The Role of Empathy in Supporting Teaching Moves of Engineering Design Peer Educators

Ms. Emilia Dewi Tanu, University of Maryland, College Park

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. She hopes to eventually pursue graduate studies in Engineering Education. Her research interests include emotion in design and empathetic classroom practices.

Ms. Gina Marie Quan, University of Maryland, College Park

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, and an elected member of the Physics Education Research Leadership and Organizing Council (PERLOC).

Dr. Ayush Gupta, University of Maryland, College Park

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 models of learning (based in microgenetic analysis, or drawing on interaction analysis). 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 (ontological) underlying students' reasoning in physics. Lately, he has been interested in engineering design thinking, how engineering students come to understand and practice design, and how engineering students think about ethics and social responsibility.

Dr. Chandra Anne Turpen, University of Maryland

Chandra Turpen is a Research Assistant Professor at the University of Maryland, College Park with the Physics Education Research Group. 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.

The Role of Empathy in Supporting Teaching Moves of Engineering Design Peer Educators

Abstract

Empathy is a diverse and complex phenomena by which humans relate their experiences to one another. This work explores empathy as a resource for engineering educators attending to student emotion within an engineering design environment. Our research setting takes place in a 3-credit pedagogy seminar (EDCI488E) for undergraduate engineering peer educators who are teaching concurrently in a first-year engineering design course (ENES100). The pedagogy seminar is modeled after the Learning Assistant Program developed at University of Colorado-Boulder. The seminar focuses on engineering content and pedagogy relevant to teaching engineering design (i.e. design thinking, reflective decision-making, and teamwork and collaboration). Our research analyzes for how empathy impacted peer educators' teaching practices in the seminar. Using field notes, coursework, and videotapes of the pedagogy seminar, we analyzed the peer educators' speech, gesture, and actions in video-recorded data. We present a case study of a role play activity in the seminar in which peer educators simulated giving feedback and critique to ENES100 students during a design review. We specifically analyze how a focal peer educator utilized empathy to recognize a tension between productive student learning and student emotion. Empathy supported the focal peer educator in developing new teaching moves that responded to the pseudo-student's emotions. Our analysis focuses on identifying features of her empathetic practice, and how such features could support a variety of teaching moves.

Introduction

Engineering education literature typically does not directly focus on student emotion or student emotion in design. Literature in engineering curriculum development and facilitation successfully focuses on creating conceptual and epistemological impact. Although the role of student emotion is implied in such literature, it is rarely the focus of study and often does not consider the relationships between instructor, curriculum, student learning and student emotion. Tonso and Bales note how emotion plays an important role in undergraduate design courses as social and emotional task functions within teamwork can contribute to a student's role and involvement on a team.[1-2] Literature in science education speaks to the role which emotion can help or hinder learning.[3] We suggest that when educators consider student emotion as part of their instructional design, emotion can become part of the engineering classroom culture, resulting in students valuing their own emotions and their peers' emotions as well. Thus, from a user-centered design perspective, valuing student emotion is in the interest of stakeholders. Within an educational space, instructors' stakeholders are their students and instructors should be able to empathize with them. In this work we explore how engineering peer educators empathize toward their students to understand the role of emotion in an engineering design course. We argue that empathy enables instructors to unpack student emotion in the classroom which can likely support better instructional design.

This work involves the study of empathy in a pedagogy seminar for engineering undergraduate peer educators. In this paper, we present two classroom episodes where peer educators simulated teaching scenarios in a classroom roleplay. This role play activity emulated a design review,[4] and the goal of the roleplay was to support divergent thinking.[5] During the roleplay, our focal student Michaela (all the following names are pseudonyms), utilized empathy to identify a tension between productive student learning and student emotion. She elaborated on this tension by recognizing student emotion, defining the conditions of the situation which the student was emoting, and reimagining a new design review setting for productive student learning. This new setting was used by the seminar course instructors for a second iteration of the design review roleplay. Michaela's new setting for the second design review roleplay had an empathetic focus on student emotion. During this second roleplay, other peer educators generated prompts more aligned with divergent thinking while focused on attending to student emotion. These two episode arcs illustrate the significant role that empathy can play in envisioning classroom environments, potentially providing an opportunity to understand student emotion better. We believe that this process of envisioning is valuable for enacting empathetic instruction in actual classroom practice.

Course Context

At this institution all first-year engineering students are required to enroll in the same introduction to engineering design course, or Introduction to Engineering Design: ENES100. In ENES100, first-year engineering students are required to conceptualize, fabricate, and test a prototype of an autonomous vehicle that can navigate a sandy terrain. ENES100 is staffed by instructor and an undergraduate peer educator. The undergraduate peer educator is a engineering student who has successfully completed ENES100. Our instructional team designed a pedagogy seminar to support the undergraduate peer educators who staff ENES100.[6] Undergraduate peer educators are synonymous to teaching assistants. In this paper we call undergraduate peer educators who staff ENES100, UTFs, or undergraduate teaching fellows. The pedagogy seminar was a 3-credit course based on the pedagogy courses part of the Learning Assistant model developed at University of Colorado-Boulder.[7] This study occurred during the pilot implementation of the pedagogy seminar.[6] As the seminar was specifically designed for the UTFs staffing ENES100, its coursework covered engineering pedagogical concepts such as design thinking, metacognition, teamwork and collaboration, equity, and convergent and divergent thinking. Some of the seminar's activities assigned to UTFs included reading and reflecting on engineering/math/science education literature, creating field notes on their teaching moments in ENES100, and analyzing video of students reasoning with design thinking and scientific concepts. The course instructors intended the pedagogy seminar to include in-class discussions and activities which were relevant to some of the teaching duties UTFs would encounter in ENES100.

Episode Context

The context of our design review role-play episodes began during the seminar's second class of the fall semester, with the theme of "Facilitating Classroom Discourse and Constructive Design

Reviews".[6] Drawing from the course instructors' collaborative weekly lesson plans, the learning goals of this seminar period were:

- Facilitating the connection between concepts in assigned reading to UTFs' design reviews experiences in ENES100.
- Acknowledging multiple UTF instructional goals as legitimate.
- Facilitating UTFs' classroom discourse to articulate multiple possible goals/purposes.
- Building more experiences for the UTFs to notice student ideas in classroom discussion.
- Help UTFs press each other for reasoning/elaboration.
- Noticing what the UTFs are getting out of class discussions.

