Pre-Service Faculty Learning Processes and Teaching Approaches

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Abstract— **This is a full paper examining Pre-Service Faculty (PSF) conceptions of learning and the influences of those upon their enacted or theorized teaching practices. PSF are our analogy to pre-service teachers, and denotes people on a pathway towards a faculty position, who have not yet landed their first faculty job. Specifically, we study engineering graduate students in this project. We thematically analyzed ten interviews with PSF at a large R1 US institution. We developed an analytical framework to describe the relationships between PSFs' learning processes and teaching approaches. This framework is composed of four elements: PSFs' personal learning processes, embraced teaching actions, rejected teaching actions, and the learning processes that the PSF considers viable. PSFs' conceptions of effective engineering teaching can be deduced from this framework. This framework is in agreement with the literature on teaching processes of engineering faculty, who describe several of the same influences. We also found that these PSF describe more constructivist pedagogy than anticipated, especially considering that the majority of the PSF had minimal formal pedagogical training. We conclude that this inclination to implement constructivist pedagogies represents a productive beginning, that these PSF have considered what it means to effectively teach, and consequently represent a promising population for structured interventions to train them in educational theory, methods of enacting active learning, or these constructivist pedagogical methods which they describe thereby empowering them to introduce these methods within their future classrooms.**

Keywords—conceptual learning, teaching skills, graduate education

I. INTRODUCTION

This full paper examines pre-service faculty (PSF) learning processes and the influences of those processes on their theorized teaching methods. Despite some twenty years of research pointing to the increased knowledge gains when using student-centered techniques such as active learning activities, engineering classrooms are still predominantly teacher-centered environments. Workshops such as the National Teaching Institutes (NETI) and other professional development efforts [1] have transformed participating instructors. Yet, barriers to faculty adaptation are extensive and well documented. These include time, incentives or rewards from the department or university, the pressure to bring in research funding, a lack of financial resources or guidance during adoption, the pressure to cover material, beliefs students are going to resist new teaching methods, and uncertainty that the investment to make the changes will lead to a benefit for students [2-6]. Our research team is designing professional development for graduate students to support them to learn student-centered pedagogies. We believe that if PSF learn to teach in student-centered ways before they become faculty, they will be likely to continue to teach in these ways once they become faculty. The goal of this study is to understand how current pre-service faculty think about their own learning and approaches to teaching students in order to create a baseline for creating coursework or professional development.

While some have argued the training of PSF as teachers should begin at the start of graduate school [7], there are few opportunities for graduate students to explore their ideas about teaching and learning as they are expected to focus on their research output [8,9]. Some students receive training in seminars for teaching assistants [10,11] but these seminars focus more on creating the structure of a course and introducing instructional methods to fulfill departmental needs [12] rather than creating a space for graduate students to reflect on their own teaching, discuss learning theory, and develop a teaching philosophy. Many studies discuss the structure of the professional development programs and not the teaching assistants' conceptions on teaching and learning.

One study by Winters and Matusovich [13] began this work by surveying graduate teaching assistants (GTAs) on their teaching beliefs. The survey asked students to disagree or agree with statements about their teaching. They found the engineering GTAs had more student-centered teaching beliefs, and those who taught first-year general engineering had more student-centered beliefs than those who taught upper level courses. The study was limited as the data could not explain reasons for more teacher-centered or research-centered beliefs.

Our study aims to begin to fill this gap in understanding development of faculty teaching practices by starting with graduate students considering faculty positions (PSF). As these students have little experience teaching at this point, we look both to their theorized teaching methods as well as their learning processes to better understand the ways in which PSF think about teaching and learning. With this goal, we ask:

How do PSF describe their process of learning engineering?

How do PSF describe their enacted or theoretical approach to teaching engineering?

How do PSF's processes of learning engineering and their approaches to teaching engineering intersect?

II. BACKGROUND

Research suggests pre-service K-12 teachers develop stances toward learning and teaching before they begin teaching, and

that those stances are influenced by their own experiences as students in the classroom [14]. Similarly, literature on career socialization implies that a student's understanding of the faculty career begins with the graduate school experience or even earlier [12]. Therefore, we would expect graduate students to have stances towards teaching. We would also expect these stances towards teaching are influenced by their own experiences in the classroom or in other types of informal learning, both in how teaching was modeled in front of them and how those pedagogical choices engaged or did not engage them in learning.

