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WIP: Chemical Engineering Faculty Attitudes Towards Evidence-based Instruction Practices and Growth Mindset

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WIP: Chemical Engineering Faculty Attitudes towards Evidence Based Instruction Practices and Growth Mindset

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Introduction

In the Chemical Engineering (CHE) department at a large public R1 university, we are working on changing the climate and culture of our department through a multipronged approach involving students, faculty, and alumni. In working towards this change, we are gathering data from our stakeholders with the goal of initiating substantial and lasting change. In this work in progress (WIP), we will share our data gathering process and some of our early feedback from our faculty, who will be agents of this change.

The CHE department at Penn State is one of the larger chemical engineering departments in the United States, graduating around 150 undergraduate chemical engineers per year and having 32 faculty members. A unique challenge and opportunity for our department is that roughly 25% of our students enter our program from another campus sometime during their second year. These students must adapt to a new campus while simultaneously engaging in their first two major-specific CHE courses. To ensure that the department is equipping our graduates with the appropriate skills and knowledge to thrive in the modern workforce, we first approached the departmental change through the lens of curriculum revision.

Over our long history, we have made curriculum changes to meet the changing landscape of chemical engineering and student needs, although the last major curriculum revision for our department was in 2015. However, with the evolving accreditation requirements from ABET [1] and other institutional demands, our curriculum has become increasingly rigid and difficult to adapt to individual student needs and timelines. The inflexibility of the curriculum became particularly salient after we returned to campus in the wake of the COVID-19 pandemic, and we also noticed that the culture in the department felt lacking in certain aspects, especially as it pertained to student engagement in the classroom and a perceived disconnect between different groups in the department (e.g., undergraduate students, graduate students, faculty). So, although we initially intended to update our curriculum, we quickly realized that focusing on improving departmental climate and culture would create more substantial and sustainable change.

The departmental culture surrounding teaching is the focus of this WIP, as we sought to explore how faculty perceived their role in instructional change efforts. Several researchers have demonstrated that achieving instructional change is difficult. Cruz et al. (2019) conducted a literature review and summarized the factors that impact change initiatives in engineering departments into six primary categories: culture, change management, institutional support, pedagogical knowledge, student's experience, and faculty motivation [2]. This solidified our belief that we needed to take a few steps back from the curriculum work and instead gather comprehensive data from our key stakeholders in the department (faculty, students, and alumni). The purpose of this data gathering and feedback process was two-fold: 1) to get a better understanding of these factors as they exist in our department post-COVID, and 2) to illustrate our desire to co-construct a shared vision of change within the department to increase "buy-in" from faculty and students themselves. Over time, it became clear that faculty would likely be the major drivers of change in these efforts; therefore, we center faculty perspectives in this WIP.

Focus Group Discussions

Our initial step in the data-gathering process was a series of six focus groups to better understand the needs and frustrations of current students and faculty. To encourage authentic responses from focus group members and to foster a sense of psychological safety, we asked engineering education researchers from another university to conduct these in-person focus groups. The external researchers conducted three one-hour focus groups with sophomore, junior, and senior students respectively, as well as two focus groups with faculty, and one focus group with graduate teaching assistants. Faculty were divided into two focus groups: those teaching junior-level and those teaching senior-level core courses. Topics covered during the focus groups included the awareness of Evidence-Based Instructional Practices (EBIPs) and their use in the classroom [3], [4], how participants felt that the curriculum could be enhanced to better support students, career discovery, and their perception of the current diversity and inclusion in the department. As the focus of this WIP is on faculty perspective, we will present student focus group perspectives in future work.

Results from the focus groups indicated that faculty felt that the department as a "whole is less than the sum of [its] parts," and suggested that there was a lack of shared vision among faculty, leading to classroom efforts feeling siloed rather than a part of an integrated framework of student development across the curriculum. Furthermore, there was a general sense of helplessness when it came to enhancing the curriculum, citing concerns that the curriculum already felt too rigid and overloaded. Faculty recognized that representation and equity problems existed, in that different students entered the program with a wide range of experiences, skills, and knowledge. Diversity and inclusion efforts to help reduce these differentials were recognized for their value, although faculty felt they needed more guidance to improve effectiveness. Regarding the use of EBIPs, faculty expressed openness and a willingness to learn, but identified the biggest barriers to adopting EBIPs as: 1) lack of time, 2) lack of formal exposure/training to these tools, 3) impenetrable or difficult-to-understand literature surrounding their use in engineering education, and 4) confusion surrounding how and which EBIPs would best be applied in the specific courses they teach.