The course instructors designed a lesson plan centered around concepts of classroom discourse from two readings: 1) Michaels & O'Connor, "Talk Science Primer,"[8] and 2) Daly & Yilmaz "Directing Convergent and Divergent Activity through Design Feedback."[5] Michaels & O'Connor discussed nine talk moves that instructors could use to draw out student reasoning and discourse.[8] Daly & Yilmaz discussed how instructors directed convergent and divergent thinking through design feedback in courses such as dance choreography or mechanical engineering design.[5] To scaffold the concept of talk moves and facilitating convergent and divergent thinking before conducting the design review activity, the UTFs discussed the readings and watched "Isaac's Wheels," a video case study part of a larger case study series of elementary students sense-making basic science concepts, such as Isaac explaining how wheels make a car move.[9] The design review role-play was designed as an opportunity for the UTFs to practice creating prompts to encourage their ENES100 students to think divergently about their design ideas. The design review activity consisted of Instructor 2 role-playing a pseudo-student who was presenting his team's payload system design to a design review panel consisting of UTFs. The role-play was supposed to simulate a real design review that takes place in ENES100, MS1: Milestone 1, in which student teams present their preliminary design ideas. (Note that in the transcript the pseudo-student/Instructor 2 refers to "MS1".)

Besides building a fully functional autonomous OSV, each ENES100 team is assigned a mission to solve with their OSV design. The students will test their OSVs in a sand pit containing geographical features such as a liquid pool and varying terrain. In the context of the role-play, pseudo-student/Instructor 2's "team" was assigned the chemical mission; the "team" had to measure and neutralize the pH of the liquid in the pool.

The fishbowl structure of the design review roleplay included an inner and outer circle of UTFs. The inner part of the fishbowl contained pseudo-student/Instructor 2 and five UTFs. The outer circle contained the rest of the class including Instructor 1, 3, 4, and Michaela, our focal student. The course instructors randomly sorted the UTFs into the inner circle or outer circle by counting off the students. The inner circle of UTFs roleplayed as UTFs serving on the design review panel. They jotted down their questions and feedback concerning pseudo-student/Instructor 2's presentation of his team's design ideas and communicated them. The outer circle of UTFs observed the roleplay. They were tasked with evaluating the prompts and talk moves enacted by the UTFs in the inner circle. After the roleplay was completed, the entire class reconvened, and the outer circle of UTFs shared their observations with the inner circle of UTFs.

Our paper consists of two arcs for two extended episodes. Design Review Day 1 (DR#1) took place during the seminar's second class period of the semester (9/6/16) and encompasses the arc of the first iteration of the design review role play activity, where Michaela's empathy allowed her to identity the tension between productive student learning and student emotion. This led her to the reimagining of a new setting for encouraging divergent and convergent thinking within the space of a design review. Michaela's reimagining provided the scaffolding and setting for the second iteration of the design review role play activity, Design Review Day 2 (DR#2). DR#2 occurred the following seminar period, or third seminar period of semester (9/13/2016).

Analytical Approach

Our initial research questions were centered around peer educators' resources for teaching and how they attend to their students' emotions. The research team members were interested in a range of research questions pertaining to the relationships between emotion, engineering design, engineering classroom culture, and teaching goals of undergraduate peer educators. The team is personally committed to identifying opportunities for engineering learning spaces to value student emotion. These interests and values guided what we observed in our data and what we chose to pursue for exploratory analysis.

We recruited UTFs enrolled in the pedagogy seminar to participate in this study. A total of 14 UTFs were enrolled in the pedagogy seminar. 6 UTFs were veteran engineering peer educators who staffed ENES100 before, and 8 UTFs were first-time peer educators. The research team included a graduate student who was a co-instructor for the seminar and an undergraduate engineering student who was not a UTF and not enrolled in the pedagogy seminar. We provided the options for students to consent to various levels of research concerning the seminar: 1) videotapes of the seminar periods, 2) videotapes of their teaching duties in ENES100, and 3) interviews. A total of 11 UTFs (6 males and 5 females) consented to videotapes of the seminar period. The UTFs who participated in this research were all undergraduate engineering students who were sophomore grade-level or higher and from a variety of engineering majors. At this institution, achieving the position of an ENES100 UTF is considered prestigious within the Clark School of Engineering. These UTFs are active students on-campus, participating in various extracurriculars such as Greek life, engineering research, outreach programs, and Honors College programs.

We collected classroom videotapes and field notes each seminar period, and conducted pre-interviews and pre-/post- surveys. To analyze classroom video, we draw from video analysis and interaction analysis, which have been useful for understanding science and engineering learning in classrooms.[10-12] Video data is useful for conducting micro-analyses of learning in classrooms because it allows researchers to view video data collaboratively and conduct multiple viewings.[10, 13] To make the camera less conspicuous, we placed the camera at the periphery of the classroom with no operator.[13] In this paper, we only present analysis from classroom video.

We refined our research questions based on what emerged in the data. In the early weeks of the seminar we examined UTFs' coursework such as reading reflections and written in-class

brainstorming activities (i.e. brainstorming teaching moves, teaching scenarios, and applications of pedagogical concepts) to identify what pedagogical concepts were relevant and meaningful to the UTFs. We noticed that UTFs often brought up emotional aspects of their experience as students in ENES100 and oriented to the emotions of their students. Additionally, UTFs often reflected on emotions during moments of reasoning what teaching moves to use. Some of these moments of responding to and reasoning with students were specifically driven by a UTF's empathy. Thus, we began a more systematic analysis around the research question of how empathy impacted UTFs' teaching moves when student emotion was at play. To identify these moments, we followed with preliminary analysis of our field notes, tagging moments of emotion and refining analyses to moments where UTFs responded to scenarios of student emotion with empathy.

We align our work with other video-based research where identifying emergent themes from classroom video occurred.[11] Therefore, we selected two episodes where a UTF's empathy was highly present and developed, resulting in two episodes with design review role play iterations. We selected these two episodes particularly because student emotion was the primary cause for a UTF's empathy to be present. We choose to analyze these two episodes in this paper as examples of a UTF's high empathy or, Michaela's high empathy. Due to her clear and unique utilization of her empathy, she is the focal student of this study. These episodes are not intended to be a general representation of UTFs' empathy, rather they are examples where empathy was salient and tied with responding to student emotion.

We transcribed the video data from the two episodes and developed analytical memos.[11] The process of developing these analytical memos involved analyzing transcribed segments of video data to develop preliminary claims of data.[11, 13] To refine our analyses, we iteratively moved between our analyses and comparison with the data.[11] We further analyzed our preliminary claims along with observed themes in literature.

