

## **Overriding Tradition? An Initial Exploration of the Intersection of Institutional and Disciplinary Cultures from the Student Perspective**

### **Mr. Ashish Agrawal, Virginia Tech**

Ashish Agrawal is a PhD candidate in the Department of Engineering Education at Virginia Polytechnic Institute and State University. He did his B-Tech from Indian Institute of Technology Roorkee and his MS from Virginia Polytechnic Institute and State University, both in Electric Engineering. His research interests include experiences of international faculty and students in US classrooms, sociology of education, and critical and inclusive pedagogies.

### **Dr. Cassandra J. Groen, Virginia Tech**

Dr. Cassandra Groen is a post-doctoral researcher in the Department of Engineering Education and the Myers-Lawson School of Construction at Virginia Tech. Her primary research interests include professional identity formation in undergraduate civil engineering students, grounded theory methods, and theory development. Her current work includes the exploration of professional identity formation in civil engineering students who experience disabilities and the ways in which this identity is influenced by students' academic relationships, events, and experiences. Dr. Groen holds B.S. and M.S. degrees in Civil Engineering from the South Dakota School of Mines & Technology.

### **Ms. Amy L. Hermundstad Nave, Virginia Tech**

Amy Hermundstad Nave is a doctoral student and Graduate Research Assistant at Virginia Tech. She received her B.S. in Mechanical Engineering from Colorado State University and is currently pursuing an M.S. in Mechanical Engineering and a Ph.D. in Engineering Education. Her research interests include the professional development of engineering students through out-of-class activities.

### **Dr. Lisa D. McNair, Virginia Tech**

Lisa D. McNair is a Professor of Engineering Education at Virginia Tech, where she also serves as Director of the Center for Research in SEAD Education at the Institute for Creativity, Arts, and Technology (ICAT). Her research interests include interdisciplinary collaboration, design education, communication studies, identity theory and reflective practice. Projects supported by the National Science Foundation include exploring disciplines as cultures, liberatory maker spaces, and a RED grant to increase pathways in ECE for the professional formation of engineers.

### **Prof. Thomas Martin, Virginia Tech**

Tom Martin is a Professor in the Bradley Department of Electrical and Computer Engineering at Virginia Tech, with courtesy appointments in Computer Science and the School of Architecture + Design. He is the co-director of the Virginia Tech E-textiles Lab and the associate director of the Institute for Creativity, Arts, and Technology. He received his Ph.D. in Electrical and Computer Engineering from Carnegie Mellon University and his B.S. in Electrical Engineering from the University of Cincinnati. His research and teaching interests include wearable computing, electronic textiles, and interdisciplinary design teams for pervasive computing. In 2006 he was selected for the National Science Foundation's Presidential Early Career Award for Scientists and Engineers (PECASE) for his research in e-textile-based wearable computing.

### **Dr. Marie C. Paretti, Virginia Tech**

Marie C. Paretti is a Professor of Engineering Education at Virginia Tech, where she co-directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication in engineering design, interdisciplinary communication and collaboration, design education, and gender in engineering. She was awarded a CAREER grant from the National Science Foundation to study expert teaching in capstone design courses, and is co-PI on numerous NSF grants exploring communication,



design, and identity in engineering. Drawing on theories of situated learning and identity development, her work includes studies on the teaching and learning of communication, effective teaching practices in design education, the effects of differing design pedagogies on retention and motivation, the dynamics of cross-disciplinary collaboration in both academic and industry design environments, and gender and identity in engineering.

# **Overriding Tradition?: An Initial Exploration of the Intersection of Institutional and Disciplinary Cultures from the Student Perspective**

## **Abstract**

Prior work has highlighted differences in the nature and structure of knowledge across various academic disciplines. These differences manifest themselves in a number of ways, including teaching and learning practices, methods of assessing student learning, and roles and expectations of students and teachers – all of which influence and shape the culture of a specific discipline within an institution. While prior work has focused on disciplinary and institutional cultures separately, little work has been done to understand how these two cultures intersect to create a unique culture within each academic department.

In this exploratory study, we draw on Hofstede’s dimensions of national cultures to better understand the intersections of institutional and disciplinary cultures in shaping students’ experiences. We situate the study within two different engineering disciplines: electrical and computer engineering (ECE) and industrial and systems engineering (ISE). Semi-structured interviews were conducted with 59 undergraduate students from six universities across the U.S. Our cross-institutional analysis reveals variations in student perceptions that suggest ways in which local cultures may influence approaches to learning and perceptions of teaching practices locally, indicating that local cultures may override traditional characterizations of engineering disciplines. These emerging findings suggest that changes at departmental and institutional levels can significantly impact students’ experiences of disciplinary practices and values and challenge the idea of engineering culture as monolithic and immovable. As a result, these local cultures can – and should – play a transformative role in revolutionizing students’ development as engineers.

