Characterizing Framing Agency in Design Team Discourse

Dr. Vanessa Svihla, University of New Mexico

Dr. Vanessa Svihla is a learning scientist and associate professor at the University of New Mexico in the Organization, Information & Learning Sciences program and in the Chemical & Biological Engineering Department. She served as Co-PI on an NSF RET Grant and a USDA NIFA grant, and is currently co-PI on three NSF-funded projects in engineering and computer science education, including a Revolutionizing Engineering Departments project. She was selected as a National Academy of Education / Spencer Post-doctoral Fellow and a 2018 NSF CAREER awardee in engineering education research. Dr. Svihla studies learning in authentic, real world conditions; this includes a two-strand research program focused on (1) authentic assessment, often aided by interactive technology, and (2) design learning, in which she studies engineers designing devices, scientists designing investigations, teachers designing learning experiences and students designing to learn.

Dr. Jamie Gomez, University of New Mexico

Jamie Gomez, Ph.D., is a Senior Lecturer III in the department of Chemical & Biological Engineering (CBE) at the University of New Mexico. She is a co- principal investigator for the following National Science Foundation (NSF) funded projects: Professional Formation of Engineers: Research Initiation in Engineering Formation (PFE: RIEF) - Using Digital Badging and Design Challenge Modules to Develop Professional Identity; Professional Formation of Engineers: REvolutionizing engineering and computer science Departments (IUSE PFE\RED) - Formation of Accomplished Chemical Engineers for Transforming Society. She is a member of the CBE department's ABET and Undergraduate Curriculum Committee, as well as faculty advisor for several student societies. She is the instructor of several courses in the CBE curriculum including the Material and Energy Balances, junior laboratories and Capstone Design courses. She is associated with several professional organizations including the American Institute of Chemical Engineers (AIChE) and American Society of Chemical Engineering Education (ASEE) where she adopts and contributes to innovative pedagogical methods aimed at improving student learning and retention.

Martin A. Watkins, University of New Mexico

Martin A. Watkins is a PhD student in Educational Linguistics at the University of New Mexico. He earned his BA degrees in Deaf Studies (ASL/English Interpretation) and Linguistics from California State University, Northridge, and his MA degree in Linguistics from Gallaudet University. His research employs critical ethnography and discourse analysis to investigate language ideologies and language planning & policy in Deaf Education, particularly focusing on how signed language interpreters influence Deaf students' learning experiences.

Tryphenia B. Peele-Eady Ph.D., University of New Mexico

Tryphenia B. Peele-Eady is Associate Professor in Department of Language, Literacy, and Sociocultural Studies, in the College of Education at the University of New Mexico. She specializes in African American Education and Ethnographic Research. Her email address is tbpeele@unm.edu.

Characterizing Framing Agency in Design Team Discourse

Abstract

Purpose. To make course-based, undergraduate design projects more manageable, instructors often reduce or remove the open-ended quality, which in turn limits opportunities for students to learn to frame design problems. Here we introduce and characterize the construct, *framing agency*, which involves taking up opportunities to make consequential decisions about design problems and how to proceed in learning and developing solutions.

Methodology. We employed a multi-case study design, selecting cases of student design teams across different sites and levels, all in undergraduate engineering courses. Teams were audio/video recorded during their design process. We adapted a functional linguistics tool [1] to identify markers of agency in students' design discourse, comparing and contrasting the cases to illuminate the nuances of framing agency. We also identified learning versus task-completion orientations.

Results. All students exhibited agency in some form, but not all exhibited framing agency. Analysis suggests that framing agency, when exhibited, is commonly shared across collaborating designers and tentative in nature early in the design process. Students who exhibited framing agency tended to adopt a learning rather than task-completion orientation. Students who exhibited agency, but not framing agency, made decisions that foregrounded accuracy and efficiency at the expense of exploring tentative ideas, and tended to treat the problem as having a single right answer.

Conclusions. We argue that how students negotiate *design problem framing* depends on whether or not they consider the design problem relevant and authentic, the belief that each member brings different and potentially useful information to the task, and the opportunity to iterate design ideas over time. Framing agency provides a lens for understanding the kinds of design learning experiences students need to direct their own learning and negotiate that learning with peers in design projects.

Introduction

Managing design projects in undergraduate coursework is challenging, in large part because design problems are ill-structured, meaning there are many possible solutions and framings of any design problem [2]. As engineering programs have increasingly incorporated design challenges into first year and core courses, faculty must make difficult decisions about feasibly managing design challenges, often with little or no support. Such faculty may or may not have experience as designers themselves. In such cases, it is not surprising that instructors elect to reduce or remove the ill-structuredness of design altogether. However, this limits students' opportunities to learn to frame design problems.

Here we introduce the construct *framing agency*, which involves taking up opportunities to make consequential decisions about design problems and how to proceed in learning

and developing solutions. We argue that framing agency is a useful lens for instructors as they develop realistic yet feasible course-based design experiences.

Literature Review

Design problems are ill-structured, meaning that not only do they have multiple possible solutions, but there are also several paths to solution [3]. Compared to well-structured problems, with their single correct answers and canonical solution paths, design problems are framed—and reframed—by the designer.

This problem framing work exists across a range of fields [4]. Because of this, problem framing is known by a number of aliases, including problem posing, scoping, formulation, representation, defining, finding, and construction. While the specific activities can vary [5, 6], the focus is on understanding and bounding the problem to be solved. In this process, designers make many decisions that are consequential for both the problem to be solved and the problem solver [7]. Decisions about the scope of the design problem for instance, influence what the designers will need to learn and do to reach a solution. Thus, this process involves agency—defined here as autonomy to make decisions [8]. While we know designers have agency over framing design problems, we know much less about how to support students to develop this sort of agency. The shift from solving routine well-structured problems to designing is difficult for students to manage [9]; as a result, they may repeatedly try to solve a design problem with a single correct answer in mind. In doing so, they may adopt performance rather than learning orientation [10-12]. Whereas a performance orientation emphasizes accurate—typically as judged by an external measure—and often efficient completion of a task, a learning orientation emphasizes growth and often exploratory engagement.