We justify the process of identifying emergent themes due to their valuable contributions in discovering new causal mechanisms to be further studied.[11] Given that the pedagogy seminar itself was a pilot effort, it is particularly suited for noticing and attending to emergent themes. The course instructors had never taught this course to this population, nor co-designed a pedagogy course for engineering peer educators.[7] Thus, we did not have robust hypotheses about how emotions would emerge and support engineering UTFs' teaching, especially in the space of a pedagogy seminar. Our study, which looks at two classroom episodes in great detail, is aligned with other work that has studied a single student in great detail.[14-16] Using a single "revelatory" case is useful to develop theory about mechanisms of learning.[17] This kind of work is not intended to generalize across populations of students, but instead points to ideas that can be explored in other settings.[18-19]

Conceptual Framework

Empathy and Empathetic Pathways

Empathy is typically defined as a state of being. Batson reports 4 different psychological states of empathy, the cognitive/perceptual and the affective/emotional, which involve (1) imagining how one would think and feel in another's situation or "shoes," (2) imagining how another person thinks or feels given his/her situation, (3) feeling as another person feels, (4) feeling for another person who is in need.[20] We identify with Baston's forms of empathy which involve perspective-taking, such as (1) and (2), in our own understanding of empathy within this work.[20] However, Carl Rogers defines empathy as a dynamic process which involves facets such as being sensitive, moment to moment, to the changing of feelings felt in another person and communicating one's sensing of another person's world.[21] Thus, from an UTF's standpoint, we also found empathy to be process rather than state of being. We call this "process of empathy" an empathetic pathway, which consists of empathetic actions achieved by perspective-taking, resulting in the ultimate empathetic action of responding with an instructional move. Our empathetic pathway is similar to what Fila and Hess define as a designer's empathic design process,[22] however ours is from the role of a peer educator.

We suggest an analogy based on reaction kinetics in chemistry for further understanding of an empathetic pathway. There is reactant *A*, the UTF, who seeks to create the product *B*, or the ultimate empathetic action of responding with an instructional move

$$(1)\ A \rightarrow B$$

Like in most basic chemistry classes, we assume that *A* is directly converted to *B*. However, in reality, such as in the physiological conditions of the human body, the reaction could most likely look like this

$$(2)\ A \xrightarrow{c} C \xrightarrow{c} D \xrightarrow{c} E \xrightarrow{c} F \xrightarrow{c} B$$

The reaction of *A* to *B* is the empathetic pathway. Reaction intermediates *C, D, E*, and *F* are the different empathetic actions which the UTF can perform to achieve product *B*. Thus, an empathetic pathway is a chronological series of different empathetic actions which the UTF processed to achieve an empathetic instructional move. The catalyst of each step in the reaction, *c*, is perspective-taking which involves "sensing in someone's shoes" or trying to observe and understand that person's shoes as if one was that person. In order to achieve each "reaction intermediate" or empathetic action, the UTF must have the involvement of perspective-taking. Thus, once the UTF commits to perspective-taking, the UTF performs empathetic actions to follow an empathetic pathway.

We recognized 4 forms of empathetic actions that UTFs performed: (1) recognizing student emotion, (2) elaborating on the conditions of the situation or the emotional stakes, (3) analyzing how emotions might be causally related to the conditions of the situation, and (4) thinking about how to act or respond based on the understanding developed from the analysis completed in (3).

Table 1. Empathetic actions and what they involve.

Empathetic Action	Definition
(1) Recognizing student emotion	Noticing how a student is feeling, whether they communicated it or by changes in their behavior from neutral to emotional.
(2) Elaborating on the conditions of the situation or the emotional stakes	Conditions of a situation which can heighten student emotion, discussed in the following section.
(3) Analyzing how emotions might be causally related to the emotional stakes	Trying to form a causal relationship or expanding on why a person might be feeling a certain way.
(4) Thinking about how to act or respond based on the analysis completed in (3)	Creating an instructor move based on actions (1) through (3).
(5) Enacting the devised instructional move in (4)	—

In order to achieve product *B,* or to respond with an empathetic instructional move, it does not necessarily require a linear or completed process of actions (1) through (4). Rather, we could observe UTFs performing a variety of these actions in different chronological manners resulting in different empathetic pathways for different UTFs. For example, our focal student Michaela completed actions (1) through (4), but another UTF could complete only (3) through (4). Additionally, within the context of our episodes, we were not able to observe the conclusion of an empathetic pathway which is the UTF attempting their empathetic instructional moves in real-time classroom situations, such as during ENES100.

Emotional Stakes

As mentioned in the previous section, one of the empathetic actions is (2) elaborating on the conditions of the situation or the emotional stakes. Emotional stakes are the conditions of a situation which can heighten student emotion. Understanding and analyzing the emotional stakes is similar to what Kouprie & Visser identify as the immersion state of empathetic design,[23] where a designer is taking the user's point of reference to understand the user's world and the different aspects which influence it. In our context, the user's world is a situation in the classroom where emotions are at play. The different aspects which influence the classroom situation are the emotional stakes, which increase the likelihood for student emotion, both "negative" (i.e. frustration, anger, fear) or "positive" (i.e. proudness,[24] confidence, excitement). We discuss 3 different emotional stakes in this work: the vulnerability of a peer audience, high academic evaluation, and assessment of personal investment. For example, the emotional stake of a large and public peer audience heightens student emotion due to the increased pressure on a student if

they are presenting their design ideas to their peers. Having a peer audience can invite potential judgement on a student's engineering ability, thus heightening the emotion of pressure, which the student may already feel from having to perform a public presentation.

In our analyses, we identified emotional stakes through UTFs' talk. We found key language and phrasing where UTFs described aspects of a situation which threaten the student as having something to lose. Referring to our previous example of a peer audience, the student has the opinion of their peers' to lose if they present in front of their peers. The student may lose their "academic-social standing" if they do not present "well," and could be considered less desirable team member for future group projects. The emotional stakes within the context of our episodes are further elaborated in the following section.

Design Review Day 1

As previously stated, the first iteration of the design review involved Instructor 2 role playing a student presenting his team's preliminary design ideas of their OSV's payload system to complete their chemical mission objectives. In the following transcript we label Instructor 2 who was role-playing a student in ENES100 as "Pseudo-Student/Instructor 2."