We see these relationships between learning experiences and teaching stances in recent work by Kellam and colleagues that examines the processes through which professors take up student-centered teaching [15], [16]. Faculty in these studies described their own undergraduate experiences as influencing their teaching, indicating that ideas about learning and teaching emerge before one becomes a professor. Kellam et al found that the process of shifting to more student-centered pedagogies could overcome barriers when faculty had a desire to change based on personal experiences, a supportive community or network, and authority to make pedagogical changes.

III. METHODS

Since we seek to better understand the teaching methods and learning processes of our PSF, we elected to conduct interviews as they allow for rich descriptions and the ability to listen and seek clarification or elaboration. We seek to learn what existent thoughts and instincts our PSF have regarding teaching methods, what influences (if any) they may have from their learning processes, and what methods they describe as the idealized version of their enacted or theorized teaching methods. Seeking these conceptions, or novice ideas, is our first exploratory step in designing educational professional development interventions for graduate students who wish to become faculty. These interventions will teach PSF educational theory and methods, as well as empower them to implement student-centered teaching methods such as active learning. These professional development interventions we see as eventually building upon novice conceptions of teaching to develop and advance PSF thinking and planning into more nuanced, student-centered conceptions.

These interviews were all conducted at a large R1 US institution during a single academic year. Participants were given the choice of Zoom or in-person interviews. Two participants chose to engage in in-person interviews while eight participants chose to interview via online video conferencing. Regardless of the format of the interview, the contents were audio recorded and transcribed.

Interview participants were recruited via email scripts distributed through engineering departments. Possible candidates were sent a questionnaire to screen potential participants to meet our target population: engineering PhD or masters students intending to pursue a faculty position after graduation. Once this criterion was met, those students were sent a consent form and then an interview was scheduled. The dataset for this project was ten current engineering students who indicated they met our criterion for PSF. We selected and interviewed the first ten participants who responded to the survey who met our pre-screen criterion. We did not differentiate where the PSF had completed their previous engineering education. The identity markers for our PSF are presented below in Table 1. These are how our PSF self-identified when asked their ethnicity, pronouns, and other dimensions of their identity. These identity components are important to present, though not integral to our analysis since we as a research team acknowledge how our personal experiences and identity influence our perceptions and lived experiences. It is important within engineering education to include a broad range of participants within research [25]. Thus, we want to present our participants as they choose to present themselves.

The semi-structured interview was comprised of questions written by the second author, who has over ten years of experience interviewing students and teachers about engineering, and an engineering education researcher with over 20 years of experience interviewing students and teachers about engineering. Many of our questions related to learning processes

TABLE I: PSF IDENTITY

PSF Pseudonym	Gender	Year	Major	Undergrad Location	Industry Experience	Teaching Experience	Ethnicity	Additional Dimensions
Jeff	M	1	Biomedical	Canada	No	No	Asian	No
Scott	M	1	Industrial	USA	No	No	White	LGBTQ
Faye	F	4	Mechanical/ Aerospace	USA	Work full time	No	White	No
Janelle	F	4	Chemical	China	No	TA	Asian	No
Morgan	F	4	Industrial	USA	Work full time	TA	White	Non-Traditional
Alex	M	3	Industrial	India	Internships	Solo and TA	Asian, Indian	No
Bob	M	5	Computer	India	Internships	Solo and TA	Asian	No
Jeanne	F	5	Industrial	USA	No	Solo, TA, Adjunct	White	LGBTQ, First Gen, Low-income family
Deepika	M	3	Chemical	USA	No	TA	Black	Low-income family
Red	M	2	Chemical	USA	Internships	No, Expect to TA	White	No

and teaching methods, as these were our key areas of inquiry with this project, and we anticipated finding some connection between these key areas of inquiry within our participants. Below, we present a subset of questions from our interview protocol, which probe learning processes and teaching methods.

- Describe your favorite learning activity or learning experience in your undergraduate education.
- How do you learn engineering knowledge?
- How do you learn engineering practices?
- How do you think other students learn engineering? Can other methods than yours be effective?
- How do you plan on teaching engineering?