These two orientations affect the *opportunity structure* [13] or, whether opportunities to make decisions exist, whether people actually make decisions, and whether they are satisfied with the outcomes of their decisions [8]. Authentic design problems present a broad opportunity structure, as designers must make a host of tentative decisions and assess the quality of those decisions. However, in school settings, students typically have limited opportunities to enact this kind of agency. Even in student-centered classrooms, students commonly only make choices about format (e.g. poster or presentation) or 'menu' options (e.g., pick a surgical device to report on). Seldom do students have say about what to learn or how to proceed in their own problem framing and solving processes. Consequently, students may flounder when asked to make decisions about things that matter to them.

As a construct, agency lacks the specificity needed to fully understand the range of decisions students could have opportunities to make. For instance, students may make decisions about whether to come to class, whether to do their homework, whether to pay attention, how to take notes, etc. But they seldom make decisions about what to learn and how to direct that process. Agency, as we use it here, inextricably links to the domains in which students must make decisions, such as whether and how to participate in tasks, and how to direct design decisions in an ill-structured design challenge [14]. As a narrower

construct, framing agency foregrounds decisions about the problem as they define it and how to proceed in understanding it.

As experienced designers frame problems, they learn about the problem and take ownership of it. They gather information to understand the problem through various means [15], including assessing stakeholder needs and perspectives, investigating design requirements, researching shortcomings of existing solutions, and identifying available resources [16]. Designers also gather information deliberately to clarify ambiguity, rule out untenable solution paths [17], and address gaps in their own understanding [18]. Our point is that for these activities to constitute problem framing, the designer must take ownership of the problem. Not doing so renders these activities, as well as their potential to support learning of and through the design process, inert. We conjecture that framing agency helps differentiate between experiences that foster ownership and support learning in design processes and those that do not.

Methodology

Research design

We conducted a multiple case study [19] from an interpretative lens. We selected cases from a database of cases collected by the first author over 10 years. All cases involved similar methods to document student participation in collaborative engineering design settings. Although prior manuscripts have reported results for each setting, for this study we conducted new analyses, using a discourse analytic approach to investigate the following research question:

- What does student discourse reveal about the process of making decisions that are consequential to students' designing and learning in a team setting?

Settings, participants, & case selection

We first restricted cases to those from undergraduate engineering courses in which design was either the primary focus of the course or threaded through the course. Although we want to inform early and core course faculty about ways framing agency might be a productive construct, we also sought cases from capstone senior design. We felt that such cases might provide a lens into student behavior under the most authentic design situations.

All cases in the database have the following characteristics:

- the design process was documented in detail, including field notes collected through participant observation and at least 10 hours of audio/video data of usable quality;
- the design challenge or project was assigned in an undergraduate course and addressed by students working in a team;
- the design problem was ill-structured, meaning there were countless possible solutions and solution paths;

- students were encouraged by their instructor to define the problems; and
- students struggled with the ill-structured nature of the problems.

From the database, we deliberately selected cases that spanned settings as a means to enhance transferability of our results. We selected cases in which students successfully treated design problems as ill-structured, as well as cases in which they treated design problems well-structured (Table 1). These characteristics had been assessed in earlier analysis; for instance, teams that treated the problem as well-structured tended to repeatedly refer to the design problem as "this is what we were assigned to do" and focused on the accuracy of their answers when talking to instructors.

Table 1. Cases and settings selected

Case name	***Setting***	***How students treated the design problem***
Tom's team (Tom, Cynthia, Addai, and Greg, mentored by TA Shanti). Physical therapist client wanted means to objectively measure spasticity in patients' limbs.	Client-driven, industry-sponsored biomedical engineering capstone senior design course at the University of Texas at Austin. Two-semester course with mini-design project at start. Students were mentored by faculty advisors and teaching assistants. As a capstone model, students lacked prior course-based design experiences.	Ill-structured
Steve's team (Steve, Daniela, Dillon, and Bob, mentored by TA Michelle). Director of biomedical technology company wanted way to measure specific biochemical processes in the body as an early warning system for sepsis following surgery. Team conducted animal testing to determine if a sensor could measure CO2		Well-structured
Josiah's team (Josiah, Derek, Mia, Manuel, Miriam, Abdullah, and Jorge; n=7, 2 women) Cohort 1	Chemical engineering sophomore course on material and energy balances at the University of New Mexico. Course included an algal biofuel design challenge threaded through course. Several undergraduate peer-learning facilitators provided support to teams.	Ill-structured
Amber's team (Amber, Kyle, Matt, Delia, Angelica, Shaun, Geoff; n=7, 3 women) Cohort 2		Well-structured

It is important to note that Josiah's team and Amber's team were in different cohorts and the instructor made several changes across these cohorts. In cohort 1, members of Josiah's team were given *specializations* tied to the design problem of algal biofuel production—growing, harvesting, and extracting the fuel. Based on student feedback, the instructor decided to have every student in cohort 2 consider each phase on production. We present detailed analysis of the impact of these changes elsewhere, but refer to them in our analysis.