> **Pseudo-Student/Instructor 2**: Hi folks! This is our MS1 presentation...I'm a representative of my team, "I Don't Give a Crap About Sand" that's our team name. *laughter* Our mission is the chemical mission.
> **Pseudo-Student/Instructor 2**: So we are thinking about like how we will measure pH and we're thinking that we might use a probe or a meter or a litmus paper or maybe even a color sensor of some kind. And then for indicators we were like experimenting with either cabbage juice or sort of like...chemical indicators, playing with the idea of either sodium carbonate or sodium bicarbonate as the neutralizer.
> **Pseudo-Student/Instructor 2**: And we came up with two different design ideas of solving the mission and the one was, sort of like, we'll put the pH probe inside a robot arm and sort of like um, attach um also a syringe, the syringe will be connected to the gear system, so that the syringe will go inside the water, and the gear system syringe will pull up the syringe collecting the water, and there's a squeezable container filled with sodium bicarbonate to neutralize the pH of the chemical pool.
> **Pseudo-Student/Instructor 2**: And then our second idea is sort of kind of the same contraption, but instead of like the pH probe we'll use a color sensor and a chemical indicator that will change the color when it is put inside the chemical pool.
> **Pseudo-Student/Instructor 2**: Um, and, and we will be collecting the sample with the test tube flap, and so we drew a small diagram of that. *pointing to presentation* So it's like this test tube and this is sort of the um, the sensor, the test tube has a little flap so that the chemical goes inside there and the flap shuts down so that it doesn't fall out kind of thing and reel the test tube in.
> **Pseudo-Student/Instructor 2**: And so those are our two design ideas, thank you.

Pseudo-student/Instructor 2 delivered his initial presentation with confidence. His speech contained a few fillers (4 "um" s) and a couple of unnatural pauses or breaks. Overall, he

appeared relatively comfortable and ready to discuss his team's design ideas with the panel of UTF design reviewers. As previously scaffolded by class activities (discussion on assigned literature and watching video) the goal of the design review roleplay was for the UTFs to practice generating talk moves that would promote divergent thinking about design ideas. Pseudo-student/Instructor 2 presented 2 different design ideas, creating an accessible opportunity for the UTFs to practice divergent thinking talk moves. However, the proceeding talk moves which the UTFs asked were more aligned with the design review norm of critique, convergent thinking, and neutral feedback rather than divergent thinking.[5] This resulted in pseudo-student/Instructor 2's emotional behavior shift from comfort to nervousness. We present three examples of critique, convergent thinking, and neutral feedback. The design norm of critique involves instructors assessing the entirety of a team's presentation, such as delivery, organization, and teamwork in addition to discussing their design. For example, Christian critiques the quality of pseudo-student/Instructor 2's slides.

> **Christian**: Okay, uh, so I wrote down on a previous slide, to this one, that was, uh, too much text on the slide for me, and because you were kinda reading straight off it I was a little bit lost, it might have been better to have a diagram there, and have you explain what you have written on the slide. Um, just a, just something for me. *motioning with his pen to the slide shown on the projector*

The most common form of feedback that pseudo-student/Instructor 2 received was convergent feedback. Daly and Yilmaz define convergent feedback as facilitating students to converge on their design ideas by asking for specific design details or reasoning behind a design decision.[5] For example, Thomas asks pseudo-student/Instructor 2 about the measuring mechanism of the test tube, and Christian asks about the mechanical mechanism of the flap.

> **Thomas**: So then how do you measure, the pH of what's in a test tube?
> **Christian**: Let's uh hear more about this flap design, what's going to stop, can you tell me more about how that's going to work?

An example of neutral feedback would be Anthony speaking about the feasibility of incorporating multiple color sensors. Daly and Yilmaz define neutral feedback as feedback which provided students with the opportunity to decide themselves whether to converge or diverge.[5] Anthony points out a technical caution of using color sensors, prompting pseudo-student/Instructor 2 to either converge on exploring the possibilities of using color sensors or diverge away from that option.

> **Anthony**: Another thing I want to comment on that specific mechanism would be um, a lot of the color sensors that you might need, purchase ... just could be due to the price, might not be precise enough to uh, accurately read, because uh, a lot of the chemicals that change colors, um, number one they're not really too precise of a measurement anyways, and then you have the added inaccuracies with the sensors as well, so I would look into the feasibility of that.

These examples illustrate how the outcome of roleplay did not exactly meet the course instructors' expectations of facilitating divergent thinking around design ideas. After the roleplay was completed, the course instructors invited the outer circle of the fishbowl consisting of the remaining UTFs who did not participate in the roleplay, to share their observations about the quality of the talk moves generated by the UTFs in the roleplay. Michaela, a UTF in the outer circle, made the observation that the design review setting is not preferable for encouraging students to think divergently about their design ideas due to the student's emotional experience.

> **Michaela**: It's kind of unrelated to what we're talking about, like an overall like comment though about presentations in ENES100, uh I feel like, kind of no matter how you go about it students don't like to admit faults in their design, especially in front of people when they're, for like uh a 100 pt grade assignment. So like uh, even like pseudo-student/Instructor 2 was kinda like defensive about his ideas when someone came up to question, you know just like put an hour worth of work into like a presentation and these people are like poking flaws, and it's easy to get defensive, like I know I like got very defensive in ENES100 when they try to roast me but uh. *class laughs* But yeah, so I don't how to better go about that, but just...that kind of idea.

Thus, Michaela identified a tension in the setting of a design review between the productive student learning and a student's emotion. Productive student learning entails a student successfully engaging with the convergent and divergent prompts generated by instructors and a student's emotional experience is defined as how the student emotionally feels during that engagement. Michaela's empathetic pathway consists of her explicit notice of the emotional discomfort of the pseudo-student/Instructor 2 in the roleplay. She outlines the emotional stakes associated with the design review context in order to define the tension between attending to students' learning and their emotion. This results in her final empathetic action where she reimagines a setting with lower emotional stakes, and therefore, more conducive for productive student learning. Michaela is the only student to use this empathetic pathway during this specific episode. We will elaborate on the steps of Michaela's empathetic pathway in the following sections.

(1) Recognizing Student Emotion

Michaela's first step in her empathetic pathway was recognizing a student's emotion or pseudo-student/Instructor 2's emotions during the design review roleplay. Michaela uses the term "roast" to describe the characteristics of the UTFs questioning.

> **Michaela**: So like uh, even like pseudo-student/Instructor 2 was kinda like defensive about his ideas when someone came up to question...and it's easy to get defensive, like I know I like got very defensive in ENES100 when they try to roast me but uh.

She believes that the "roast" quality of engaging with the UTFs promoted pseudo-student/Instructor 2's emotional discomfort. From his initial presentation, pseudo-student/Instructor 2's emotional behavior devolved from feeling confident and neutral to feeling defensive when engaging with the UTFs' questioning. He was less comfortable and

excited about communicating his design ideas, evident by an increase in the number of speech fillers such as um's, repeated phrases, and longer unnatural pauses. The following examples portray pseudo-student/Instructor 2's emotional discomfort recognized by Michaela. The following examples involve pseudo-student/Instructor 2 engaging with Christian's and Mason's convergent feedback. This first example is an exchange between Christian and pseudo-student/Instructor 2 about the exact mechanism of the flap design. Christian's question more focused on the specifics of the design's movement, rather a divergent focus such as questioning if Instructor had any alternatives to the flap design.