TABLE 2: THEMES

Theme	Definition	Examples
Learning Process Themes		
Interest	PSF noted that personal interest in the topic improved their learning	"I **enjoyed [the classes] that I thought was effective** in teaching me things" -Deepika "**so cool to like take a code that was like a simulation so that you may see industry and then like make a modification to it that was requested** " -Red
Applications	PSF stated seeing knowledge applied improved their understanding	"**Actually seeing like how you apply those principles and use them to solve a problem or design something was the most useful for me**." -Faye
Projects	PSF noted the use of projects for learning a topic or being assessed	"So I think **project or doing project design is actually really helpful** when you get to like more later stage engineering" -Red "**get involved in some of some projects which actually use that concept**" -Alex
Personal Actions	Actions PSF preferred to engage in for their own learning	"**Reading books trying to find some YouTube videos** which have which, like use that concept to showcase some application and **then like learn from that**." -Alex "it's basically **reaching out to the person who is good at it**." -Bob
Methods	PSF discussed various methods by which their learning of a topic was enhanced	"flexibility of just, **come up with your own ideas** of how to do it. **The freedom and the flexibility**. To be fully creative" -Scott "great opportunity to **actually get taught from somebody that was working in industry**" -Morgan
Labeled Learning Process	PSF had a definition for their learning process: either an established term, a self-defined label, or a definition from which the researchers could derive a label	"Pick a topic, **search about it, come up with your own notes and that it's kind of an unsupervised way**"-Bob "I love **collaborative learning**. I am very much of a visual person " -Jeanne "Usually you do that first, you like do the reading you do the theory first, **I do that last. I learn backwards"** -Red
Number of Valid Learning Processes	The number of learning processes the PSF considered valid or potentially successful within engineering	"If someone wants to learning engineering**, this is the way everyone follows**" -Alex "**it's different ways of learning things so. isn't necessarily, the only way to do it**"" -Scott
Teaching Methods Themes		
Resources	PSF noted they would provide resources or tools to students for self-guided learning	"**A list of resources for students**." -Jeanne "**know what the open courses are out there**"- Bob
Interactions	PSF asserted they would work to get students to engage and interact	"Like making sure everyone is interested**. Making the students ask me questions**" -Alex "I'll give you the resources **and ask me questions**" -Deepika
Multiple Presentations	PSF stated they would present material in a variety of manners and media	"Then inclusively bring in **different ways of presenting that information so that everybody styles** are met" -Morgan "**everybody. takes a. little bit of all** of those learning styles" -Faye
Course Activities	PSF noted some activities which they would use within the confines of a course	"I like **projects where the problem is kind of ill defined** " -Jeanne "**group-based learning**." -Morgan
Application	PSF described presenting applications of the content they taught	"Hackathons or some something hold is like an external event which helps again **students diversify their knowledge about what they are getting into**" -Bob
Course Strategies	PSF described several strategies which they would use over the duration of an entire course	"**Student led project, some realistic problem**, students come up with solutions" -Alex "giving **students open ended problems**" -Deepika
Student Centered Ideas [26]	PSF discussed ideas which they had in their theorized teaching which would be classified as student-centered	"there's **no wrong answer, it's how you defend your answer**, that is what makes it right or wrong." -Morgan "I want to know **did you gather the concepts from last week**" -Faye
Teacher Centered Ideas [26]	PSF discussed ideas which they had in their theorized teaching which would be classified as teacher-centered	"My role is to be a **dictator, in learning**, I think. You have to have control over like the direction of the class" -Red "[Students] **read ahead of time** and they come to class, to me they **put the effort that they want to learn** this and then **I can explain**" -Faye