Analysis

We reviewed the original records from the cases, re-transcribing segments of data not already transcribed with verisimilitude, including notable pauses, cross talk and non-lexical conversational sounds [20]. Guided by *sociolinguistics* we analyzed how participants talked to one another and considered the significance of their talk in the classroom [21]. This means we first examined how each student tended to talk over time, as a way to learn about their tendencies; for instance, some students might use hedge words, more frequently than others. Our analytic approach is similar to analysis conducted of teams in sophomore-level chemical engineering courses; in that work, the authors found two distinct patterns of talk: transfer-of-knowledge sequences in which some students acted like teachers and others acted like pupils-as-knowledge receivers; and collaborative sequences in which students built upon each other's ideas [22]. They also found that some students habitually occupied a pupil-as-knowledge receiver role, which because it was a relatively passive role, is actually less likely to support learning. Based on their analysis, they argued that instructors could support students by encouraging them to take on different roles. Thus, we hoped that by closely analyzing design team talk, especially with a focus on framing agency, we might clarify more and less productive types of interactions that instructors can attend to.

To specify our focus on framing agency, we adapted the agency toolkit [1]. In adapting this toolkit, we sought to characterize talk among the students in design teams, and therefore speculated that students might commonly *share* agency with their team members, because design decisions are often negotiated (Table 2). We considered hedging language [23], in which the speaker includes words that diminish the impact, perhaps of a design idea that could be viewed by others as untenable. We also wanted to differentiate between justifications attributed to external forces (e.g., "because it was available") and those that displayed reasoned choices (e.g., "because it could convert the voltages to what we needed.").

Table 2. Framing agency toolkit, adapted from Konopasky & Sheridan [1]. Many are initially autocoded using functions in Excel, but then checked for accuracy. Tool for autocoding is available for download: http://www.vanessasvihla.org/publications-products--press.html. Colors indicate highlighting used in presentation of results.

I	High agency marker. Speaker uses first person singular pronoun. Autocoded (I, I've, I'm, I'll)
We	Shared agency marker. Speaker uses first person plural pronoun. Autocoded (we, we're, we've, we'll)
Objective	Low agency marker. Speaker places self or self and team as object, using objective pronoun. Autocoded (me, us, our)
Generic	Low agency marker. Speaker uses generic "you" or places self among many others. Do not count "you" when used to reference a specific person. Autocoded (you, your, human coder must check for generic use)
Hedge	Lower agency marker. Speaker modifies statement with diminishing hedge terms. Autocoded (seem, like, a bit, almost, mostly, actually, a little, nearly, really, perhaps, maybe, kind of, somewhat, sort of, any, possibly, I believe, probably, might, apparently, some, just, sometimes, hardly, I mean, I think, guess)
Modality	Low agency marker. Speaker uses modal verbs that indicate a lack of control over the situation, such as "had to" "needed to" "were required to" in place of "did"; "have to" "Should" "must" in place of "do"
Conjunction	Mitigation via subordinate conjunction. Autocoded ('cause, since, although, so, in order to, if, though)

Lee [24] argues that students' talk provides important cues that students draw on to determine what roles they can play in learning together. Paying attention to their talk reveals much about the ways students orient to and influence one another in learning settings. Therefore, to identify learning versus performance orientations, we attended to how students responded to one another and the task at hand (Table 3). We categorized interactional sequences as learning or performance oriented, omitting sequences when an instructor was giving direction or students were talking about concerns other than the design challenge (e.g., which instructor to take chemistry with, where to go for lunch). We considered how students oriented: to time, under or over estimating how much of it they had; to task expectations, including whether they ignored expectations in order to pursue deeper understanding or checking expectations to assess their accuracy; and to the process, such as by spending time engaging one another's ideas versus dividing a task up to more efficiently complete it.

Table 3. Coding guide for learning versus performance orientations

Markers of:	***Learning orientation***	***Performance orientation***
Time	Student provides underestimate in accounting for amount of time spent, suggesting they lost track of time Ex: *We had a long discussion—probably about ten minutes*. (It was actually 40 minutes)	Student references time as a limited commodity or speaks with urgency Ex 1: *Oh my god. Hang on.* Ex 2: *S1: So... since we're under time constraint do you think we should just keep those three right there?* *S2: Yeah! Why, how much time do we have?* *S1: I think like 20 minutes.*

Task expectations	Student ignores direction from instructor or assignment in order to continue or deepen investigation Ex: *S1: Okay, I feel like we should move something like this, over here.* *S2: Shh. Let's just keep discussing.*	Student checks with resources, others or instructor to confirm they are doing or have done the task correctly. Ex: *So, do we have to fill that out?*
Process	Student engages with others' ideas, poses open or exploratory questions, follows up with related/building ideas. Ex: *S1: Wait, are we still trying to decide which one we are-* *S2: Well, she's asking for cons about* *S3: 'Cause I wanna-yeah I wanna hear more*	Student suggests/uses divide-and-conquer or efficient strategy to get task completed. Students supply unelaborated answers when prompted to, and responses to answers may clarify accuracy or affirm that answer was received. Ex: *You know what guys would be really helpful if you don't write down what your strains were right there on the GoogleDocs*

Results & Discussion

Although we analyzed several hours of data for each case, here we share vignettes from each case to characterize framing agency.

Tom's team

Tom's team planned to design a glove with a pressure sensor and accelerometer to measure limb spasticity. Their contextual understanding of the problem—that a patient must be made comfortable and not made to contort in strange ways, led them to rule out a number of possible solutions and instead focus on a wearable device. However, after receiving the accelerometer, Tom realized that if one were to move in a direction opposite to the direction of gravity at the same acceleration as gravity, no motion would be recorded. Later (in mid-February), he spent an hour carefully presenting this anticipated problem to his team. The team members seemed concerned there was no way forward. Addai put forward a tentative solution, displaying relatively low agency (Figure 1). Consequently, the team worked to frame and reframe the problem. We argue they maintained an opportunity structure for members to have agency over framing the design problem.