> **Christian**: Let's uh hear more about this flap design, what's going to stop, can you tell me more about how that's going to work?
> **Pseudo-Student/Instructor 2**: So we had some idea that, we'll have like, a little flap like a wall kind of thing *Pseudo-student/Instructor 2 motions with his hands* and then as the test tube sort of like is thrown into the water, the water pushes, pushes the chemical pool, the water, the chemical pool pushes the, um, the um, the flap *motions with hands* a little bit and the chemical will go inside. And then like if we lift it up, we were thinking sorta of like the flap would fall, and sort of like hold the mount of the test, test tube in place.

Although pseudo-student/Instructor 2 had already summarized the design of the flap, his response to Christian's more detailed question about the flap mechanics was not as comfortable as before. His speech had multiple repeated phrases ("water pushes, pushes the chemical pool, the water, the chemical pool pushes the, um, the um, the flap) representing his nervousness. In addition, pseudo-student/Instructor 2 spoke more words of unsureness (2 "sort of like" s), indicating a decrease in his confidence when responding to Christian's prompt. This second example is an exchange between Mason and pseudo-student/Instructor 2, where Mason questions the construction of a large sensing package. Mason's question focused on a specific design recommendation instead of drawing on a more divergent focus such as questioning pseudo-student/Instructor 2's about the perceived the positives and negatives of the number of autonomous sensors.

> **Mason**: You also uh, you're using a lot of different sensors that uh kinda on their own like, just string, or uh on their own arm or something? Is there anyway you could kinda uh, eliminate the number of like autonomous sensors you have, maybe combine them all into one big, you know sensing package or something?
> **Pseudo-student/Instructor 2**: Um... *several seconds of pausing*
> **Pseudo-student/Instructor 2**: Ah, could you ask that again?

Pseudo-student/Instructor 2 hearing Mason's question, spends several seconds pausing in confusion and nervousness with "um." Pseudo-student/Instructor 2 then asks Mason to repeat the question again, and responds to each of his feedback questions with more speech fillers (3 "umhm" s or "um" s), and spends several seconds pausing before tentatively answering Mason's question about the sensors in the design schematic ("Um that's a test tube).

> **Mason**: So you have a lot of sensors, can you uh, scroll down one slide?

> **Mason**: That's the one yeah, so uh in model 1 and you have, it looks like two different probes or sensors so you got the syringe and, the, I assume the box of the sensor right?
> **Pseudo-student/Instructor 2**: Umhm.
> **Mason**: And then in model 2, you have the same two things and then what's the third thing?
> **Pseudo-student/Instructor 2**: Umm. *glances at his presentation* *several seconds of pausing*
> **Pseudo-student/Instructor 2**: Um that's a test tube?

Thus, pseudo-student/Instructor 2's emotional behavior shifted from confident and neutral to discomfort and defensiveness. Michaela is able to perspective-take his pseudo-student position, even identifying her own personal experience of feeling defensive during a design review ("like I know I like got very defensive in ENES100 when they try to roast me but uh"). Additionally, pseudo-student/Instructor 2, on DR#2 where the second iteration of the design review roleplay occurred, shared that he was actually feeling the emotion of defensiveness during his roleplay of a pseudo-student while being questioned by the UTFs.

> **Pseudo-student/Instructor 2**: And in a funny interesting way, I was really trying to get into sort of how a student would feel in that moment. And I can sort of almost say when people were saying that, I was feeling it, and that helped me sort of like maybe emote better with my ENES100 kids. So I want to take that into the classroom this semester.

(2)-(3) Defining a Causal Relationship with Emotional Stakes

After Michaela recognizes pseudo-student/Instructor 2's emotional discomfort, Michaela proceeds to define the emotional stakes of the design review setting as the second step in her empathetic pathway. She defines the emotional stakes of the situation, or conditions of a situation which increase the likelihood for heightened student emotion, as evident in pseudo-student/Instructor 2's heightened emotional behavior when subject to the UTFs' questioning. Recognizing these stakes enable Michaela to elaborate on the tension between productive student learning and student emotion. Due to the presence of emotional discomfort, she determines that attempting to achieve productive learning goal of divergent thinking within the setting of the design review could result in an increase of negative student emotion. Michaela observes that emotional stakes of the vulnerability of a peer audience, academic evaluation, and assessment of work ethic contribute to heightened student emotion.

Vulnerability of a Peer Audience

Within the context of ENES100, design reviews are typically held in the presence of peers. Michaela notes that in general, ("kind of no matter how you go about it") when students are subject to questioning about their design, there already may be resistance ("students don't like to admit faults in their design").

> **Michaela**: It's kind of unrelated to what we're talking about, like an overall like comment though about presentations in ENES100, uh I feel like, kind of no matter how you go about it students don't like to admit faults in their design, **especially in front of people**…

She further notes that a student's resistance, due to feelings of defensiveness, is heightened in the presence of the emotional stake of a peer audience ("especially in front of people"). Thus, there is a tension between a student productively responding to instructor questioning and their emotions of defensiveness and fear of peer judgement. Michaela implies that a student productively engaging with an instructor's questioning could result in a student admitting faults about their design in front of their peers. Admitting faults in front of their peers invites peer judgement concerning things such as the student's engineering design ability. The student's resistance to productively respond increases, as the initial emotion of defensiveness is heightened by the fear of peer judgement.

High Academic Evaluation

50% of a student's grade in ENES100 is derived from team-based performance demonstrations which are labeled milestones. During the initial conceptualization phase, the milestones consist of reports and presentations in which students are evaluated on their preliminary design ideas, project management, and communication skills. The design review panel for a specific section of ENES100 usually consists of the instructor and UTF for that section as well as two external evaluators (typically other faculty from the Clark School of Engineering). Thus, the design review settings can have high stakes for the students, both in terms of being publicly evaluated and that evaluation counting towards their course grade. This is what Michaela also tunes into. Continuing her observations of the student's initial resistance to productively respond due to feelings of defensiveness, Michaela identifies the emotional stake of high academic evaluation as increasing the likelihood to heighten student emotions of defensiveness and fear; she elaborates another tension between a student productively responding to instructor questioning and their emotions of defensiveness and fear of academic failure.