## **1. Introduction**

Beginning with the pioneering work of Anthony Biglan [1], scholars have explored the ways in which academic disciplines differ in terms of the nature and structure of knowledge, which can in turn account for differences in teaching and learning practices [2], [3]. These differences impart a unique disciplinary “culture” to academic disciplines within a university setting. Notwithstanding the complexity of attempting to define “culture” as a construct, we adopt the term here to describe the lens through which people in a given group experience and understand the world [4]. Similarly, we define an “academic discipline” as a field of specialization with a unique set of subject matter as its core knowledge within the university setting [1]. Disciplinary cultures, such research argues, guides the pedagogical practices adopted by faculty, influences student learning within a field, and affects the nature of collaboration and interaction among individuals [2]. Studies of academic disciplines, broadly, often include engineering, typifying it as hard (i.e., with well-structured, tightly defined epistemological paradigms) and applied (i.e., focused on practical applications) [1], [5], [6]. Within engineering education research, a number of studies have explored the nature of engineering culture both within national contexts (e.g., [7], [8]) and across national boundaries (e.g., [9], [10]).

While such categorizations are useful in understanding how faculty and students subscribe to the culture of their engineering disciplines broadly, these cultures are enacted through local teaching

and learning practices at the departmental level and are shaped by a number of other cultural influences. First, the national academic culture at large influences the behavior and beliefs of faculty and students in a given department [11]. Even within a given national boundary, scholars have explored variations that can result from both institutional and departmental influences. For example, Austin [12] explores the ways in which the relative balance between teaching and research – and particularly the value placed on teaching – for faculty are heavily influenced by both institutional cultures (e.g., undergraduate teaching institutions versus research-intensive institutions) and local department cultures. Studies by other scholars continue to bear these findings out. For example, Pifer et al. [13] found substantial differences in the functions of academic departments in liberal arts institutions in contrast to other types of colleges.

Such findings suggest that any given engineering department sits at the intersection of at least four layers: 1) engineering disciplinary culture, 2) national academic culture 3) institutional culture, and 4) departmental culture. Yet in much of the research on engineering education, “engineering” is often treated as a monolithic construct that remains invariant across institutions and subfields. While general characterizations of teaching and learning in engineering are not without merit, such characterizations may mask significant local variations that can sharply influence students’ experiences in and perceptions of engineering. To begin to unpack this complexity, we present an initial exploration of the intersections of disciplinary, institutional, and national cultures on the departmental cultures within two different engineering disciplines across six universities.

## **2. Examining culture**

### **2.1 Disciplinary culture**

As noted above, research on academic disciplines as cultures began to emerge in the 1970s as Biglan [1] explored the ways in which the values, norms, and beliefs of students and faculty are also shaped by disciplinary cultures. As Becher [14] explains, “[d]isciplines are also cultural phenomena: they are embodied in collections of like-minded people, each with their own codes of conduct, sets of values and distinctive intellectual tasks” (p. 109). Within academia, we can observe these influences in ourselves and in our students within engineering departments. For example, engineering students typically align with interests and skills that they perceive as related to engineering (e.g., being good at math and physics, fixing things, etc.) or a specific engineering discipline. Also, students with more traditional perceptions of engineering, in some instances, reject skills and interests they perceive as unrelated (e.g., reading, writing, art, etc.) [15].

These differences in disciplines may be attributed to the underlying paradigms that determine both appropriate objects of study and methods by which studies are conducted within a discipline. The degree to which members hold consensus regarding the disciplinary paradigm can then be used to classify a discipline as “hard” (i.e., high consensus) or “soft” (i.e., low consensus) [1]. Hard disciplines are typically those considered to be part of the physical or natural sciences such as physics, mathematics, and chemistry, with traditionally more rigid boundaries around subject matter and methods. Soft disciplines are generally those belonging to the humanities and social sciences such as sociology, history, and English, with more porous boundaries. These paradigmatic differences in disciplines lend themselves to variations in

teaching practices, learning approaches, and assessment of student learning within academic departments. Given the hard, applied nature of the engineering discipline, engineering instructors tend to adopt lecture-based teaching approaches typical of the hard disciplines from which engineering is derived [1], [16], and Donald [3] notes that they also emphasize problem-solving skills with right answers. On the other hand, faculty in soft disciplines tend to adopt more discussion-based teaching approaches that focus on the development of critical thinking and communication skills [17].

Such characterizations, however, typically treat all engineering subdisciplines as homogeneous. Such is the case, for example, in prior studies of teaching and learning across academic disciplines, as in Nulty and Barrett's [6] exploration of student learning styles across disciplines or Bradbeer's [5] exploration of the challenges providing interdisciplinary learning experiences for students. Yet significant variations exist among the various subfields of engineering – not only in content, but in approach and in the demographic make of individual fields. For example, ECE derives its core body of knowledge from physical sciences (i.e., hard disciplines) [18] whereas ISE has its roots in organizational and management psychology (i.e., soft disciplines) [19]. These two disciplines also have markedly different national profiles, with nearly 32% of bachelor's degrees in industrial/systems engineering going to women, but just under 13% of bachelor's degrees in electrical engineering going to women [20]. Both the perceived epistemological differences and the differences in demographic profile suggest that additional frameworks are necessary to understand the cultures within engineering in a more nuanced way.