Vignette 1: Feb 11

Addai: Instead of taking measurements in three dimensions, this is this is like maybe a first draft. //
Tom: //hm!//
Addai: //You throw away the position information.
Tom: Right.
Addai: And we roll the XYZ coordinates into just one combined vector and that way we've always accounted for your full gravitational contribution.
Shanti: That's a good idea!
Cynthia: Yeah.
Shanti: Like a magnitude (.) of all three of them like a//
Addai: //Exactly. Exactly. So if you roll them all together you can still figure out//
Shanti: //That's a good idea.

Vignette 2: Feb 11, 5 min. later

Addai: Like I said I'm still not sold on it, but. I'm not sold on it, but I like the way it looks.
Tom: mmhmm [positive]
Shanti: Yeah anyway try it out it might work I don't know.
Addai: [quietly] You do lose, uh I think you do lose your position because you rolled all of your axes. [louder] But it would be a much easier way also to keep track of your overall change in, uh, applied force, velocity.

Vignette 3: Apr 21

Addai: We calibrated the accelerometer and by doing a square root of sum of squares
Shanti: mhmm
Addai: He says that it works the way it should.
Shanti: Okay.
Addai: And we subtract out gravity and then we'll stay at zero in a non-moving orientation.
Shanti: So you're taking the sum of squares? Uh:: and then you're subtracting out gravity how?
Addai: Yeah we're doing the square root of sum of squares first what we do is we convert each of those channels by the calibration curves to the units per second squared
Shanti: Okay.
Addai: And then we have, so then we have three axes where there's 100% square root values and then we do sum of squares square rooted
Shanti: Okay
Addai: [quieter] And then we would just subtract 9.8 (.) [quieter still] 'cause 9.8 meters per second per second is the value of g (.)
Tom: It's basically getting a. (.) uh net. (.) acceleration. uh (.) magnitude.
Shanti: [looks concerned] Right.
Tom: and uh (.) which is one contribution of gravity and then mechanical contributions from movement
Shanti: And we don't anticipate any situations like we talked about where the two components would // cancel out
Tom: //Oh yeah like moving around, uh we // only transiently//
Addai: //We don't. // We don't anticipate it, we're gonna look at it.

Figure 2. Vignettes from Tom's team, color-coded as defined in Table 2

In vignette 1, Addai minimized risk associated with introducing his idea by calling it a "first draft." His hedge words and use of the generic "you" mitigated his agency. Tom reacted positively, widening the opportunity for Addai to pursue this line of thinking, which scaffolded Addai to continue reframing the problem. In response, Addai's discourse was less tentative; he shared agency with his team ("we"). In this vignette, the students displayed a learning rather than performance orientation, even as they discussed the potential of an idea Tom had previously rejected. Tom did not discourage his peers'

participation. In calling Addai's idea a draft, for instance, we see a commitment to understanding and improving that is perhaps agnostic to time pressures and assignments that scaffold their progress.

In vignette 2, although Addai presented his idea as one he was not yet "sold on," Shanti encouraged the group to "try it out" because "it might work." She scaffolded Addai's thinking and advanced the team's framing process, without taking an authoritative role. This move also encouraged a learning rather than performance orientation, encouraging them to try something that was not guaranteed to be successful. Addai acknowledged the team's concerns, but exhibited a firm belief in his idea by increasing the volume of his talk.

The exchange presented in vignette 3 happened just after the team implemented Addai's suggestion. Addai was less tentative, including himself in the collective "we." With their solution in sight, Addai displayed a performance orientation, highlighting the accuracy and functionality of their testing with their prototype. Shanti's filler responses assured the team she was listening, but she generally remained noncommittal, leaving agency in their hands, and herself engaging with a learning orientation as she sought to understand their solution. When Shanti asked "how," she acknowledged the information but prompted and supported Addai to provide a more detailed explanation. However, Addai appeared to lose some of his confidence, particularly as he began to define a well-established construct ("g"). Tom stepped in as a more capable peer bringing together the loose ends in Addai's explanation.

Across these interactions, Tom and Shanti—both in more powerful roles—maintained opportunities for other members to reframe the problem. They scaffolded Addai to move from throwing forward the earliest draft of an idea to displaying shared ownership of a solution that came from his reframing of the problem.

Steve's team

Steve's team generally displayed agency to solve the problem as given to them (Figure 2). Concerned they were not *designing* anything, Michelle encouraged them to "try to have some kind of engineering analysis" and pressed them to explain why their project was "so great." Her concern reflected the instructor's comment, "What can you really uniquely contribute as an engineer?" as she pressed, "Why is there a need for it?" The students explained the potential for saving lives by having a way to detect symptoms of shock. Steve's team struggled to define this as a design problem and resisted reframing the problem. Instead, they treated the problem as well-structured and their task as finding the right answer, primarily adopting a performance orientation.