> **Michaela**: It's kind of unrelated to what we're talking about, like an overall like comment though about presentations in ENES100, uh I feel like, kind of no matter how you go about it students don't like to admit faults in their design, especially in front of people when they're, for like uh a **100 point grade assignment**.

Michaela implies that a student productively engaging with an instructor's questioning could result in a student admitting faults about their design while being academically evaluated on the merit of their design. By admitting faults about their design, students perceive that they are reinforcing instructors' academic evaluations of their design. Thus, students perceive that they are contributing to a lower milestone grade. Therefore, their resistance to productively respond increases, as the initial emotion of defensiveness is heightened by the fear of academic failure.

Assessment of Personal Investment

The last emotional stake Michaela identifies is the emotional stake of assessment of personal investment. She notes that a student's resistance, due to feelings of defensiveness when questioned by their design ideas, is heightened by the fear of instructor and peer assessment of how much they invested in their work.

> **Michaela**: So like uh, even like pseudo-student/Instructor 2 was kinda like defensive about his ideas when someone came up to question, you know **just like put an hour worth of work into a presentation**…

The student who put "an hour work of worth" or more into creating the presentation and, most likely, participating in the team's design process is more emotionally invested toward instructor questioning due to the implied assessment of the quality of the time spent working on the presentation. Thus, a student could feel an increase in fear or defensiveness due to the potential emotions associated with their input and effort on the design presentation.

These emotional stakes are specific to what Michaela observes in the design review setting. Michaela's empathetic pathway is additionally influenced by her own instructional goals of generating positive student emotion, which she believes enables students to be more receptive to critique and divergent questioning. Thus, through her analysis of these emotional stakes, she decides to reimagine a new setting where the emotional stakes are lowered and utilizes the tension between productive student learning and positive student emotion.

(4) Reimagining a new setting

Due to Michaela's observations, she suggests a new alternative setting where she believes that the emotional stakes are lowered and decrease the likelihood for heightened student emotion, resulting in a setting more preferable for encouraging divergent thinking. Her analysis of how emotional stakes can influence student emotion enables her to reason how to act and respond as an instructor, which is the last step in her empathetic pathway.

> **Instructor 1**: So you're noting a like potential shortcoming of trying to encourage this kind of divergent thinking-
> **Michaela**: Yeah.
> **Instructor 1:** The space and the setting, might not be set up for that.
> **Michaela**: It would almost be better in like small groups, if you met, if the TF met team by team on like an individual basis, rather than in front of all your classmates and in front of other professors and stuff like that, cause I feel like the pressure, there's a lot of pressure associated with it, that like people might react poorly to uh questions.
> **Instructor 1**: Hm, so an alternative would be to do it, to talk to them more privately about it.
> **Michaela**: Yeah, like before a presentation or something.

Michaela's new suggested setting addresses the emotional stakes she outlined in her primary observations. She suggests to try divergent thinking in "small groups," where the UTF was just meeting "team by team on an individual basis," eliminating the emotional stake of vulnerability

of a peer audience and high academic evaluation ("rather than in front of all your classmates and in front of other professors"). She reiterates the emotions commonly associated with the design review setting ("there's a lot of pressure associated with it"), and that students "react[ing] poorly to uh questions" would not benefit productive student learning. Michaela also address the emotional stake of assessment of personal investment, by suggesting that this meeting between the UTF and team about design ideas takes place before a presentation. This suggestion would create a setting where there was already an awareness and understanding of the effort and time each team member has invested per the more one-on-one setting. She implies that a presentation format involves both the emotional stakes of assessment of work ethic and academic evaluation.

Michaela's reimagined setting is adopted by the course instructors for DR#2 where a second iteration of the design review roleplay occurs. Thus, Michaela's empathetic pathway which results in this new reimagined setting creates a new opportunity for her peers to further practice encouraging divergent thinking. Additionally, her extensive observations about the emotional stakes of the design review setting provide fodder for the course instructors to discuss student emotion and how respond to the student emotion they witnessed in pseudo-student/Instructor 2's behavior.

Design Review Day 2

Instructor 2's Scaffolding of Michaela's Reimagined Setting

Michaela's suggestion for a new setting to practice engaging students with divergent thinking was elaborated in DR#2. The course instructors, after reflecting on DR#1, determined that not only was Michaela's suggestion significant to reiterate, with its focus on productive student learning and student emotion, but also an opportunity to improve the application of concepts of divergent thinking. The course instructors hoped that this second iteration of the design review roleplay would generate more prompts aligned with divergent thinking. Instructor 2, who played the pseudo-student in the first iteration of the design review roleplay, shared the course instructors' assessment of the quality of the talk moves generated and reflected about the emotions he felt during the roleplay.

> **Instructor 2**: And within that, when we sort of like did the MS1 role play activity last week, some of our judgement of the prompts that were asked seemed to be, um sort of like our observations of how we would categorize it, didn't quite fit within the notion of divergent thinking, as sort of like, uh, uh, a kind of thinking where a person is expanding the space of ideas that they're playing in. Right.
> **Instructor 2**: So some of the moves we saw were clarification moves, like you know 'tell me a little bit more about how this would work,' which is great, like in Talk Moves[8] sense we would say is like 'say more,' the more neutral one, um and, it makes me wonder, like what are the different pathways in which neutral could keep open the possibility of divergent and convergent. How will a neutral opening flow into divergent thinking for example, like by asking clarification questions, after that actually once again you face this choice, is that once the student has clarified you could narrow them down or expand their thinking, and so how would that play out? And that was one thing.

Instructor 2: And then the second thing was, a lot of the other moves were like, 'oh have you considered this,' or like 'here's a flaw in your idea' kind of a thing, and maybe 'how would you fix this,' kind of a thing.
Instructor 2: So like redirection kind of thing, so a student is sort of going in this direction and saying 'uh there's a pitfall there,' look in that way, and um, somebody oh Diane, in the, in the, sort of like discussion around that reading shared the notion that redirection to a student can actually feel, they can experience it as 'my idea is wrong and you're pointing out why my idea is wrong.' And in a funny interesting way, I was really trying to get into sort of how a student would feel in that moment. And I can sort of almost say when people were saying that, I was feeling it, and that helped me sort of like maybe emote better with my ENES100 kids. So I want to take that into the classroom this semester. (Authors' note: Instructor 2 misattributed Michaela's suggestion as Diane's suggestion in this last utterance.)

