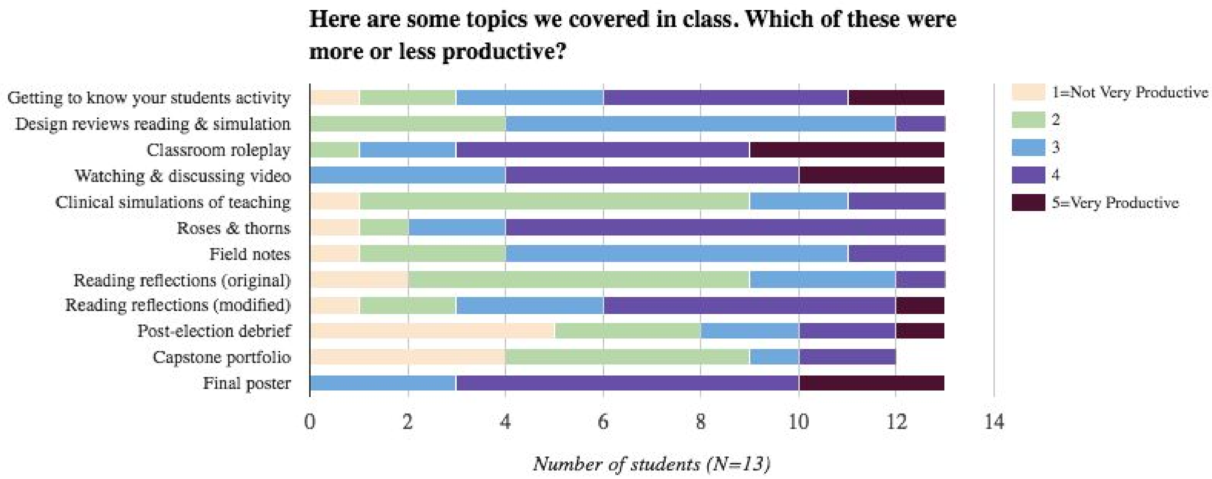

Figure 4: Productivity ratings for classroom activities

In the post-survey, Thomas elaborated on the utility of the roleplay: "The classroom roleplay was particularly helpful because it gave all of us a chance to 'experience' a classroom situation together and provide feedback for each other."

In her Capstone reflection, Diane wrote about the roses and thorns discussion as being particularly useful as a first-time LA:

> "Having the space to open up about 'roses and thorns' in our classrooms, and gaining differing perspectives on interactions greatly increased my confidence within the classroom. I especially appreciated the advice received from those teaching fellows who already had classroom experience, and could relate that previous experience to the course readings. This not only helped me see some of the readings in a new light, but it also gave me more experiences to draw upon if I was faced with a difficult situation."

Diane outlines how the roses and thorns activity helped her gain perspectives from other LAs, and was particularly appreciative of the advice from returning LAs. She also described the roses and thorns activity as providing opportunities to develop confidence, connect her teaching experiences to seminar readings, and impacting future teaching scenarios.

Challenges to implementation

We have presented some evidence that we met our teaching goals for some students. However, we also encountered several challenges in our implementation and aspects of the seminar that were rocky. As classroom designers, we see these challenges as opportunities for growth in future iterations of the seminar.

One of the biggest challenges to the seminar was setting expectations with students about the workload of the seminar. We planned the seminar to take the same amount of work as a 3-credit course. Because of logistical challenges, most students did not know they would have to take the three credit seminar until they had already registered for classes, so the addition of the three credit seminar made their schedules much more full. UTAs in prior years only had to attend a one credit seminar, so many of them felt that the seminar was unnecessary. Within the first several weeks of the seminar, we received feedback that the workload was too overwhelming for students. In response to that, we shortened the weekly reading reflections and cut several readings. We also cut one field note assignment. In future years, we hope to advertise the course farther in advance and make the coursework expectations clear, so that applicants to the teaching fellowship can make more informed decisions.