Vignette 4: Feb 4

Daniela: I just thought that something bothers me the fact that (.) yeah we're gonna put the sensor on the stomach (.) right? During surgery? (.) But then (.) we're gonna, the surgery only lasts like one::: to two hours and we're gonna take it off and the patient is gonna be, (.) um well the surgery is gonna be over and there's not gonna be any monitoring afterwards, and I'm thinking (.) Well there's higher chance of sepsis or shock appearing after surgery. So::: should we think about leaving the sensor? or::: (.) 'cause I don't really think it's//
Dillon: //Seriously, that could be like, the next step.
Steve: Yeah.
Dillon: Right.
Steve: I think that—are you talking about like for like in real life? like
Daniela: Yeah. Like what what's the use of it if// you're just gonna
Steve: //I think
Bob: //I thought [increasing volume] // I thought the problem—the project was to do an internal sensor that it could be left there.
Daniela: So we are gonna leave it there?
Steve: I think that that'll//
Daniela: // How are we gonna secure it there?
Steve: to—wull
Daniela: 'cause we//
Steve: //Yeah. We were talking about that cyanoacrylate gel [super glue].
Bob: They use cyanoacrylate gel right now, for uh the rat testing. But as for uh future
Steve: I mean I would-
Bob: I'm not sure uh (.)
Steve: I would think that would be something left up to a surgeon or something to be honest I mean likelikeliek our project. I think it's kinda outside the scope of our project our project is//
Bob: //If we left it up to the surgeon and whoever actually designs the sensor.
Steve: Yeah whoever is really doing this.
Bob: 'cause we're not supposed to be designing anything.
Steve: Yeah we're just seeing if we can do it. We just have two types of sensors and we're gonna see if we can do it.
Bob: We're gonna see if a shock patient whether or not the CO2 levels if it can be measured or changed to a measurable degree enough to be able to detect shock or the on—the //oncoming shock //using currently available sensors
Daniela: I don't even know if it's okay to just leave it there
Steve: it'sallright
Daniela: These are—I mean just for a certain number of days?
Steve: mmhmm
Dillon: They're not gonna want to cut them up again and just take it out
Bob: When they do open abdomen though they also do um basically a screen for a while
Dillon: Yeah but after//
Bob: //'kay so you have the patients coming back. Even days after.
Steve: mm. I //don't know.//
Dillon: //I don't know.//
Daniela: I keep thinking about what Dr. Riley said, that it could be (.) implanted in the uter—yeah uterus or bladder? I'm thinking that's more feasible than what YOU're doing so.
Steve: Right
Daniela: I don't know. It's just
Michelle: So okay now I'm like (.) really confused. [Steve laughs] um (.) So you're testing basically um (.) Whatever testing you're gonna do on the animal. It's one kind of like what a doctor would do on like on an open abdomen surgery right?

Figure 2. Vignette from Steve's team, color-coded as defined in table 2

Daniela showed framing agency as she brought up her concern about the plan, but Steve and Dillon rejected her idea as out of scope. This pattern was common: Steve displayed high agency and Dillon repeated Steve's words as if to amplify them. Steve generally displayed high agency and made decisions, but they were not consequential to the framing of a design problem, and most of his lower agency moves allowed him to avoid framing the problem. In this, he and Dillon shut down Daniela's attempts to frame the problem, limiting the impact of her ideas on the discussion.

Bob's crosstalk allowed Daniela to reframe the problem, offering other important aspects of the new design space. When Steve pointed out their plan for how to attach the sensor, Bob appeared to waffle in his allegiance, briefly hinting that their plan might not be ideal for human surgery. This also reduced the chance of conflict in the framing process, and still allowed everyone to maintain a positive stance.

Steve quickly shut down this line of thinking, and Bob switched his position. Daniela persisted in trying to reframe the problem, invoking suggestions from one of their mentors and more clearly distancing herself from Steve's version. During this exchange, TA Michelle offered no scaffolding, and the problem failed to become a design problem. Daniela expressed frustration multiple times.

Across this vignette, the students primarily displayed performance orientations as they justified their ideas using outside, sometimes generic and sometimes "assigned" sources.

Josiah's team

Josiah's team generally displayed framing agency as they navigated the task at hand, in this case, bringing their independent work together and coming to consensus about the best way to grow algae, in a "parley" session (Figure 3). Across the sessions, we observed that they dipped quickly into performance orientation before returning to a learning orientation. They struggled to come to consensus, yet spent time listening to and learning from one another. They treated the problem as ill-structured and their task as making an important and informed decision that would influence subsequent decisions in their design work.

In Vignette 5, Josiah and Derek both used low agency language, offloading ownership onto the assignment and the generic "you." Just three minutes later (Vignette 6), the instructor prompted groups to merge and come to a consensus across groups, but at Josiah's "Shh. Let's just keep discussing" the team decided to stay and continued their conversation. While "Shh" can be interpreted as aggressive, here is was subtle, creating a moment that required intentional social negotiation. This "Shh" functioned as a tool that govern their work, communicating to the team, *let's stay on this task and not get distracted*. Despite a felt time pressure, the team ignored the instructor's directions and continued their conversation until almost the end of the class (Vignette 7). Though Josiah passionately argued in favor of growing algae in open ponds, he was unable to convince his team members, who preferred bioreactors, even though they listened and engaged with his suggestions.

Vignette 5: 7:00 minutes into parley

Derek: But then you also have to—also take into consideration the evaporative losses in the water.
Josiah: That's the con that I put on the open. Like if it's an open pond we're gonna lose all the CO2 in all the water, so that's gonna be the most expensive operating cost, probably, after start up.
Mia: One thing I read about the open systems is it has a larger surface area to volume ratio which is really important for exposing algae to all the nutrients it requires so, and that was like—big thing is, it's like way more efficient
Josiah: Yo do we need to make this matrix right now?
Mia: I believe it's after we discuss

Vignette 6: 10:00 minutes into parley

Derek: Okay, I feel like we should move something like this, over here.
Josiah: Shh. Let's just keep discussing.
Manuel: Are we the only –
Derek: No, there's four groups of Harvest, there's four groups of—no, there's five groups.
Manuel: We don't know what's going on, we're sorry. Yeah, we're Harvest.
Josiah: The problem with having the first parley session, is there's no time to do anything.