## **2.2 National academic culture**

Given that current models of disciplinary culture tend to homogenize engineering, we turned to the three other dimensions of culture noted earlier to help explore variations within engineering subfields and across departments and institutions, beginning with national culture. Prior research demonstrates multiple ways in which the practice of teaching and learning is nationally situated. Within engineering, seminal work by Downey and Lucena [9] has highlighted multiple ways in which the practice – and consequently the teaching and learning – of engineering is closely tied to national values and histories. Their work highlights ways in which values of progress, precision, theoretical elegance, practical ingenuity, and other constructs can shape the content focus of engineering education, emphasizing, for example, hands-on apprenticeship versus theoretical mathematical modeling.

More broadly, what constitutes “effective” teaching varies across national cultures and reflects the values and norms of the culture in which it is practiced [21]. One approach to gaining an understanding of these variations in academic cultures is through Hofstede's [22] theory of cultural dimensions, which categorizes national cultures in four dimensions: 1) power distance—how people in a culture view authority; 2) uncertainty avoidance—how people in a culture deal with ambiguity; 3) individualism—the relationship between the individual and the group; and 4) masculinity—the implications of being born as male or female in that culture.

Hofstede's theory, when applied to educational settings, explains how academic cultures vary across nations in terms of the roles and expectations of teachers and students, the purpose of education, the way instruction is delivered, and accepted classroom behavior. In an academic setting, for example, power distance can be used to describe how students view their instructors' authority and how comfortable students feel when interacting with these instructors; uncertainty

avoidance can be used to point to clarity (or lack thereof) in classroom rules and assignment guidelines; individualism can be used to capture student engagement in collaborative practices during their learning; and masculinity can be used to understand students' perceptions of gender and classroom diversity. Hofstede argues that differences in these dimensions lead to distinct national academic cultures [22]. Given the range of factors that Hofstede's framework takes into account, it formed the primary framework shaping this study.

### **2.3 Institutional culture**

While disciplinary culture links individuals through similar discipline-based values and beliefs across institutions, institutional culture connects individuals through shared values and beliefs within the institution (i.e., college or university) of which they are part [12]. Institutional culture can also influence the ways in which faculty emphasize teaching and research activities within their universities. For example, in their examination of 193 institutions across the U.S., Astin and Chang [23] found that the universities that scored high on research orientation and low on student orientation were classified as research-intensive universities. On the other hand, universities that scored high on both attributes were private, liberal arts colleges. Their results were supported by Pascarella et al. [24] who, in their study comparing practices in undergraduate education at various types of institutions, found that liberal arts colleges scored higher on measures related to effective teaching practices and teaching focused activities. These variations in activities may be attributed to evaluation mechanisms set in place by universities; within liberal arts institutions, faculty tend to be evaluated on both teaching and research as compared to research-intensive universities where promotion and tenure is primarily evaluated through research activities such as obtaining grant funding and academic publications. In these cases, faculty promotion and tenure are both shaped and communicated by institutional culture.

### **2.4 Departmental culture**

Academic departments are where disciplinary and institutional cultures intersect. As Austin [12] notes, the culture of a department "results from the interaction of disciplinary and institutional norms and values" (p. 58), thus imparting a unique culture to each academic department within an institution. In addition to the influence of disciplinary and institutional culture, departmental culture is shaped by its own myriad of characteristics such as current and prior leadership; history; faculty, staff, and student personality; faculty rewards systems; and institutional location [12]. These characteristics can vary across departments within a single institution or across a particular discipline; therefore, departmental cultures may vary from one another on a number of levels in a variety of ways.

Drawing from this discussion, it can be argued that departmental cultures are not simply replicas of a disciplinary culture, but rather serve as intersectional cultures that are influenced locally by institutional culture and more broadly by national academic culture and disciplinary culture. This relationship, as adapted from Lee [25] and depicted in Figure 1, provides the conceptual framework for this study. As shown in the figure, departmental culture lies within the intersection of institutional and disciplinary cultures. Further, institutional culture is embedded within the larger national academic culture. Because the institution and the department are located within the national boundary, they are represented inside the larger dotted circle representing national academic culture, shown in Figure 1. However, some disciplinary values

(e.g., epistemological roots, core body of knowledge, etc.) may also span nations and institutions. Hence, a part of the circle representing disciplinary culture lies outside the circles representing national and institutional cultures in the figure.

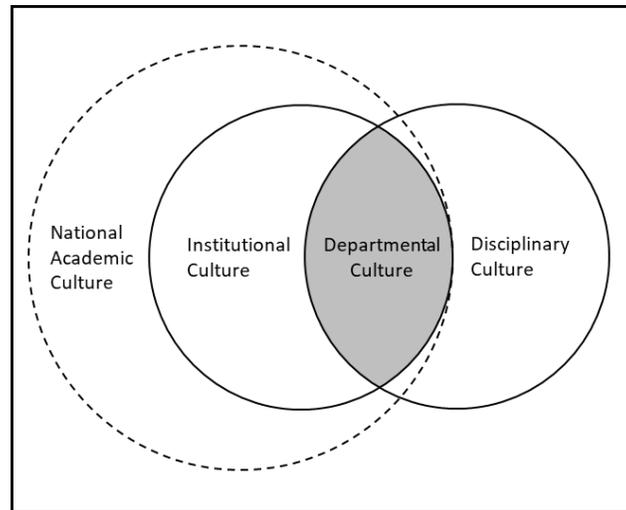


Figure 1: Conceptual framework of relationships among types of culture [25]