Faculty Retreat Discussions

Analyzing the focus group data across both faculty and student stakeholders, our team and the external educational researchers worked together to curate ten potential "goals" for the departmental change effort that would address the sentiments expressed by focus group participants. We then brought these goals to a spring faculty retreat, in which the faculty were invited to use these goals to help brainstorm and formulate a list of potential "aims" to guide the departmental change efforts. Following collective brainstorming, we engaged faculty in a cascading agreement multi-voting activity to prioritize which aims they felt were most important to address as a department [5]. Facilitating this collaborative strategic planning technique allowed us to ensure that all faculty had a chance to express their opinions in small groups without feeling that any one departmental leader was influencing the activity too heavily.

After the cascading agreement activity, we were left with a prioritized list of five aims. We then asked faculty to discuss student outcomes and specific, actionable tasks that would be associated with each aim. There was great engagement and enthusiasm at the retreat, even more so than anticipated, which was highly encouraging and further underscored the faculty's willingness to support change to benefit student learning.

One of the top three aims was to incorporate Evidence-Based Instructional Practices (EBIPs) into our teaching strategies by actively educating and supporting our faculty in implementing EBIPs in their classrooms in ways that highlight their direct applicability to the courses we teach. In our next step, we designed a faculty survey with questions to explore faculty attitude to growth mindset in teaching chemical engineering as well as what resources and support they felt they would need in order to make changes to incorporate EBIPs in their teaching.

Faculty Survey

The faculty survey was designed to help quantify faculty opinions on the curriculum, teaching practices, and the mindsets in teaching chemical engineering. The Yeager et al. 2022 study found that teacher mindset in high school math teachers was a key factor for a student mindset intervention to be successful, and cultivating a student's growth mindset needed intentional teacher support [6]. With that in mind, we decided to find out how our faculty felt about growth mindset.

The term "growth mindset" refers to those who believe that abilities and intelligence can be developed over time (for example, a belief that students can improve their math abilities through study practice) [7]. In contrast, those who subscribe to a "fixed mindset" believe that abilities are fixed – that is, that each person has innate skills and abilities that cannot be changed; for example, someone with a fixed mindset may suggest that studying will not help them, because they are "just bad at math."

Our hypothesis is that faculty who have a fixed mindset may resist incorporating EBIPs into their teaching. While not as strong a predictor as trust in the instructor, a recent study by Wang et al. (2021) found that undergraduate STEM students who subscribed to a more fixed mindset tended to exhibit much less "buy-in" to engaging with EBIPs in the classroom [8], and we feel this trend may also exist in instructors who do not believe that one can improve beyond their initial abilities in CHE.

In total, we achieved a 75% response rate from 28 core targeted faculty on the survey. We did not include faculty on leave or sabbatical and did not try hard to get responses who have mainly administrative duties (deans). One part of the survey presented the following three statements (the first two are adapted from Yeager et al. [6]) and asked whether respondents agreed or disagreed on a 6-point Likert scale:

1) People have a certain amount of intelligence, and they really can't do much to change it.
2) Being a top chemical engineering student requires a special talent that can't be taught.
3) Successfully completing a chemical engineering degree requires a special talent that can't be taught.

The first statement is a general fixed versus growth mindset statement. The second statement is specific to CHE. The third statement we added ourselves, as we thought there could be a perceived difference of opinion between a student simply being successful in the degree program versus being a “top student” (however the faculty respondent may choose to define that).

In another segment of the survey to aid our curriculum development efforts, we presented a list of 23 skills/knowledge/experiences important to chemical engineers (e.g., critical thinking, process design, research experience, technical writing, public speaking, use of spreadsheets for data analysis, study abroad etc.). For each skill or experience, we asked faculty to rate it on the following scale for how important they felt it was in relation to being taught in the official curriculum:

Must be required (essential)	5
Should be required (highly valuable)	4
Doesn't need to be required (but still valuable)	3
Not as valuable	2
Not valuable	1

In the final survey segment, we asked the following open-ended questions to evaluate current teaching practices, willingness to learn EBIPs, and the desired support necessary for faculty to learn and implement EBIPs:

- What are you doing to improve student learning? (e.g., techniques, strategies, resources)
- What are students doing to improve their learning in your classes?
- What else is helping to contribute to student learning in your classes? (e.g., environment, setting, timing, etc.)
- What would you like to change in your course to improve student learning, if you had the necessary time/funds/support?
- What would you need (in terms of support, training, etc.) in order to be able to make those changes to improve student learning in your courses?