Vignette 7: 11:00 minutes into parley

Josiah: Hey. You need some more cons?
Mia: Yeah.
Josiah: So, I read that there's many-there's many issues associated with scale-up. like-of-so like So right now, most photo—like the phot-bio-reactors are small. ish. Like the size of like//
Mia: //Yeah//
Josiah: //one building, you know. They're not large-scale. And so it said that some of the issues that that are involved with scale-up include um photorespiration – so if they're having trouble with removing O2 from the systems
Mia: Okay
Josiah: So that, when that builds up then the plant no longer uses CO2 to make what it needs to make, and it just uses the O2 to do photo-respiration.
Derek: Wait, are we still trying to decide which one we are
Josiah: Well, she's asking for cons about
Mia: 'Cause I wanna - yeah I wanna hear more

Figure 3. Vignettes from Josiah's team, color-coded as defined in table 2

Amber's team

Like Steve's team, Amber's team generally displayed agency to solve the problem as given to them (Figure 4). They spent time checking the accuracy of their interpretation of the problem, uncertain if they had done it correctly. This suggests that they were unaware that they should frame the problem. Instead, they treated the problem as well-structured and their task as finding the right answer, primarily adopting a performance orientation.

Just prior to the vignette 8, Amber explained in detail the algal strains she researched. When her teammates decided the task was actually to quickly report out whether they had researched red, brown, or green algal, Amber apologized multiple times. In vignette 8, the members establish whether they share understanding of the complex task set to them. Amidst confusion, they focus on confirming the sameness of their answers, though review of their individual worksheets revealed that they actually research many different species. As they talked, they displayed uncertainty about the task, but not about their design ideas. They use modality to mitigate their ownership over that task.

In vignettes 9-11, one week later, the team members again oriented to the task at hand, focusing on their understanding of the task and providing factual information, rather than sharing what they researched independently with one another. They did not display

framing agency or a learning orientation, but instead, sought to efficiently complete the task. With a felt time pressure in vignette 11, they again left the ownership of the problem with the instructor. While students in other semesters debated and negotiated which criteria should be used, Amber's team (vignette 10) treated this problem as trivial.

Vignette 8: 1:00 minute into pre-parley

Amber: So who here is from team 1?
Matt: Who is from team 1?
Amber: Oh I'm from team 1. My bad.
Kyle: I was assigned a letter?
Amber: I don't know what the assigned letter is. uh.
Kyle: So what are we supposed to do?
Amber: I didn't know that we were supposed to - What I did was, I actually looked up specific species and I was - I didn't know that we had to look, like, red, brown, or green
Kyle: I think maybe that's what I did
Matt: I looked up species
Amber: Did everybody look up species?
All: Yes
Kyle: We all looked up species

Vignette 9: 1:30 minutes into parley

Amber: So criteria.. Now I have to write the criteria down
Angelica: So... Actually I have a uhhh. kind of question 'cause Kyle and mine mine my choice is just a specific type of Kyle's.
Kyle: Yeah...
Angelica: Yeah!
Kyle: So... I'll go with the same strain

Vignette 10: 2:00 minutes into parley

Amber: Alright cool. So criteria... We need to write the criteria to these steps, so what are the criteria that we're looking for.
Angelica: So copy and paste from the ones that we got on that thing?
Delia: Yeah you can do that.
Kyle: Lipid content? Right.

Vignette 11: 14:00 minutes into parley

Matt: We need this done. We only have 10 minutes left.
Kyle: Yeah.
Matt: So
Amber: Okay. So we have to rate each criteria with a weight from 0 to 3 right? So::, the most important one do you want to give that a 3 and choose the least important one
Kyle: Well what we do with rating is we say how how good this particular strain is at that
Amber: Right, but we have to decide what to weight too.
Kyle: Yeah.
Amber: How important it is.
Kyle: Exactly yeah.

Figure 4. Vignettes from Amber's team, color-coded as defined in table 2

Conclusions

In this paper, we characterized framing agency by analyzing design team talk across two settings. By analyzing design team talk, we identified discourse patterns connected to agency in problem framing. By comparing the teams that displayed framing agency—Tom's and Josiah's teams—to those that did not—Steve's and Amber's teams, we see key differences in discourse.

We argue that how students negotiate design problem framing depends on whether or not they consider the design problem relevant and authentic, the belief that each member

brings different and potentially useful information to the task, and the opportunity to iterate design ideas over time. Framing agency provides a lens for understanding the kinds of design learning experiences students need to direct their own learning and negotiate that learning with peers in design projects.

Targets of tentative language

Tentative talk—commonly noted as suggesting low agency [1]—was not a barrier to Addai developing his idea because his collaborators nurtured his participation. This aligns with past work showing that responsiveness/politeness helps groups successfully solve well-structured but complex problems [25, 26] when they have authority to work on problems [27].

While all of they teams used some hedge words and other forms of tentative talk, the teams that displayed framing agency did so when talking about their design ideas, rather than about the task or assignment. More experienced designers know to stay tentative during early design work [28], but they are not uncertain about their ownership over the design problem. In both Steve's and Amber's team, students used modality to place ownership of their work on someone else. In Amber's team, the ownership of the assignment consistently stayed with the instructor. In contrast, Josiah's team ignored explicit instructions so they could continue to discuss. Although Josiah passionately argued for his preferred approach to growing algae, he easily relinquished this when it was clear that his team mates preferred another method, suggesting that he remained tentative in his thinking. In Steve's team, although they use many hedge words, these are primarily about the scope of their task and external expectations placed on them, rather than their design ideas. In Tom's team, Addai's tentative idea eventually became part of the final solution, which yielded a reframed problem. Tom and Shanti opened spaces for Addai to reframe the problem.

Breadth and context are central to problem framing

While expert designers consider the broader problem context early in the problem framing process [29, 30], novice designers appear less likely to attend to this, though women may be more likely to consider context in design problems than men [31]. Ignoring problem context may stem from concerns that context increases the complexity of the problem or because most of the problems they have previously dealt with have been narrower in scope, suggesting that such concerns are frivolous. Consider, for instance, how students sometimes view word problems in mathematics. They hunt for the needed information and ignore information that is distracting. However, treating a design problem as reducible in the same manner fundamentally changes what and how students can learn as they design.