## 2.5 Summary

We argue here that this intersection of national, institutional, departmental, and disciplinary cultures is critical in our understanding of and attempts to transform engineering education. As noted earlier, a number of scholars have written insightfully about engineering culture as a whole (e.g., [7], [26]) and as defined by national boundaries (e.g., [9]). However, as also noted, engineering subfields vary in terms of their core bodies of knowledge, which they derive from diverse academic disciplines. Beyond these differences, we also find variations across institutions – and even among departments – in a given institution in terms of both methods of teaching and learning and modes of faculty-student interaction. However, little work has been done to explore these differences. Thus, given the complex interactions among disciplinary, national, institutional, and departmental cultures, we conducted an exploratory study to better understand how students perceive and experience these interactions. Our study focuses on two specific subfields of engineering (i.e., ISE and ECE) across six institutions in the U.S. To guide our inquiry, we asked the following research question: **What similarities and differences emerge in engineering students’ perceptions of department culture within and across both disciplines and institutions?**

## 3. Methods

### 3.1 Participants and data collection

To address our research question, we conducted a multi-case study [27], collecting interview data from 59 undergraduate students in two engineering departments, Electrical and Computer Engineering (ECE) and Industrial and Systems Engineering (ISE), in six universities across the U.S. Each department (or discipline/institution pair) is considered a case. For example, ECE at University 1, represented by U1ECE, is one case and ISE at University 2, represented by U2ISE,

is a separate case. Participants within each case are identified by their university followed by their program (ECE or ISE) and a number indicating the order in which they were interviewed. For example, U2ISE3 is the third ISE student interviewed at university U2.

We chose to explore two different engineering disciplines because, while engineering culture is often treated monolithically, disciplines can differ quite significantly in both the questions asked and the research methods employed. Factors such as diversity profiles [20] further suggest that student experiences may be markedly different among disciplines. We selected ECE and ISE for this study due to significant differences in disciplinary characteristics such as curricula-shaping bodies of knowledge (i.e., relevant content for entering the field) and gender diversity present within each discipline. As noted earlier, ECE maintains a body of knowledge that has close ties to the physical sciences [18], and ISE primarily draws its knowledge base from organizational management and psychology [19]. With regard to gender diversity, ISE tends to have the highest gender diversity in its student enrollment among all engineering disciplines whereas ECE tends to have the least gender-diverse student enrollment [20]. For the purpose of this study, engineering programs offering degrees in computer engineering, electrical engineering, computer science, and software engineering were grouped under the ECE disciplinary category. Programs offering degrees in industrial and systems engineering and industrial and management engineering were grouped as an ISE disciplinary category.

In identifying institutional sites for the study, we sought diversity in terms of student population (i.e., large versus small), focus (i.e., research versus teaching), source of funding (i.e., public versus private), and campus type (i.e., urban versus suburban versus rural). Details about each university based on the Carnegie Classification System [28] are presented in Table 1.

Table 1: University characteristics

University ID*	Student Population	Research/Teaching Focus	Source of Funding	Campus type
U1	Large	Master's Colleges & Universities: Larger Programs	Public	Suburban
U2	Medium	Doctoral Universities: Moderate Research Activity	Public	Urban
U3	Large	Doctoral Universities: Highest Research Activity	Public	College town
U5	Large	Doctoral Universities: Highest Research Activity	Public	Urban
U6	Large	Higher Research Activity	Public	Rural
U7	Medium	Master's Colleges & Universities: Larger Programs	Private	Suburban

*\*U4 did not participate in this phase of data collection.*

We recruited participants through a combination of electronic advertisement and in-person classroom visits. The electronic advertisement included a recruitment survey distributed via email to all students in participating ECE and ISE programs at each university. Note that U5 does not have an ISE program, so the study includes a total of 11 cases. To enhance recruitment efforts at some locations, survey recruitment was combined with in-person, classroom visits by a

member of the research team. The recruitment survey was used to collect students' demographic information (i.e., gender and academic year in program) as well as perceptions regarding their sense of belonging in the program. Sense of belonging items included three statements, as shown below, in which students indicated their level of agreement using a 5-point Likert-type scale (1 – “strongly disagree” to 5 – “strongly agree”).

- Being good at [major] is important to me.
- I feel like a real part of the [major] program.
- It matters to me how well I do in [major] courses.

To the extent possible, participants were purposely sampled to achieve variation in gender, year in program, and perceived sense of belonging. Variation in perceived belonging was desired to minimize inherent bias from students who maintain a high sense of belonging to their department (i.e., strongly agree with all belonging items). In some cases, however, response rates were low and all survey respondents from a given discipline at a site were interviewed, regardless of perceived belonging. Table 2 provides the breakdown of participant gender and academic discipline, and Table 3 provides participant breakdown based on year of study. Notably, due to the varied structures of the university (e.g., U3 is a traditional four-year university whereas U5 embeds a co-op/internship year within the curriculum), year of study was identified as the number of years a student has been enrolled in college rather than academic rank (i.e., freshman, sophomore, junior, senior).