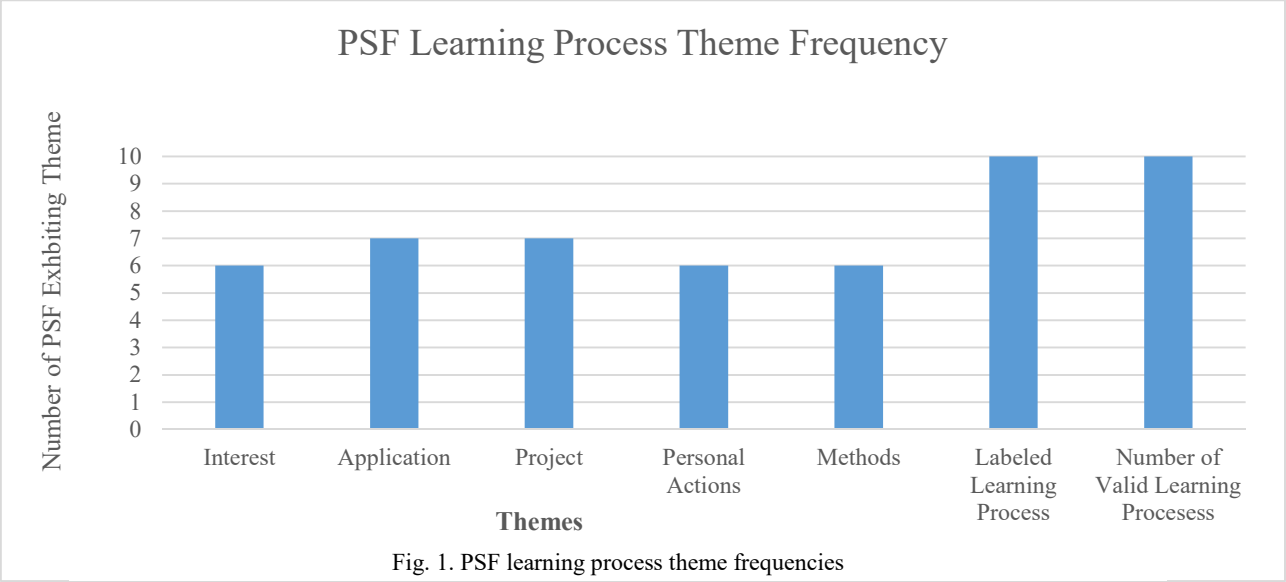

Fig. 1. PSF learning process theme frequencies

IV. DATA ANALYSIS

Data analysis proceeded via thematic analysis with frequent collaborative comparison between the two authors. We elected to utilize inductive thematic analysis as this study is exploratory in nature, seeking to better understand PSF learning processes, teaching methods, and the connection between the two, if any.

We followed the thematic analysis process set forth by Braun and Clarke [18]: familiarize oneself with the data, generate initial codes, search these codes for themes, review the data for further instances of those themes, define and name the themes, and generate a report. Familiarization was accomplished through the initial transcription process. A total of five passes through the data were performed between the two authors to find codes, which could be words or key phrases. Initial codes were generated from the data, specifically the questions relating to learning process or theorized teaching methods. This process defined in Braun and Clarke [18] specifies a code as the initial step, located when examining the text in depth, and can be anything that indicates the presence of an idea or important topic. The codes were then grouped with similar items into themes, which guided our next pass through the data, searching for further instances of these themes. The process we followed as defined in Braun and Clarke [18] specifies themes as groupings of codes, with defined labels.

We compiled all the instances of these themes and examined each theme along with the codes which compose it to determine an appropriate name for the theme, as is described in more detail below in the findings. These themes could have arisen from multiple codes which were grouped under a cohesive theme to describe a core facet or component of the PSF's learning process or teaching method. We created a set of Learning Process themes and a set of Teaching Methods themes. Our learning process themes are *Interest, Applications, Projects, Personal Actions, Methods, Labeled Learning Process,* and *Number of Valid Learning Processes*. Our themes relating to Teaching Methods are *Resources, Interactions, Multiple Presentations, Course Activities, Application, Course Strategies, Student Centered Ideas,* and *Teacher Centered Ideas.*

V. FINDINGS

We found seven themes within PSF learning processes with a total of 34 different codes which led us to these themes. We found eight themes within PSF with a total of 34 different codes which led us to these themes. Table 2 above shows the themes for both learning process and teaching methods, alongside those codes, a definition of the theme, and several PSF quotations which illustrate these codes.

Figures 1 and 2 present the PSF's description of their learning process and teaching methods, respectively. We noted the frequency of each theme, or how many PSF exhibited each theme. Below we present some examples of the emergence of these themes.

A. Learning Process Themes

Example 1: *Labeled Learning Process*

The theme *Labeled Learning Process* we define as when a label or defined term could be applied to a PSF's learning process. There were three primary types of codes which led to this theme: PSF presenting a defined label for their learning style which they developed, PSF ascribing to a defined learning style as created by Pashler et al [17], or a descriptive title being provided by the authors based upon the PSF's description. We found 15 total references to a *Labeled Learning Process* within our interviews.

One example of this theme is how Jeanne described her learning as a "Visual Learner," ascribing to a commonly accepted learning style such as discussed in [17] or [27] present within learning sciences literature as described by [28]. Similarly, Red defined his own learning style with a personal label, stating that he learns with a "very backwards way of doing things," characterizing his learning as backwards. He explains this to be that he searches for an example problem or

application to learning, then works from that example to the core theory of the topic he is learning.