We saw differences in how teams attended to context or narrowed the scope of their problems. While at first pass, context seems missing from Tom's team as they discuss Addai's idea tentatively. Yet, it was Cynthia's clear focus on context that led them to rule out other possible solutions and determine that a wearable device would best meet the physical therapist's and patients' needs. In contrast, Steve's team presented a very

narrowed problem context, focused on characterizing the performance of two sensors. While still ambitious work, it was not design work. And when Daniela suggested leaving the sensor in, Steve and Dillon rejected her idea as out of scope, outside the narrow framing they had set. Steve's displays of confidence prevented negotiation of the problem frame. While Bob opened a space to reconsider Daniela's reframing, his effort was fleeting. This pattern was consistent when new ideas were put forth, as if the team did not see its role as shaping the problem. We do not know if Daniela's experiences drove her to find design encounters elsewhere, but we see this as a missed opportunity to learn to frame problems and her peers did not get to learn from her through this process.

In Josiah's team, members considered a broader context than Amber's team, which shared little detail as they offered facts they had gleaned from their research. As Josiah's team considered their various decisions, they also considered the rural context they were designing for.

Connections between framing agency and learning orientation

Our findings suggest a connection between framing agency and predominantly orienting to learning rather than task-completion, as well as an initially tentative quality. In the capstone biomedical engineering course for example, Tom's team shared tentative, exploratory ideas at the outset of the task, and as they worked together to test those ideas, developed shared ownership over them. In contrast, students in Steve's and Amber's teams treated the design problem as an artificial task to complete, used intentionally decisive language, and discouraged member exploration of tentative design ideas.

In Amber's team, the students approached choosing an algal genus as a task to be completed quickly and accurately, and tended to view the overall potential of algal biofuel as limited. They checked to see if they had the same answers as their peers. In contrast, when students were given specializations (e.g., one member focused on growing algae, another on harvesting algae) they approached team decisions from a learning orientation and shared decisions tentatively across members.

Implications for instruction

By seeking to conceptualize framing agency as a specific skill set within interactional contexts, we bring renewed focus and clarity to the kinds of framing moves learners might make, and the ways their peers and instructors can support them to develop tentative ideas into solutions over which they feel a sense of ownership.

While these data are limited in time and scope, we argue the contrast between cases provides suggestions for the kinds of experiences that can help learners develop increased framing agency capacity. For students to develop capacity to frame problems, they need experiences and supports that help them move beyond the typical well-structured problems they are so used to. Based on our analysis, we first argue that design team talk can be very useful to instructors as a means to gauge student participation and respond effectively. For instance, if you hear students talking like Tom's or Josiah's teams, you might decide to extend the time allotted for their discussion. In contrast, if you hear talk

like in Steve's and Amber's teams, you could pause the discussion, provide instruction about the task, but then emphasize the value of learning from one another. In the case of Amber's team, we heard many teams expressing similar confusion, focusing on getting the task completed, and affirming sameness in their answers. Yet, based on our review of the citations each student provided from their independent research, we know they had learned different things. As an instructor, showing that you value this and emphasizing that they may even have conflicting information could set them up to share what they found with one another.

When providing a complex assignment for students, there is value in allowing the time to try it out and get a little confused before giving them instruction. We call this the "flat-pack furniture problem." If you are like most people, you don't read the instructions book carefully, cover-to-cover, prior to starting to assemble a piece of furniture. Most people reference this resource once they are stuck, when they have a *need to know*. Giving students a few minutes to get confused about a complex task can make them more ready to listen to instruction effectively. Others have expanded this notion, finding that there is latent value in failing to solve, but engaging deeply with complex problems [32].

Finally, when orchestrating teamwork, specializations, rather than roles, may be beneficial for novice designers. While we already had a strong preference for avoiding roles that included secretarial duties (e.g., note taker, time keeper) because these roles often get assigned to women instead of men [33-35], we found that providing specializations had the advantage of encouraging greater attention to breadth and context, an area that novice designers notoriously struggle with [29]. Based on our findings, we would encourage the use of content specializations paired with time for students to learn from one another. This fosters interdependence and helps prevent coattail riders because students have a legitimate reason to expect that their peers do not have the same information as one another, and to depend on each other to learn what they need to complete their project. While this can happen naturally in capstone design projects, it can be fostered in course-based design by dividing up topics or subtopics.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. EEC 1751369. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] A. W. Konopasky and K. M. Sheridan, "Towards a Diagnostic Toolkit for the Language of Agency," *Mind, Culture, and Activity,* vol. 23, pp. 108-123, 2016.

[2] S. Harfield, "On design `problematization': Theorising differences in designed outcomes," *Design Studies,* vol. 28, pp. 159-173, 2007.

[3] D. H. Jonassen, "Toward a Design Theory of Problem Solving," *Educational Technology Research and Development,* vol. 48, pp. 63-85, 2000.