Table 2: Participant numbers based on gender and major

University ID	Males	Females	ECE Majors	ISE Majors	Total
U1	7	3	5	5	10
U2	7	1	6	2	8
U3	8	4	6	6	12
U5	7	3	10	---	10
U6	6	6	6	6	12
U7	5	2	3	4	7

Table 3: Participant numbers based on academic rank

University ID	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
U1	1	2	3	3	1	---	10
U2	---	---	8	---	---	---	8
U3	---	---	5	7	---	---	12
U5	---	1	2	3	3	1	10
U6	---	2	4	3	3	---	12
U7	---	1	3	3	---	---	7
Total	1	6	25	19	7	1	59

A single semi-structured interview lasting between 30 to 60 minutes was conducted with each participant and guided by an interview protocol based broadly on Hofstede’s [22] four cultural dimensions. The protocol included questions aimed to capture students’ classroom experiences;

interactions with instructors; teaching practices in their major; approaches to learning new concepts; and experiences in in-major, team-based projects. The protocol was tested with five students during a pilot study and minor adjustments were made to the protocol accordingly [29].

### 3.2 Data analysis

Interview data were audio-recorded and transcribed by professional transcription services. Transcripts were reviewed to ensure transcriber accuracy, then thematically coded by two members of the research team using Dedoose™ software. The codebook used during analysis was developed over multiple iterations of interview analyses, the foundation of which was published in [29] during Murzi’s exploration of disciplinary culture at a single institution. The initial codebook was developed using both Hofstede’s four dimensions of culture (i.e., power distance, uncertainty avoidance, individualism, and masculinity) and prior work on disciplinary differences in teaching and learning [5], [6] as sensitizing concepts, then refined by both operationalizing these concepts in our data and adding emergent codes not captured by prior work. Coded interview segments were then clustered into three categories that captured students’ experiences of culture in three themes: 1) student approaches to learning, 2) perceived teaching approaches, and 3) perceived disciplinary values. Each emergent category is further described in the following paragraphs, with representative participant quotes for each listed in Table 4 and is further described in the following sections.

Table 4: Codebook and example quotes used in analysis

Category	Dimension	Example Quote
Individual approaches to learning	Individual approach to learning	“[...] I feel like with group work, I don't learn as much... I feel like it sticks in your head more when you do it individually.” [U7ISE2]
	Collaborative approach to learning	“It would be very hard to not be in groups because I just feel like there's so many different components to everything. Let's say you need more than one person, like more than one pair of eyes to let's say, collect data, or then put that to use.” [U7ISE1]
	Active learning	“I actually do like more of the hands-on stuff. That's why I like [University Name].” [U1ECE1]
	Rote learning	“But first I think you need to memorize basic concepts [long pause] yeah, the theory is really important, first learning the theory, then practice and more practice.” [U3ECE5]
Teaching approaches	Traditional teaching methods	“[The instructor] just read over the textbook, gave some homework and exam and that's all the interaction for the first class.” [U5ECE10]
	Contemporary teaching methods	“Whatever problems he [the instructor] would give us, he wouldn't just give us undergrad level problems. We did problems like hacking into a system and diffusing bombs. It was so amazing what we did with real life things. We did it all in assembly.” [U5ECE8]

Table 4 (cont.): Codebook and example quotes used in analysis

Category	Dimension	Example Quote
Teaching approaches (cont.)	Teaching based on prescribed methods	“I do remember that the instructions of the project were very specific, like you totally knew what you had to do, I think [the instructor] was very good providing clear rules.” [U3ECE6]
	Teaching based on open-ended approaches	“Some of them we had to go to [Sandwich Restaurant Name], and see like the ergonomics of them making sandwiches, and like go on campus somewhere to look at things and it was just, it was all like hands on stuff, it wasn't just like reading.” [U6ISE6]
Disciplinary values	High power distance	“It was the kind of thing where he would explain a thing, and I like to clarify things a lot just to make sure I understand it, so if I was to ask something that he ended up explaining, he would end up kind of...it'll feel like he tried to make me feel bad for having asked it. So, by the end of that class, I just decided to stop asking questions.” [U2ISE2]
	Low power distance	“I have bluntly told him I think he's screwed up at points. Yeah, I'm comfortable with [Professor Name]. Yeah. I am very comfortable with going to him, telling him I'm having issues.” [U6ECE4]
	Learning as product	“[In] ECE it's all about getting the right answer, you need to become good at learning whatever it takes to get the right answer, if you don't get the right answer you don't get a good grade.” [U3ECE5]
	Learning as process	“I think [what is considered right answer] is how well we applied our knowledge, because like I said, it's less about the architecture. They don't mind us using equation sheets and stuff like that, but they want us to know how to make it work for what we're trying to do.... There's going to be 10 different ways you ask.” [U7ISE4]

**Student approaches to learning.** The first theme describes the ways in which students approach learning course content within their department. Approaches to learning are described across two dimensions: individual versus collaborative and rote versus active. The individual versus collaborative dimension signifies whether students prefer to engage in the process of learning (e.g., doing homework, studying for exams) on their own or collaboratively with others. The rote versus active dimension describes whether students focus on rote memorization of things like procedures, formulas, or terms or on actively applying underlying concepts and/or engaging in critical thinking and metacognition.