Deepika provides an example of the third type of code within this theme, as he never labeled his learning style. However, we developed the code "Self-Directed Learning" (within our theme Labeled Learning Process) from his description of his learning. Deepika described his learning, how "the times I learned was when I actually read the textbook before coming into class. I felt like the lectures if I wasn't doing the readings were not effective," and that he found most productive the times when he was "struggling with the problems and trying to solve and figure out how to do it so you look through the textbook, look through example problems and it's a really good way to learn." From this description we developed the code "Self-Directed Learning" within our theme *Labeled Learning Process* to encompass this process. "Self-Directed Learning" was the most frequent code within this theme, appearing five distinct times within the data. PSF showed an unexpected level of reflection and metacognitive awareness of the methods by which they learn.

Example 2: *Application*

The theme of *Application* emerged as many of our PSF discussed requiring some description of the application of a topic, concept, or theory in order to finalize their understanding of the topic. Within this theme there were two codes, "Application for knowledge" and "Real world application," which occurred a total of nine times within our interviews.

Morgan presented the theme of *Application* within her description of her learning, stating that "you can learn something conceptually in a book, but if you don't understand how it's applied it doesn't really sink in," and specifically recalls getting to "design practical projects which I loved." This was an example of our code of "Real world application" due to the requirement for application being not just an application, but an application within a practical project. Scott states in describing his ideal learning process that "I think having applied projects is very useful to help give…some sort of application visibility of that theory." This falls under our code of "Application for knowledge" as Scott asserts that an application of a theory is very useful. Within the theme *Application* the code "Application for knowledge" was present six times, while the code "Real world application" was present only three times.

B. *Teaching Methods*

Example 1: *Multiple Presentations*

This theme relates to PSF who describe within their teaching methods utilizing multiple presentations of materials, either via multiple styles, media, or attempts to present the material. Across the three codes for this theme, we saw six instances.

Morgan exhibits this theme when she states a desire within her future classroom to "inclusively bring in different ways of presenting that information so that everybody's styles are met." This is an example of the code "Diverse methods of presentation." Alex presents the same theme. Alex describes teaching towards students "definitely [changing] my approach based on what how they learn. Someone wants to learn only by textbook he can learn only when I give out like some equations, or give out some monotonous lectures, adopt my style to match that." This we coded as an instance of "multiple presentations."

Example 2: *Resources*

Several PSF noted within their descriptions of teaching methods that they would provide resources and tools for their students, allowing students to engage with these resources outside of the classroom for structuring their own learning. We found five instances of this theme within our interview data.

Jeanne is explicit in this, desiring to compile and present "A list of resources for students." This is an explicit example of the code "Produce Resources." Bob presents this theme when he discusses advice; he counsels students "if they're not understanding [what the] Professor [is] saying what I try to tell students [is] it doesn't matter, just take notes on what exact topic has been taught, go back, look at the open courses which are out there. If still you do not understand then go [into some] books which are recommended."