[4] M. A. Runco and I. Chand, "Problem finding, problem solving, and creativity," in *Problem finding, problem solving, and creativity*, M. Runco, Ed., ed Norwood, NJ: Ablex Publishing, 1994.
[5] J. Restrepo and H. Christiaans, "Problem Structuring and Information Access in Design," *Expertise in design,* 2003.
[6] N. Cross, "Design cognition: Results from protocol and other empirical studies of design activity," in *Design knowing and learning: Cognition in design education*. vol. 5, C. M. Eastman, W. M. McCracken, and W. C. Newstetter, Eds., ed Oxford, UK: Elsevier Science, 2001, pp. 79-103.
[7] N. i. S. Nasir and T. B. Peele-Eady, Eds., *Identity and learning* (Encyclopedia of the sciences of learning. New York, NY: Springer Science & Business Media, 2012, p.^pp. Pages.
[8] R. Alsop, M. F. Bertelsen, and J. Holland, *Empowerment in practice: From analysis to implementation*. Washington, DC: World Bank Publications, 2006.
[9] V. Svihla, "Contingent Identification in a Biomedical Engineering Classroom," in *Learning in the Disciplines*. vol. 1, K. Gomez, L. Lyons, and J. Radinsky, Eds., ed Chicago, IL: International Society of the Learning Sciences, 2010, pp. 913-920.
[10] A. L. Kristof-Brown and C. K. Stevens, "Goal congruence in project teams: Does the fit between members' personal mastery and performance goals matter?," *Journal of Applied Psychology,* vol. 86, p. 1083, 2001.
[11] C. S. Dweck and E. L. Leggett, "A social-cognitive approach to motivation and personality," *Psychological review,* vol. 95, p. 256, 1988.
[12] D. VandeWalle, S. P. Brown, W. L. Cron, and J. W. Slocum Jr, "The influence of goal orientation and self-regulation tactics on sales performance: A longitudinal field test," *Journal of Applied Psychology,* vol. 84, p. 249, 1999.
[13] D. Narayan and P. Petesch, "Agency, opportunity structure, and poverty escapes," *Moving Out of Poverty: Cross-Disciplinary Perspectives on Mobility,* pp. 1-44, 2007.
[14] V. Svihla and L. Kittinger, "Agentic Trajectories: Development and Learning in a Project-Based High School for Marginalized Students," in *Transforming Learning, Empowering Learners*. vol. 1, C.-K. Looi, U. Cress, J. L. Polman, and P. Reimann, Eds., ed: International Society of the Learning Sciences, 2016.
[15] K. M. Bursic and C. J. Atman, "Information gathering: a critical step for quality in the design process," *Quality Management Journal,* vol. 4, 1997.
[16] P. G. Dominick, *Tools and tactics of design*: Wiley, 2001.
[17] M. Basadur, G. B. Graen, and S. G. Green, "Training in creative problem solving: Effects on ideation and problem finding and solving in an industrial research organization," *Organizational Behavior and Human Performance,* vol. 30, pp. 41-70, 1982.
[18] P. Tracy, "Design and Problem Finding in High Schools: A Study of Students and Their Teacher in One Queensland School," Masters, Education, Griffith University, 2005.
[19] R. E. Stake, *Multiple case study analysis*: Guilford Press, 2013.
[20] N. Ward, "Non-lexical conversational sounds in American English," *Pragmatics & Cognition,* vol. 14, pp. 129-182, 2006.

[21] J. P. Gee, *An introduction to discourse analysis: Theory and method*: Routledge, 2014.
[22] C. R. Haller, V. J. Gallagher, T. L. Weldon, and R. M. Felder, "Dynamics of peer education in cooperative learning workgroups," *Journal of Engineering Education,* vol. 89, pp. 285-293, 2000.
[23] I. Boncea, "Hedging Patterns Used as Mitigation and Politeness Strategies," *Annals of the University of Craiova. Series: Philology, English,* pp. 7-23, 2014.
[24] C. D. Lee, "'Every good-bye ain't gone': analyzing the cultural underpinnings of classroom talk," *International Journal of Qualitative Studies in Education,* vol. 19, pp. 305-327, 2006.
[25] B. Barron, "When Smart Groups Fail," *Journal of the Learning Sciences,* vol. 12, pp. 307-359, 2003.
[26] M. M. Chiu, "Flowing Toward Correct Contributions During Group Problem Solving: A Statistical Discourse Analysis," *Journal of the Learning Sciences,* vol. 17, pp. 415-463, 2008.
[27] A. L. Brown and J. C. Campione, "Designing a community of young learners: Theoretical and practical lessons," in *How students learn: Reforming schools through learner-centered education*, N. M. Lambert and B. L. McCombs, Eds., ed Washington, D.C.: American Psychological Association, 1998, pp. 153-186.
[28] N. Cross, "Expertise in design: an overview," *Design Studies,* vol. 25, pp. 427-441, 2004.
[29] C. J. Atman, K. Yasuhara, R. S. Adams, T. J. Barker, J. Turns, and E. Rhone, "Breadth in Problem Scoping: a Comparison of Freshman and Senior Engineering Students," *International Journal of Engineering Education,* vol. 24, pp. 234-245, 2008.
[30] C. J. Atman, M. E. Cardella, J. Turns, and R. S. Adams, "Comparing freshman and senior engineering design processes: an in-depth follow-up study," *Design Studies,* vol. 26, pp. 325-357, 2005.
[31] D. Kilgore, C. J. Atman, K. Yasuhara, T. Barker, and A. Morozov, "Considering Context: A Study of First-Year Engineering Students," *Journal of Engineering Education,* vol. 96, p. 321, 2007.
[32] M. Kapur, "Examining productive failure, productive success, unproductive failure, and unproductive success in learning," *Educational Psychologist,* vol. 51, pp. 289-299, 2016.
[33] M. Natishan, L. Schmidt, and P. Mead, "Student focus group results on student team performance issues," *Journal of Engineering Education,* vol. 89, pp. 269-272, 2000.
[34] J. Wolfe, "The role of writing in effective team projects: students and professionals differ," in *Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference*, 2005, pp. T4F-19.
[35] S. Gowen and A. Waller, "ABET 2000 Criteria 3 G And The Meaning Of Communication," in *2002 Annual Conference*, 2002, pp. 7.133. 1-7.133. 12.