Preliminary Survey Results and Analysis

Our external research partners at Clemson University were able to tease out response trends among faculty along tenure lines, as well as separate the responses of white male faculty versus other faculty (i.e., all women and non-white men). These responses were presented in aggregate to the Penn State research team as long as the groups were large enough to remain unidentifiable in order to support ethical validity of this work. We feel that having our research partners at Clemson send out invitations to the survey helped boost the response rate significantly, and we achieved a 75% response rate from our faculty.

Regarding the growth mindset statements (restated below) results show that faculty somewhat disagree with (1), are neutral/somewhat disagree with (2), and disagree with (3). There is a large standard deviation with these responses, especially for (2). Although faculty believe, on average, that all students can learn chemical engineering, faculty feel that some inherent intelligence or skill is needed, indicating that at least some of our faculty do not subscribe to a growth mindset. Faculty are less convinced about the ability for any student to become a top student.

1) People have a certain amount of intelligence, and they really can't do much to change it.
2) Being a top chemical engineering student requires a special talent that can't be taught.
3) Successfully completing a chemical engineering degree requires a special talent that can't be taught.

The responses to the three growth mindset statements were also differentiated by full tenured professors and other faculty members (assistant/associate professors and all levels of teaching faculty). In a second analysis, these responses were then differentiated in terms of white male respondents versus all others. These comparisons are illustrated in Figures 1, 2, and 3.

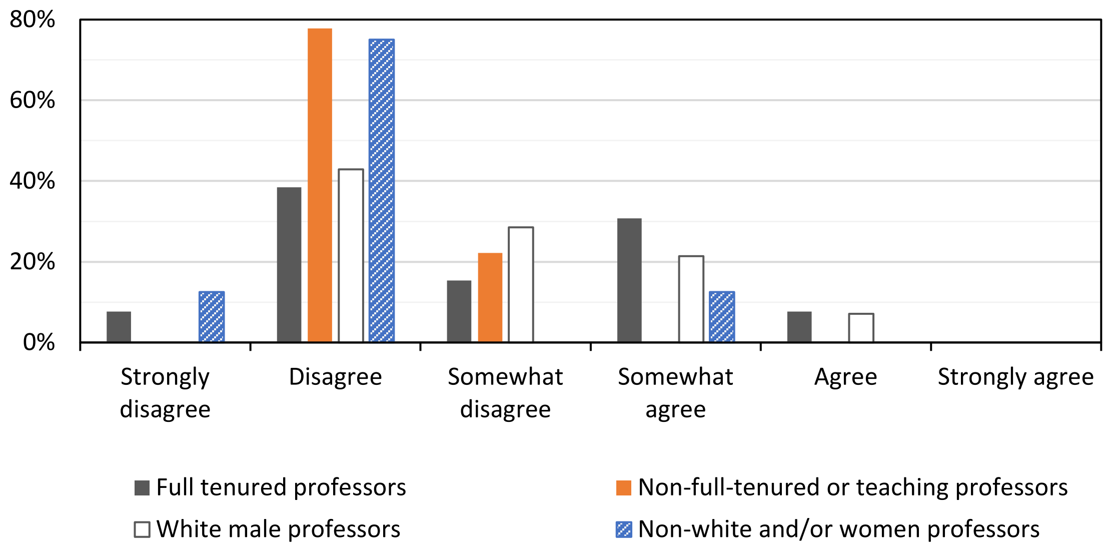

Figure 1. Responses to growth mindset statement #1: "People have a certain amount of intelligence, and they really can't do much to change it."