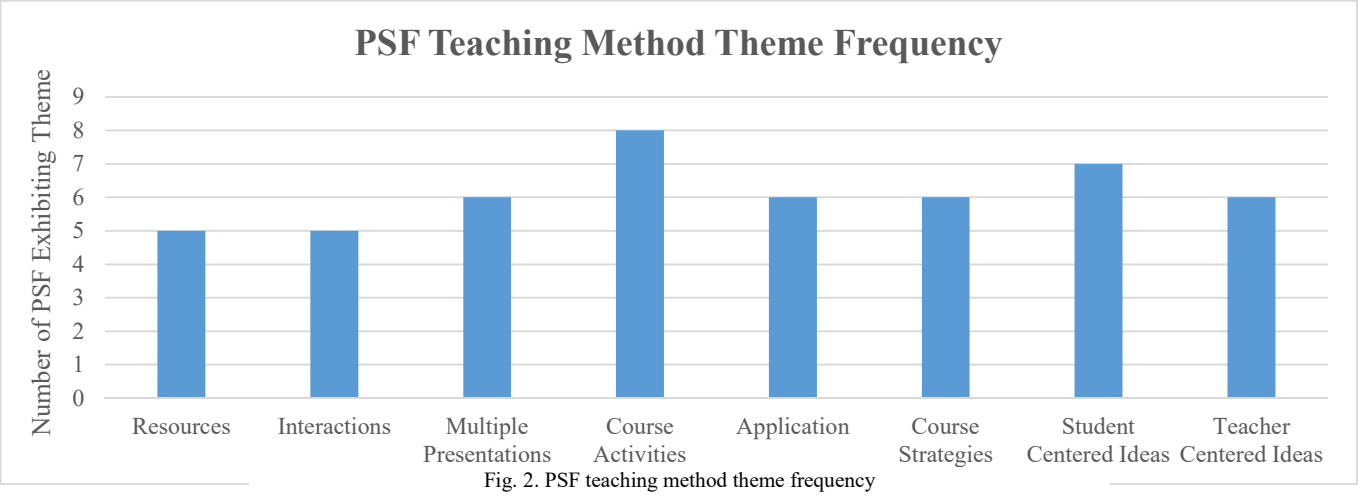

Fig. 2. PSF teaching method theme frequency

VI. DISCUSSION

We found that PSF had surprisingly metacognitive awareness of their learning processes and were able to provide rich descriptions of their personal process and key components which enhanced it. They were also able to describe their idealized version of teaching methods, despite a majority of our participants having no teaching experience or having solely served as a TA. Due to our interview protocol seeking to understand if there is a connection between the learning process and teaching method, we sought commonalities between the individual PSF's description of the two, and themes which emerged from that description. We found a clear, though indirect connection between the two concepts. We also seek to develop professional development interventions to teach and better equip these PSF to teach engineering in more student-centered, active, constructivist manners. Thus, our findings are very encouraging in that even without formal education in these methods, PSF are arriving at constructivist ideas independently.

We see two key items within both learning processes of the PSF and their described teaching methods: PSF show clear influence of their personal learning process upon their teaching, and PSF described utilizing more constructivist pedagogical strategies or methods such as described in [19-24] within their teaching methods than we anticipated. Thus, these PSF are already thinking about their teaching in a more nuanced manner than we anticipated. The PSF are considering being more active, engaged, and student-centered in their teaching methods even though the majority of them did not use the vocabulary education researchers or professional development facilitators commonly use to describe such methods.

A. Influence of Learning Process upon Teaching Method

Within each PSF's descriptions of their learning process and then their teaching methods, we see a clear connection between these items. The majority of our PSF described teaching towards themselves and their personal learning process, at least in their initial description of teaching methods. Eight of our ten participants described teaching towards their personal method at least in the initial description. Two clear examples of this which we found within our interviews were Scott and Morgan.

Scott describes his most memorable learning experiences involving "flexibility of just, come up with your own ideas of how to do [project]," and describes his own learning process as "find the theory, practice problems, then find some application." This process is directly mirrored within his description of his theorized teaching methods. He describes teaching "focused on like theory, background… have like projects or more like applied experiences," structuring courses to navigate between "background theory, then you have a project, and then you do more theory," running classes similar to a "research type class." Scott also stresses the value of projects, that if you "realize that you're actually going to use it in a future job or YouTube project or something, then you're much more willing to learn." Finally, Scott also describes using "multiple small projects" for the majority of his assessment.

All of these factors line up with his personal process. He describes teaching in the same sequence of topics by which he learns, theory to background to application, and using similar techniques which he found effective: small, applied projects as well as things which are useful beyond the confines of the course. We also see a disconnect between Scott's beliefs on learning and teaching. Scott believes there are multiple viable learning processes, yet only describes teaching towards his process.

Morgan describes her learning as best accomplished cooperatively and iteratively, learning well by using a "hands on way to teach myself" and emphasizing the value of working "in study group type settings," since "helping them understand [some concept] helps further solidify that [to] you," which combine to suggest her learning process being rooted in "diversity of thought and collaborative learning." Morgan summarized her thoughts on learning engineering, stating that "Engineering at the end of the day is the systematic approach that's repeatable."