**Perceived teaching approaches.** The second theme describes how students perceive faculty teaching approaches within their departments, again with two emergent dimensions: traditional versus contemporary and prescribed versus open-ended. The traditional versus contemporary dimension focuses on the pedagogical practices used in non-laboratory and laboratory courses. Traditional approaches are those considered prototypical of engineering. For example, students describing traditional approaches talk about classes dominated by lectures in which students are required to take notes or read PowerPoint® slides, and course assessments consist mostly of individual assignments and quizzes. Similarly, students in traditional lab courses describe following clearly-articulated procedures to replicate a foundational concept with little room for deviation. On the other hand, students who experience contemporary teaching describe practices associated with recent transformation in engineering education (see, for example, the practices

delineated by [30], [31]), characterized by hands-on learning and discussion-based activities in which students are assessed through assignments and quizzes that require students to collaborate and/or demonstrate conceptual rather than simply rote procedural knowledge. In contemporary approaches to labs, students describe applying tools and concepts learned in the classroom in ways that encourage innovative problem-solving and procedure deviation.

The prescribed versus open-ended dimension indicates the level of constraint and detail that students report for course assignments and activities. For example, students who describe prescribed approaches reported assignments that provided step-by-step or well laid-out instructions regarding the completion of class activities, while students who described an open-ended approach reported assignments with less structured problems that required students to determine solution processes with the instructor serving as a facilitator.

**Perceived disciplinary values.** The final theme captures how students perceived the values held by the discipline across two dimensions: high versus low power distance and product versus process. Power distance describes the nature of the relationships students perceived as allowed or accepted with their instructors as well as students' perceptions of instructor authority. Low power distance values equated to descriptions of informal, friendly relationships and perceptions of faculty as easily approachable and open to questions. Descriptions of high power distance consisted of formal relationships where faculty were viewed as authority figures who were less open to discussions and questions. The product versus process dimension describes whether students perceived successful learning being valued in terms of a final outcome or an encompassing, immersive learning process. When students described learning predominantly in terms of valuing the ability to achieve a final answer or outcome, the environment was classified as product-oriented. Conversely, environments in which students reported treating learning in terms of the approaches taken to accomplish a task, with value placed on the thought processes and the experiences gained during that process, were classified as process-oriented.

To visualize the data, the two dimensions within each theme were represented as a grid with the more stereotypical or conservative dimension on the lower or left side, as shown in Figure 2. Each interview was classified as predominantly one pole or the other or balanced between the two, as illustrated by the Xs in Figure 2. To enable us to consider each site holistically, the poles were then assigned a numeric value, with -1 assigned to the lower and left poles, +1 assigned to the upper and right poles, and 0 assigned to the balanced examples, as illustrated in Figure 3.

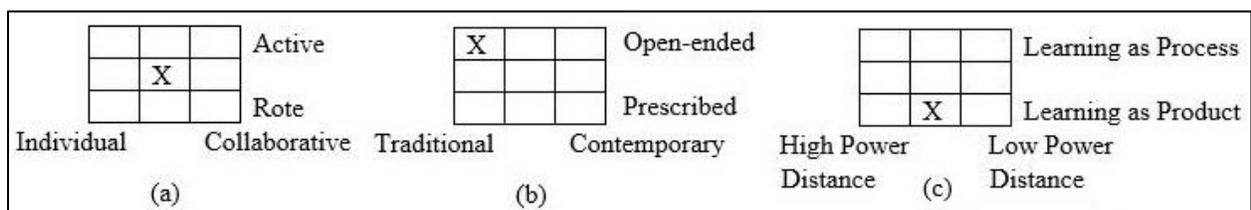


Figure 2: Example of interview rating on three the dimensions: (a) approaches to learning (b) teaching approaches (c) disciplinary values

$(-1, 1)$	$(0, 1)$	$(1, 1)$	Active	$(-1, 1)$	$(0, 1)$	$(1, 1)$	Open-ended	$(-1, 1)$	$(0, 1)$	$(1, 1)$	Learning as Process
$(-1, 0)$	$(0, 0)$	$(1, 0)$	Rote	$(-1, 0)$	$(0, 0)$	$(1, 0)$	Prescribed	$(-1, 0)$	$(0, 0)$	$(1, 0)$	Learning as Product
$(-1, -1)$	$(0, -1)$	$(1, -1)$		$(-1, -1)$	$(0, -1)$	$(1, -1)$		High Power Distance	$(-1, -1)$	$(0, -1)$	
Individual	Collaborative		Traditional	(b)		Contemporary		(c)			
(a)											

Figure 3: Score matrix used for quantizing interview data based on grid location for the three dimensions: (a) approaches to learning (b) teaching approaches (c) disciplinary values

After scores were assigned to all interviews for all three categories, the scores were averaged by case. For example, the scores assigned for all the ECE participants at university U1 were averaged. Similarly, scores for all of the ISE participants at university U2 were averaged. These average scores were then plotted on a two-dimensional graph by theme; the findings are further discussed in the next section. As discussed earlier, each academic department participating in this study was considered as a single case. While we acknowledge there might be variations within the institution based on students' year of study or sense of belonging in their degree program, the idea was to look at a department as a whole. We also note that this quantizing of the qualitative data is an artificial construct and we do not intend the numerical values to have meaning beyond providing a tool for visualizing the findings from each case; the approach offered a way to distill the original 59 interviews (which appear quite complex on a grid) down to the 11 cases. To increase the validity of the quantized data, future interviews would need to be conducted with more students across multiple institutions.