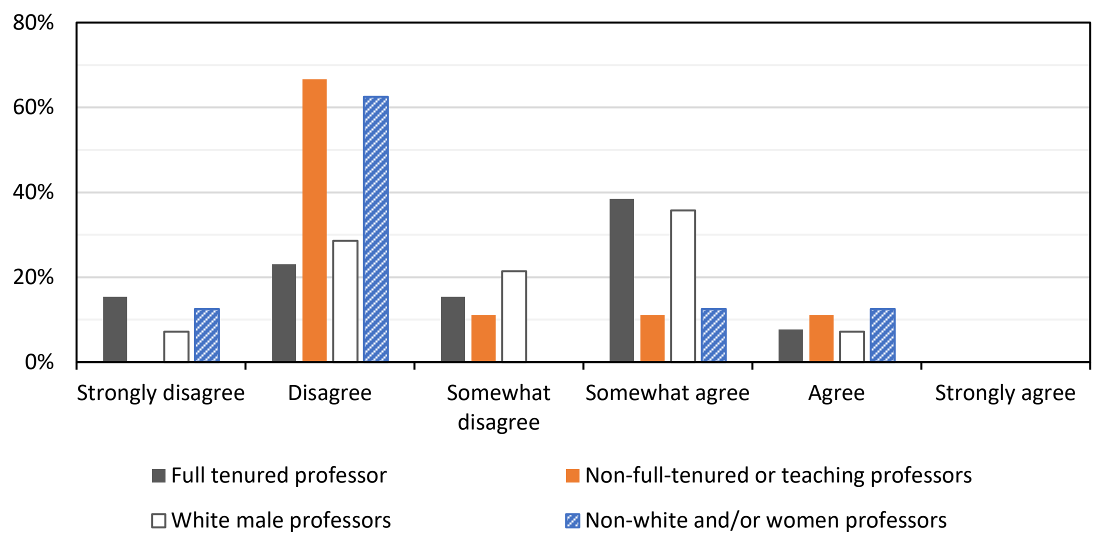

Figure 2. Responses to growth mindset statement #2: "Being a top chemical engineering student requires a special talent that can't be taught."

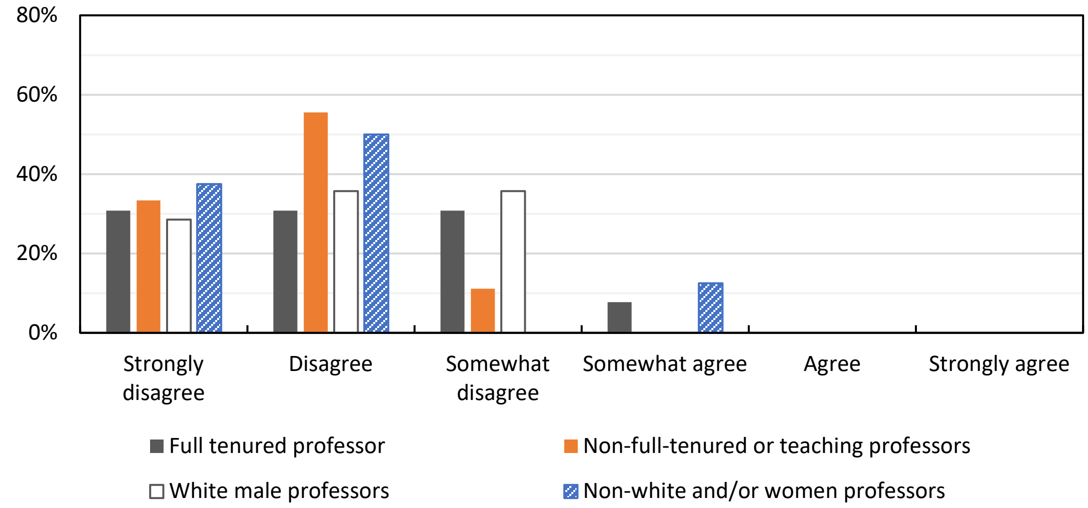

Figure 3. Responses to growth mindset statement #3: "Successfully completing a chemical engineering degree requires a special talent that can't be taught."

The non-full-tenured or teaching professors group shows a larger concentration towards disagreement with the statements than the tenured group, and only a few agreements for the "top engineering students" statement. This may point to an age distinction, as fully tenured professors tend to be older than the faculty in the non-tenured group. However, our numbers are too small to parse out these differences by age and remain unidentifiable.

The data was also examined in terms of white male respondents versus all other faculty (i.e., non-white and/or women professors). The non-white and/or women faculty responses showed a much stronger clustering towards the disagree of the statements, suggesting that this group may hold more of a growth mindset than the white male respondents.

Diving a little deeper into the individual responses, we found that only one full-tenured professor agreed with all three of the growth mindset (GM) statements (indicating that they may lean towards a more fixed mindset); however, this respondent did not provide any open-ended responses. This represents only 4.6% of our total chemical engineering faculty and 7.7% of chemical engineering full-tenured faculty. No other respondent agreed with all the GM statements. This is also the only faculty that agreed with the third GM statement about successfully completing a ChE degree requiring special talent.