This feeds into her teaching methods. Morgan states her core concept on teaching is "Un-locking [students'] freedom of thought" and emphasizes a desire for them "to take all the information and synthesize it and make their own decisions. To feel confident that they have the right amount of information to make an informed decision and then recognize the limitations." She discusses using projects to accomplish this, specifically projects "where they have to either design or build some kind of structure that meets these requirements… then the end of the project includes a reflection [on] how would they do it differently if they were given a different budget? There's no wrong answer, it's how you defend your answer." Morgan also stresses a desire to utilize "group-based learning," and within the classroom utilizing "different ways of presenting [some concept] so that everybody's styles are met throughout a series of classes." Thus, we can clearly see a link between Morgan's personal learning process and her teaching methods. She discusses how she believes she learns well within collaborative environments, so utilizes group-based learning in her classes. She learns by teaching herself as well, so enables students to accomplish this via design projects. She mentions a learning belief about engineering being an approach process, thus defining her teaching goals as allowing students to scope their solution and grading more on the defense of that solution instead of its correctness, shifting students to more of an industrial mindset instead of the academic correct answer mindset. Within this we can see both her influence of having worked within industry prior to returning to graduate school, and her experiences within her undergraduate program, where she recalls a "great opportunity to actually get taught from somebody that was working in industry."

This finding agrees with the work done by Hora and colleagues [23]. Hora et al found that the most impactful factor upon the teaching of engineering faculty was iterations

of a course and that faculty members' ability to iterate was the most significant change upon course teaching, followed by the way the faculty learned. Since our PSF have had minimal to no teaching experience and thus cannot have that influence upon their teaching, our finding that the most impactful factor regarding teaching was the way the individual learns echo theirs.

This inclination of teaching towards themselves and their own learning process, at least initially, we see repeated within the majority of our PSF. Agreeing with Hora et al [23], none of our PSF described teaching exactly towards the way they learn. The noteworthy exceptions to this were Jeff and Red. Red noted he would teach opposite the way he learns, but also classified the way he learned as "backwards," since he stated he preferred to learn "applications, then theory" and this was an intentional choice to attempt to teach towards what he assumed to be the dominant process within engineering students.

A possible reason for these PSF describing teaching not exactly in the manner which they personally learn is the majority of our PSF considered there to be other equally viable learning processes in addition to their own, with the exception of Jeff and Alex stating that their process was the only viable process, and Bob stating that all students in the program he was in learned the same way. This acceptance, awareness, or expectation of a variety of viable processes for learning thus impacted the teaching methods which these PSF described and was an unexpected item within the data.

B. Productive Beginnings of Constructivist, Student-Centered Teaching

We see a surprising, unexpected, and heartening presence of constructivist ideas, including student-centered learning and active learning, which we define in alignment with Felder [24]. Figure 3 below presents Felder's breakdown of traditional or constructivist techniques within an engineering classroom [24]. Traditional techniques include lectures, solely individual work, and teaching without set objectives from a set syllabus, while constructivist techniques include group work, discussion-based learning, flexible content, and using a variety of teaching or presentation methods.

Traditional	Constructivist
Passive Presentation of Material	Inductive Learning
Purely Lectures	Problem/Project Based Learning
Content Dense Slides	Open ended/Poorly Structured Problems
High Stakes exams	Creative Thnking
Singluar Teaching Method/Style	Learning Assessments
Focus on Algorithmic Learning	Variety of methods utilized
Derivational Processes	Discussion Based Learning
Teach without objectives	Group Work
Set Syllabus	Showing Applications
Individual Work	Flexible Content/Context

Fig. 3 Categorization of teaching actions

From this categorization we were able identify the constructivist tendencies within these PSFs' teaching methods. We examined all of the actions, stances, methods, and activities which our PSF described using within their teaching methods, and then determined what percentage of those were

Teaching analysis- More Constructivist or Traditional

More Constructivist	%	More Traditional	%
Scott	84	Jeff	25
Faye	82	Bob	33
Morgan	78		
Janelle	100		
Alex	87		
Deepika	78	% are percentage of themes	
Jeanne	89	related to teaching or actions described	
Red	55	which fall under Constructivist methods	

Fig. 4. Classification of PSF teaching methods

traditional methods by the categorization of techniques above. This breakdown is shown in Figure 4. Thus, the vast majority of our PSF describe teaching significantly more via constructivist techniques than traditional, yet even the PSF who describe using more traditional techniques still have some constructivist techniques within their described teaching methods. We find this encouraging, as this represents strong beginning knowledge or instincts within our PSF as to the use of more constructivist techniques within the classroom.