## 4. Results and discussion

The results reveal different patterns of institutional/departmental/disciplinary intersections across the different dimensions within each theme. Across some dimensions, participants cluster with their disciplinary counterparts across institutions while for other dimensions, participants cluster by university regardless of the discipline, as detailed in the following sections. Across these findings, we emphasize that the data to-date reflect only student perceptions; additional data collection focused on departmental and institutional cultures (e.g., interviews with faculty, documents such as mission statements and syllabi) is needed to better understand patterns of influence.

### 4.1 Student approaches to learning

With respect to the approaches utilized by students to learn new content, our analysis suggests a strong disciplinary pattern relative to students' adoption of individual versus collaborative learning approaches. Across institutions, ISE students tended to adopt more collaborative learning approaches while ECE students tended to adopt approaches that were more individual-based, as shown in Figure 4. While only one out of six ECE departments were located on the collaborative side of the spectrum, three out of five ISE departments were identified as collaborative. This relative clustering of the disciplines – regardless of university – suggests that disciplinary culture may strongly influence learning approaches in these departments. Given that, as Biglan [1] explained, disciplinary culture can drive both content and methods, this alignment between learning and discipline may reflect the underlying approaches to knowledge embodied in the two different disciplines.

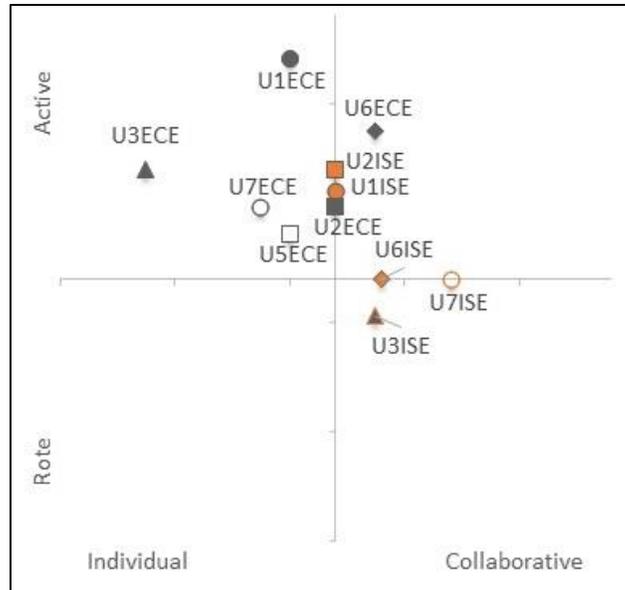


Figure 4: Representation of universities and disciplines in dimensions for student approaches to learning

However, the data also suggest that these disciplinary influences are not absolute and can be mitigated by local cultures. Thus, some institutions showed similar learning approaches regardless of discipline. For example, as shown in Figure 4, the ECE and ISE students at U2 both reported a learning approach that was active. At U3, in contrast, the results were more complex. ISE (rote and collaborative) and ECE (active and individual) students adopted strategies that both aligned and contradicted with those traditionally associated with their disciplines (i.e., all engineering as rote rather than active, ISE as more focused on teamwork than ECE). This complexity suggests that the local department culture may also be serving as a mitigating factor, with differences between departments rather than overall institutional values holding sway.

#### 4.2 Student perceptions of disciplinary teaching approaches

With respect to students' perceptions of teaching, the patterns again suggest intersections between the disciplinary and institutional levels. The most significant pattern involves the level of constraint and detail students reported regarding the completion of coursework. As shown in Figure 5, students in the majority of departments described being provided detailed instructions for performing class activities and assignments by their faculty: all institutional departments are located within the bottom half (i.e., prescribed section) of the grid, with the exception of the ISE departments located at U6 and U7. In these departments, students perceived course assignments and activities to be open-ended. This trend of prescribed rules for course assignments and activities may be due to the overarching influence of classroom practices in engineering broadly that emphasize students' ability to solve highly structured, closed-ended problems (e.g., [32], [33]). However, the trends towards open-ended assignments at U7 and the U6 ISE department may also highlight the slow emergence of pedagogical practices in STEM education to introduce more open-ended course activities and problems with ill-defined constraints and guidelines (see [30], as well as recent work such as [34], [35]).