We also found it challenging to give feedback on LAs' written work. In the design of the seminar, we ambitiously wanted to support students in tracking their growth over time through having opportunities for multiple iterations of similar assignments. For example, receiving feedback on each of the four field notes would have ideally resulted in LAs field notes becoming more detailed over the semester. We struggled with getting students feedback quickly enough for them to improve their work as much as we had hoped. This challenge of giving detailed, timely feedback is common. In the future, we hope to consider other kinds of feedback processes, such facilitating peer feedback.[41]

It was challenging to apply the designed rubrics on an ongoing basis due to limited time and a few unanticipated concerns. One such concern was in the rubric for assessing progress on reading reflections. We had initially created the rubric to assess the quality of their engagement with the reading and whether they were making connections across readings. But that specific rubric did not include whether students were connecting the concepts in the readings to aspects of their classroom practice. It turned out that the LAs' written reflections often included extended paragraphs on the latter. Given our own goal of valuing students' goals and expansive notions of success, we were unable to consistently use the reading reflection rubric for grading purposes. In future, having learned from this experience, we will update our rubrics.

We also encountered challenges with engaging LAs with some of the ideas in our curriculum. For example, one of the topics we covered was on collaboration and teamwork. LAs agreed that teamwork was a challenging issue for students in the Design Course that has big consequences for the group's learning. However, many LAs did not want to intervene during teamwork and communication problems. For example, in one of our classroom roleplays, we discussed a scenario in which students approached the LA with a question about circuits, but it was clear that the group was also having a teamwork breakdown. Several LAs expressed that if a group were to approach them with a content problem, they would choose to only focus their help on the content. We would have loved for the LAs to see their role as also supporting interpersonal relationships. In future iterations, we will think about how to get LAs more comfortable with intervening in problems related to team dynamics.

Discussion

In this paper, we describe the design and implementation of a Pedagogy Seminar for undergraduate peer-educators in a first year engineering Design Course. Rather than trying to give a comprehensive overview, we chose to zoom in on three aspects of the seminar: supporting LAs in developing knowledge of design thinking and how to teach design thinking, helping LAs recognize and value a breadth of positive outcomes, and supporting LAs in noticing and attending to students ideas by creating space for them to share and enact teaching moments. We illustrate how a diversity of assessments can be used to evaluate such a seminar. Using surveys, instructor reflections, and coursework, we found some evidence that LAs found these activities helpful. In future study, we plan to collect additional data, such as videotapes of LAs teaching, to fully understand how these impact LAs' instruction.

Finally, we describe several challenges to implementation, such as the difficulty of negotiating expectations of workload with LAs, the instructional team's struggle to give timely and detailed feedback, and LAs' resistance to addressing teamwork in their teaching. This list is by no means exhaustive, but is instead a detailed discussion of a subset of challenges that are particularly salient to us right now. As educators who value the design process, we also believe the design process can be applied to the design of engineering classrooms. Therefore we believe that the process of collecting data, reflecting on our results, and making iterations can ultimately result in a more refined seminar that better aligns with our goals.

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Appendix A

Assessment Rubric

	Field Notes	Reading Reflection	Simulations of Teaching	Capstone
Learning Outcome 1: Select and critically evaluate claims from education and/or engineering education literature and judge the utility of these claims in relation to your experiences as learners and educators.				
Clear articulation of the main claims made in the article(s) relevant to practice of engineering education.		X		X
Elaboration on coherence across articles.		X		X
Critical evaluation of claims about engineering education made in article(s).		X		X
Recognition of appropriate educational constructs as relevant.	X		X	
Learning Outcome 2a: Document classroom events in a scholarly way by selecting episodes of classroom events, and constructing descriptive accounts of student thinking and classroom interactions for critical examination.				
Descriptions of sequences of events are sufficiently and purposefully detailed.	X		X	X
Descriptions include a variety of markers.	X		X	X
Learning Outcome 2b: Recognize and practice using key concepts from education and engineering education (such as metacognition, epistemology, student collaboration, design thinking) within classroom events.				
Applying relevant constructs correctly to analyze events.	X		X	X
Appropriately distinguishes between descriptive and interpretive accounts.	X		X	X
Learning Outcome 3a: Analyze classroom events in a critical and scholarly way by substantiating claims about students' understanding/participation with evidence from classroom events or student work, building higher inference interpretations of events from supporting evidence, and exploring and considering multiple plausible interpretations of events.				
Appropriately distinguishes between low-inference and high-inference interpretations.	X		X	X
Provides mechanistic explanation for high inference interpretations.	X		X	X
Consideration of multiple interpretations of events.	X		X	X