We also found an unexpected area of potential in our interviews. Several of our PSF, when asked about how they would teach, discussed significantly more progressive pedagogical styles than are typically seen within the engineering classroom, though the majority of these participants did not use the common academic vocabulary for describing these pedagogies, leading us to suspect that these PSF did not have formal awareness or training in these methods, but rather aligned instincts. Figure 5 below presents these progressive pedagogies. This shows that there were three progressive pedagogies which our participants discussed: Problem or Project Based Learning as defined within [19], Learning Focused Education such as presented in [20-21] or inductive learning as defined by [22]. We note that there is a significant difference between Problem-Based or Project-Based Learning, yet our participants described the core values of what could be either method: using the content learned in an applied manner, very often described through the context of projects. We here use Learning-Focused Education to describe the wide variety of progressive ideas which runs the spectrum from ungrading to student-centered formative assessments. Again, since our PSF were not using the vocabulary commonly used by education researchers or professional development professionals, we group the ideas by similar concept.

VII. LIMITATIONS

Progressive Pedagogy described	PSF Presenting	citation
Inductive	Alex	22
PBL	Red, Scott, Alex, Morgan, Bob	19
Learning focused education	Red, Faye, Morgan, Jeanne	21

Fig. 5. Progressive pedagogy presentations

One of the limitations of this study is that the majority of our PSF are only theorizing on their course design. Only half of them

have TA experience, as summarized within Table 1, and only three of them have primary teaching experience. Thus, the majority of our PSF are describing their theoretical teaching methods, and the PSF who have had solo teaching experience were still constrained within their course design considerations. Furthermore, this is a single data point snapshot. Additionally, we note that with interviews there is always bias, as interviews are inherently a performance and there is coloring of the data both by participant's verbalization of concepts and by the interviewer's interpretations of those verbalizations of concepts.

Our questions yielded descriptive processes and mechanisms rather than definitions or personal descriptions. Thus, our findings are limited to the PSF and their "theorized or enacted teaching methods" rather than being able to extrapolate to broader claims regarding teaching and learning. This is a major area of improvement and iteration within future works on this project.

We acknowledge the weakness within our thematic analysis; due to our PSF describing processes for learning and teaching rather than their definition of the ideas of teaching or learning, the HOW over the WHAT, our analysis is lacking information to become complete. Future works will attempt different methodologies, seeking to more clearly describe the connection between the PSFs' learning and their teaching.

VIII. Implications and Future Work

While our preliminary results are promising, more work needs to be done to further construct professional development courses and workshops for PSF. As this area of research is rich for further exploration, we enjoin other engineering and STEM education researchers to explore PSF as well as postdoctoral, teaching faculty, and faculty development on stances and conceptions of learning and teaching. As noted previously, TA trainings and some very limited apprenticeship models currently exist to train PSF, yet these follow a just in time model focused on quick results and not an investment in developing faculty. We argue, and with these results see the potential for, programs for PSF to learn educational theory, constructivist and student-centered teaching strategies, and how to listen and respond to student thinking such as within [30-32].

Continuing to work towards this goal, we plan to continue this preliminary work in a few ways. First, we plan to perform additional analysis upon this data, along phenomenological lines, and conduct additional interviews with an adapted protocol developed for phenomenological interviewing, following the protocols set out by Vagle [29]. We also plan to apply additional analytical methods upon this dataset, seeking to deepen the analysis informed by topics which our thematic analysis rendered visible, such as further exploration of the connection between personal learning style and enacted or theorized teaching methods.

Second, we will revise our interview protocol, modifying the language of the questions that were written in the language of educational researchers well-versed in theory to general language more familiar to our PSF. For example, while we see a distinction between engineering concepts and practices, our participants did not view these as two distinct items and therefore answered questions relating to both concepts similarly . We anticipate this as a next iteration, not a final protocol.

Third, we plan to follow some PSF through teaching apprenticeships or their first faculty position if they agree to continue to participate in our study. This would allow us to compare their teaching to their initial conceptions and ideas, and understand how these were enacted. We hope these results will further inform our goal in creating interventions, through either courses or workshops, for PSF, and contribute to a shift in engineering teaching.

The findings from this preliminary work, including PSF descriptions of their learning process, thoughts on teaching, and the connections between these two serve as insights upon which to build further research. PSF showed unexpectedly metacognitive awareness of their learning process, as well as a surprising number of them accepting the existence of additional viable learning processes beyond their own. PSF also described teaching in significantly more constructivist manners than anticipated. We expected to see much more behaviorist, traditional techniques within their descriptions of teaching, and are pleasantly surprised. PSF also showed marked inclinations toward using progressive pedagogical methods. Further discussion and formal training could build upon these inclinations, thereby supporting PSF to enact progressive pedagogies in their future classrooms. This in turn, would support the development of additional progressive, student-centered classrooms.

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