Secondly, we found that 40.9% of the total chemical engineering faculty agreed with at least one of the GM statements.
This can be broken down to be understood as:

- 54% of full tenured professors
- 22% of non-full-tenured professors
- 50% of white male professors
- 25% of non-male or minority professors

Interestingly, not a single non-white faculty agreed with any of the growth mindset statements, suggesting that these faculty are more likely to encourage a growth mindset.

Moreover, 18.2% of the total ChE faculty agreed with at least two of the GM statements. This can be broken down to be understood as:

- 31% of full tenured professors
- 0% of non-full-tenured professors
- 21% of white male professors
- 13% of non-male or minority professors

In summary, when we look at the GM statements but separate out full tenured professors from all other faculty, we see that the full tenured professors tend more towards agreeing with the statements than the other faculty. Similarly, when separating faculty between white males and other groups (all minorities grouped together including females and non-white males), we see that the white male group tends to lean more towards agreeing with the statements than the other group (indicated more of a fixed mindset).

Lastly, Appendix A shows a summary of the most frequent open-ended responses we received. It is interesting to note that our faculty are already employing a variety of techniques to help improve student learning and have many ideas on what to change if they had enough time and the appropriate resources and support. One other trend that emerged suggested that some faculty are less knowledgeable about student learning than others, evidenced by numerous responses of "I don't know" to the question concerning how students are helping their own learning. Finally, the last question on the desired supports for implementing change shows the need for the departmental change efforts to consider the following, many elements of which were highlighted in the Cruz et al. review as necessary for successful instructional changes [2]:

1) Ways to reduce the existing time burden on faculty to give more time to explore new teaching strategies;
2) Developing a system that rewards innovative efforts in teaching;
3) Providing more tailored guidance in equitable pedagogies, EBIPs, and student engagement strategies

Future Work

Our data gathering process has helped us better understand faculty attitudes and perspectives on curriculum components, teaching practices, EBIPs, and growth mindset that will help guide us in our departmental change efforts. We have also administered a survey to our students to gauge their perspectives on departmental culture and aspects of their learning, and we plan to develop one for alumni to gauge the alignment of our current curriculum with modern industry and research needs. It is our hope to use the cumulative data from these surveys to collectively develop a shared vision of change for our department, revise our curriculum accordingly to support that vision, and provide support necessary for faculty and students to implement meaningful and lasting change in our departmental culture surrounding teaching and learning.

We have also given a survey to our students and plan to make one for alumni. It is our hope to use the cumulative data from these surveys to develop a vision for our department, revise our curriculum, and provide the support needed by our faculty and students to implement meaningful and lasting change.

Appendix A. Summary of faculty responses to open-ended questions

Open-ended question	Sample faculty responses
... what are you doing to improve student learning in your classes? (e.g., techniques, strategies , resources, etc.)	• active learning • provide historical context around key discovery milestones • pre-class or other low-stakes quizzes • encouraging attendance at office hours • using TopHat/Kahoot • flipped classroom • learning communities
... what are students doing to improve learning in your classes?	• coming to office hours • coming prepared to lectures and engage in material • asking questions when things are not clear • working with others • use resources beyond textbook (e.g., use web to fact check) • very hard to tell / not sure / no idea / not sure how to answer
... what else is helping to contribute to student learning in your classes? (e.g., environment, setting, timing, etc.)	• classroom environment (e.g., instructor being approachable and making students comfortable to ask questions) • enough room to spread out far enough, but not too far; moveable chairs (i.e., whether size and configurability of classroom is being conducive to type of learning - passive or active) • effective classroom technology (e.g., includes importance of working audio/video recording capabilities in rooms) • invite guest speakers from industry so students understand application side of the skills they are learning • teaching assistant support
... what would you like to change in your course to improve student learning, if you had the necessary time/funds/support?	• more practice for students on common mistakes • more interaction between students and the task with their peers • more resources for project-based learning and more prolonged engagement with design projects • recitation sections for core courses • flip the entire course • smaller class sizes (e.g., provide more individualized support) • like to learn about other EBIPs and their possible applications • co-teaching with faculty recognized for their teaching effectiveness
... what would you need (in terms of support, training, etc.) in order to be able to make those changes to improve student learning in your courses?	• more time available for teaching *(most frequent answer)* • buy-out for teaching first-time offering of a course • more teaching assistants with appropriate qualifications • help identifying EBIPs and applying to specific course • training in equitable student engagement strategies • a system that rewards teaching ("all accolades go to research success")

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