Instructor 2 chose to relay the course instructors' categorization of the talk moves seen in the first design review, noting that they were more aligned with "redirection," and neutral feedback.[5] An important preface to the second iteration of the design roleplay was his discussion of the tension Michaela identified between productive student learning and student emotion. Instructor 2 chooses to specify the move of "redirection" or directly telling students to "look in that way," such as Mason's suggestion with combining all the sensing packages due to the number of potential autonomous arms, as a potentially negative emotional experience ("my idea is wrong and you're pointing out why my idea is wrong"). Instructor 2 keys into the defensiveness which Michaela describes in her observations of the first design review and affirms her empathetic actions by sharing that he was "feeling it," and "that helped me sort of like maybe emote better with my ENES100 kids." Thus, Michaela's new setting provided the opportunity for the course instructors to not only practice refining the concepts of convergent and divergent talk moves, but also created a discussion centered around how student emotion affects learning. Instructor 2 further introduces the new change of scene, based on Michaela's suggestions.

Instructor 2: So here's a change of scene, don't think of this as the MS1 presentation. Think of it as pre-MSI, so you know, basically a team writes to you sort of like 'hey we are sort of like batting around some ideas for what exactly how we're gonna solve for the mission part and I wanted to get some feedback from you, could I come see you in office hours or some time, you know, um outside of class, and talk to you a little bit about what my team is thinking about in respect to ideas. That's the setting, okay.
Instructor 2: So you're not sitting in the classroom, you're outside the classroom, you're by yourself, small portion of a team comes to you and they're sharing their mission ideas with you and they're asking you for feedback. And the conversation is focused on the mission not navigation, locomotion, those are also important parts of the project, but here the team members are simply sharing with you the mission part.
Instructor 2: And pseudo-student of course is one of the students on the team who sort of like, ah presents these ideas to you. Um, and because I don't want you guys to engage with sort of like brand new um, sort of like, project kind of ideas, we're just going to reuse the presentation, um the role play stuff that happened last time okay, but the setting is different.

> **Instructor 2**: The setting is this is happening outside of class time, you're just meeting one-on-one with a small number of members of a team giving feedback. And so I want you to listen to the presentation and then I want you to spend a couple minutes on your own, really pushing yourself to think about if my objective was to engage the students in divergent thinking, what is it I would ask them. Solely, you could do a lot of different things, so you could critique the presentation style and that is perfectly valuable, but that's not what I want you to do in this particular 15 minutes we have left for us. I want you guys to listen to the presentation and then spend a couple minutes really thinking hard about what will I ask if my objective was to engage the students, the team in divergent thinking.

Instructor 2 sets the new scene based on Michaela's suggestion: the setting takes place in office hours or outside of class, the teams are meeting one-on-one with the UTFs, and the same objective is to engage the students in divergent thinking. Instructor 2 also spends time directly addressing the talk move of critique and states that critique is not part of the learning goals of this activity, to emphasize the learning goal of divergent thinking. Lastly, we note the truly responsive actions of the course instructors. By choosing to incorporate a student instructional design suggestion, the course instructors communicate how they value Michaela's ideas.

Discussion

Empathy as a Resource for Engineering Educators

Empathy is often viewed as a valuable tool from the perspective of the engineering designer in order to create a more user-centered product.[22] We feel that engineering instruction itself can be viewed as an opportunity for design thinking, with instructors developing curriculum as designers and students as the community experiencing the design (curriculum). We believe that empathy, and thus empathetic pathways can be a valuable tool for engineering educators to develop awareness of students' emotion in the classroom, resulting in greater attentiveness to students' learning. However, the presented framework of empathetic pathways is not intended to be generalizable model, rather, we suggest that it may be useful for understanding peer educators' learning mechanisms for responding to student emotion. Thus, if instructors choose to attend to student emotion, students may also be encouraged to engage with their own emotions and attend to their peers' as well. Therefore, we discuss several applications of utilizing empathy and the concepts of empathetic pathways as potentially fruitful instructional resources.

Empathy as Relevant for Responsive Teaching

The last step of Michaela's empathetic pathway or empathetic action (4) "thinking about how to act or respond," where she chose to reimagine a new setting, benefitted the course instructors with a new setting for another classroom activity to practice encouraging divergent thinking. Thus, from an instructor standpoint, not only were class learning goals achieved, but due to Michaela's empathy, the UTFs became aware of the tensions between productive student learning and student emotion. They were provided with the opportunity to refine their ideas with the attention on student emotion and progress toward becoming more responsive teachers,

specifically to pseudo-student/Instructor 2. In our seminar assignment of field notes we saw evidence of other UTFs keying into the emotional state of pseudo-student/Instructor 2 after undertaking Michaela's reimagined setting. One student noted her design of a divergent talk move used during her staffing in ENES100. Her talk move was centered on avoiding the student "feeling [like they were] under attack" and communicating effective divergent feedback. Therefore, we could imagine that the implementation of Michaela's new setting in ENES100 could potentially encourage first-year teams to consider divergent design ideas before they were actually evaluated during a design review. This could result in better presentation preparation for students and potentially filling a pedagogical need previously not addressed.

Empathy as a Tool for Future Conceptual and Epistemic Learning

From an instructor standpoint, utilizing an empathetic pathway as an instructional resource can facilitate understanding of students' emotions toward conceptual learning and also create better opportunities for student learning. Evidence has shown that in science education research, students' affect is critical to their disciplinary engagement and can promote shifts in group framing.[3] Science education research also notes that students may empathize with their object of study, such as physics students perspective-taking with an electron moving between orbitals, or in the chemistry classroom, such as personifying a molecule with a romantic crush who needs a wingman, or catalyst, to "make a move."[25-26] We suggest that there may be similar applications toward improving student affect toward engineering disciplinary engagement and increased student learning. For example, in fundamental courses such as mechanics or fluids, instructors could create conceptual models of different systems (forces, flow in a pipe) to empathize with. Overall, student emotion is a key factor in supporting intellectual growth and instructors could utilize empathy and empathetic pathways to better student conceptual learning.[27]

Empathy as Relevant for Learning to be Effective in Teams

From a peer standpoint, following an empathetic pathway can aid peers' mobilization to resolve emotional conflicts found in teamwork. Batson notes that two empathetic states which involve perspective-taking, (1) imagine self-perspective and (2) imagine other-perspective, can promote the intergroup effects of reduced stereotyping and and increased readiness to help the "out group."[20] Researchers at Google in their quest to find the "perfect team" discovered that their best teams all had high scores of "social sensitivity," or the ability to determine how other team members felt based on nonverbal cues like tone of voice.[28] Michaela's empathetic pathway was sparked by noticing a potentially "out group" student or the emotional discomfort of pseudo-student/Instructor 2. Thus, as a peer, the ability to perspective-take could be highly useful for creating empathetic actions to potentially support one's team members. Michaela, who drew on her own personal experiences of "roasting" in ENES100 may have previously interceded on behalf of a peer team member to mitigate emotional conflicts. We suggest that facilitating students' ability to empathize may result in better intergroup dynamics and student attentiveness to their peers' emotions.