Learning Outcome 3b: Re-envision or imagine future classroom interactions through considering how multiple features of the educational setting could be changed, considering a range of possible educator moves or actions, hypothesizing how changes to the educational setting and/or the educator's actions may influence shifts in the students' engagement/learning and developing intentions and associated plans-of-action for when similar situations arise in the future (in light of salient learning goals).				
Consideration of multiple instructional moves.	x		x	x
Consideration of immediate and long term implications of instructional moves.	x		x	x
Evaluation of the generalizability and uniqueness of classroom events.			x	x
Learning Outcome 4: Communicate effectively about their scholarly practice in written, oral and visual forms through a capstone project by writing a synthesis paper, building a visual poster representation of their argument, and presenting their poster publically.				
Clarity and coherence of ideas.	x	x	x	x
Writing (spelling, grammar, organization).	x	x	x	x
Public Speaking.				x
Visual Presentation.				x

Appendix B

Table of Course Readings

Themes	Readings
Learning and Knowing	Redish, E. F. (1994). Implications of cognitive studies for teaching physics. American Journal of Physics, 62(9), 796-803. Felder, R. M. (2012). Engineering education: A tale of two paradigms. Shaking the foundations of geo-engineering education, 9-14. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410-8415.
Facilitating Classroom Discourse & Constructive Design Reviews	Daly, S. R., & Yilmaz, S. (2015). Directing Convergent and Divergent Activity through Design Feedback. Analyzing Design Review Conversation, 21, 413-429. Michaels, S. & O'Connor, C. (2012). Talk Science Primer. TERC, pp 1-20.
Supporting Authenticity in Learning	Danielak, B., Gupta, A., & Elby, A. (2014). Alienating Deep Learners. In JEE Selects, ASEE Prism Magazine, March 2014 Issue. Little, A. (2015). Proudness: What is it? Why is it Important? And How Do We Design for It in College Physics and Astronomy Education? STATUS: A Report on Women in Astronomy, Newsletter published by the American Astronomical Society, June 2015 issue, pp 7-13.
Design Thinking	Brown, T. (2008). Design thinking. Harvard Business Review, 86(6), 84.
Productive Seeds of Scientific Inquiry & Collaboration	Hammer, D. (2004). The variability of student reasoning, lecture 1: case studies of children's inquiries. In PROCEEDINGS-INTERNATIONAL SCHOOL OF PHYSICS ENRICO FERMI (Vol. 156, pp. 321-340). IOS Press; Ohmsha; 1999. Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. Science, 323, 122-124.

Supporting Student Collaboration/Team work	Barron, B. (2003). When smart groups fail. The Journal of the Learning Sciences, 12(3), 307–359. (Excerpts) Tonso, K. L. (2006). Teams that work: Campus culture, engineer identity, and social interactions. Journal of Engineering Education, 95(1), 25. (Excerpt)
Metacognition and Reflection	Schoenfeld, A. H. (1987). What's All the Fuss About Metacognition. Cognitive science and mathematics education, 189. Wendell, K. B., Wright, C. G., & Paugh, P. C. (2015). Urban elementary school students' reflective decision-making during formal engineering learning experiences. Proceedings of the 122nd American Society for Engineering Education Annual Conference and Exposition. Seattle, WA: American Society of Engineering Education.
Expert-like Design Practices	Cross, N. (2004). Expertise in design: an overview. Design Studies, 25(5), 427–441. Watkins, J., Spencer, K., & Hammer, D. (2014). Examining Young Students' Problem Scoping in Engineering Design. Journal of Pre-College Engineering Education Research (J-PEER), 4(1). (Excerpt) Quan, G. M., & Gupta, A. (2015, June), Tensions in the Productivity in Design Task Tinkering – Fundamental Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24837
Supporting Collaboration: Expertise from Professional Engineering	Woolley, A., Malone, T., & others. (2011). What makes a team smarter? More women. Harvard Business Review, 89(6), 32–33. Katzenbach, J. R., & Smith, D. K. (2005). The discipline of teams. Harvard Business Review, 83(7), 162.
Learning through Designing and Making	Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In Design, Make, Play: Growing the Next Generation of STEM Innovators (pp. 50–70).
Equity Revisited	Secules, S. D., & Elby, A., & Gupta, A. (2016, June), "Turning away" from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26239