Conclusions and Further Work

This work has highlighted how the utilization of empathy and concepts of empathetic pathways can be an important instructional skill for generating instructional moves and awareness of student emotion in the classroom. While we were not able to see these instructional moves enacted in the engineering design classroom and determine their direct impact on student learning, we surmise that the two design review arcs were highly beneficial to "breaking the ice" for facilitating the seminar's following discussions around student emotion and physically lowering the emotional stakes for the UTFs in the classroom to share their more personal instructional experiences. An important next step would be to see where UTFs' practice was influenced by the empathetic practices in the seminar. Such a study would also look for what students learn when UTFs enact empathetic practices. This preliminary study of UTFs roleplaying teaching moves can focus our future attention on what we might look for in their actual teaching.

We note that these are only two episodes where instances of empathy were most developed and specifically connected to the pedagogical concepts of convergent and divergent thinking. We hope to further analyze our seminar data from the rest of the semester to identify any other empathetic pathways connected to learning various pedagogical concepts such as metacognition, reflective decision-making, equity in the classroom, and designing instructional experiences for "proudness." Lastly, we hope to further determine any other students in the seminar who may have used an empathetic pathway as a learning mechanism.

Acknowledgements

We would like to acknowledge and thank our students who voluntarily participated in our research study and the members of our Engineering Education Research Group (EERG) who supported us in developing our analysis. We would also like to acknowledge and thank the SEEDS Research Fellowship Program supported by the National Science Foundation (DUE 0969232), under the Women in Engineering Program at the Clark School of Engineering for making this work possible. This work is also supported by funding from the A. James Clark School of Engineering and Academy for Innovation and Entrepreneurship (NSF Mid-Atlantic I-Corps Node) at University of Maryland.

References

[1] Tonso, K. L. (2006). Teams that work: Campus culture, engineer identity, and social interactions. *Journal of Engineering Education*, 95(1), 25.

[2] Bales, R.F. Interaction Process Analysis: A Method for Studying Small Groups, Chicago, Ill.: University of Chicago Press, 1950.

[3] Jaber, Z. L., & Hammer, D. (2016). Learning to Feel like a Scientist. *Science Education*, 100, 189-220.

[4] Fong, B. (2016). Design Reviews: Going Beyond the Surface. Google Design. Retrieved from https://design.google.com/articles/going-beyond-the-surface/

[5] Daly, S. R., & Yilmaz, S. (2015). Directing Convergent and Divergent Activity through Design Feedback. *Analyzing Design Review Conversation*, 21, 413-429.

[6] Quan, G. M., Gupta, A., Turpen, C.A., & Tanu, E. D. (2017, June), "Designing a Seminar for Peer Educators in Undergraduate Engineering Design Courses." Paper presented at 2017 ASEE Annual Conference and Exposition, Columbus, Ohio.

[7] Otero, V., Pollock, S., & Finkelstein, N. (2010). A physics department's role in preparing physics teachers: The Colorado learning assistant model. *American Journal of Physics*, *78*(11), 1218-1224.

[8] Michaels, S. & O'Connor, C. (2012). Talk Science Primer. *TERC*, pp 1-20.

[9] Tufts University Department of Education (2016). Isaac's Theory of Rolling. Case Studies of Students Doing Science. Retrieved from http://studentsdoingscience.tufts.edu/case-studies/isaacs-wheels/viewthecase/

[10] Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., ... & Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The Journal of the Learning Sciences*, 19(1), 3-53.

[11] Engle, R. A., Conant, F. R., & Greeno, J. G. (2007). Progressive refinement of hypotheses in video-supported research. Video research in the learning sciences, 239-254.

[12] Erickson, F. (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. Handbook of complementary methods in education research, 3, 177-192.

[13] Jordan, B., & Henderson, A. (1994). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, 4(1), 39-103.

[14] Danielak, B. A., Gupta, A., & Elby, A. (2014). Marginalized Identities of Sense‐Makers: Reframing Engineering Student Retention. *Journal of Engineering Education*, 103(1), 8-44.

[15] Foor, C. E., Walden, S. E., & Trytten, D. A. (2007). " I Wish that I Belonged More in this Whole Engineering Group:" Achieving Individual Diversity. *Journal of Engineering Education*, 96(2), 103.

[16] Sawtelle, V., & Turpen, C. (2016). Leveraging a relationship with biology to expand a relationship with physics. *Physical Review Physics Education Research*, 12(1), 010136.

[17] Yin, R. K. (2013). Case study research: Design and methods. Sage publications.

[18] Eisenhart, M. (2009). Generalization from qualitative inquiry. Generalizing from educational research: Beyond qualitative and quantitative polarization, 51-66.

[19] Robertson, A. D., Scherr, R. E., & McKagan, S. B. (2013). Paradigms in Physics Education Research. arXiv preprint arXiv:1307.4135.

[20] Batson, C. D., & Ahmad, Y. N. (2009). Using Empathy to Improve Intergroup Attitudes and Relations. *Social Issues and Policy Reviews*, 3(1), 141-177.

[21] Rogers, R. C. (1975). Empathic: An Unappreciated Way of Being. Published by Centre for Studies of the Person.

[22] Fila, D. N., Hess, L. J. (2014). Exploring the Role of Empathy in a Service-Learning Design Project. DTRS 10: Design Thinking Research Symposium 2014 published Purdue University.

[23] Kouprie, M., & Visser, S. F. (2009) A framework for empathy in design: stepping into and out of the user's life. *Journal of Engineering Design*, 20:5, 437-448.

[24] 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.

[25] In, Ochs, E. Schegloff, E. & Thompson, S. (eds.) (1996). "When I come down I'm in the domain state: grammar and graphic representation in the interpretive activity of physicists." *Interaction and Grammar*. Cambridge: Cambridge University Press.

[26] Radhakrishnan, M. (2017). Perspectives: The chemistry between us. Chemical & Engineering News. Retrieved from http://cen.acs.org/articles/95/i1/Perspectives-chemistry-between-us.html

[27] Felder, M. R. (2004). The Intellectual Development of Science and Engineering Students, Part 1: Models and Challenges. *Journal of Engineering Education*.

[28] Duhigg, C. (2016). What Google Learned from Its Quest to Build the Perfect Team. *New York Times Magazine*. Retrieved from https://www.nytimes.com/2016/02/28/magazine/what-google-learned-from-its-quest-to-build-the-perfect-team.html?_r=0