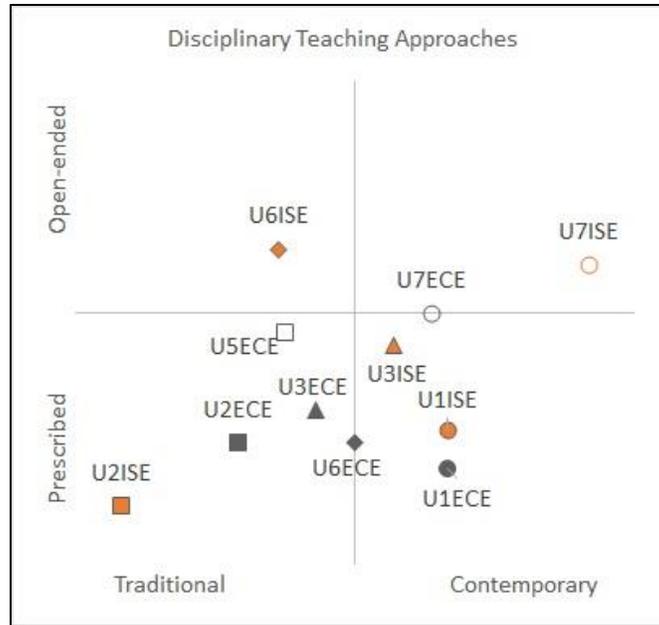


Figure 5: Representation of universities and disciplines on dimensions for teaching approaches

This shift in pedagogy is even more evident in students' accounts of classroom practices, where 5 of the 11 cases are on the contemporary side and a sixth on the border. Across all cases, similar to trends in students' learning approaches, reported classroom practices varied by discipline and institution to varying degrees. For example, both U1 and U2 showed similar practices across disciplines, suggesting a potential institutional influence. Across institutions, however, ECE students were more likely to report traditional rather than contemporary practices, suggesting a disciplinary trend. Still, the strong contemporary approach reported in the U1 ECE department points to the potential for local cultures to override disciplinary trends. Similarly, the split between ISE and ECE at U6 indicates that even within an institution, departmental cultures may align with (or deviate from) broader institutional practices.

### 4.3 Student perceptions of disciplinary values

Within the final theme, the results reveal not only disciplinary and institutional patterns, but also a potentially overriding national pattern in terms of students' perceptions of disciplinary values. First, as shown in Figure 6, most students across universities and disciplines perceived low power distance in instructor interactions, with the exception of U2ISE. In other words, most participants in this study perceived their instructors as being approachable and supportive. This finding is congruent with Hofstede's [22] finding that, in general, low level power distance is common in U.S. academic culture, thus highlighting the broader influence of national academic culture at the departmental level. However, within our small data set, more ECE participants reported a high or balanced power distance compared to ISE participants at each institution with the exception of ISE students at U2.



Figure 6: Representation of universities and disciplines on dimensions for disciplinary values

Second, the patterns in Figure 6 suggest some clustering by institution. For example, while students at both U3 and U7 perceived a low power distance, students at U3 in both disciplines valued learning in terms of product, while students in both disciplines at U7 valued learning as a process. In contrast, students at both U1 and U2 reported stronger differences by discipline, with U1 participants differing with respect to valued learning and U2 participants different with respect to power distance.

#### 4.4 Challenging the conceptualizations of disciplinary culture in academia

Across the three themes examined, student perceptions showed both patterns of convergence and patterns of divergence along disciplinary and institutional lines, and in at least one dimension – power distance – a potential overarching convergence around national culture. For dimensions related to student approaches to learning and perceptions of teaching approaches, local institutional and departmental variations often challenged characteristics typically ascribed to specific disciplines. For example, while students in the majority of ECE departments tended to adopt individual learning approaches, ECE students at U2 and U6 tended to adopt collaborative learning approaches that more closely aligned with their ISE counterparts at those institutions. However, student perceptions of disciplinary values revealed a more complex set of interactions. While national culture appears to have a strong influence given the consistent perception of low power distance across disciplines and institutions, small variations emerged that suggest the need for more research. At the same time, variations in perceptions of what learning was valued varied along both disciplinary and institutional lines, highlighting the importance of local cultures in shaping how students understand their learning experiences. Within these findings, we begin to see individual departments within particular disciplines that challenge traditional disciplinary norms in academia, suggesting the possibility of *integrating* local institutional and/or departmental practices with disciplinary norms to transform student experiences.

## **5. Conclusions and future work**

This exploratory study sought to better understand local variations in the broad characterizations of engineering teaching and learning culture across both disciplinary and institutional lines. Because an academic department serves as a site of enculturation for students entering their chosen field, we explored the ways in which students engaged and interpreted departmental courses through semi-structured interviews. Our findings revealed that across three themes - approaches to learning, perceptions of teaching, and perceptions of disciplinary values - a complex relationship exists among disciplinary, departmental, and institutional cultures. These findings help us move beyond the idea of engineering disciplinary cultures as monolithic and suggest that these local institutional and departmental cultures may override traditional characterizations and practices of the field and its subdisciplines.

While the frameworks offered here provide potentially useful ways for engineering education researchers to more fully nuance variations across disciplinary and institutional contexts – a primary aim of our work – they also point toward the ways in which characteristics at both departmental and institutional levels may influence students’ perceptions not only of teaching and learning, but of the field. The findings here remind us that these local cultures can – and should – play a significant role in transforming students’ development as engineers.

While the work discussed herein illuminates variations in engineering students’ experiences across disciplines and institutions, they also raise a new set of questions. Because these findings highlight ways in which students interpret, learn, and engage in their chosen fields of study, further work is necessary to better delineate critical sources of disciplinary and institutional influences within academic departments. Our study reveals patterns but does not establish causality. Subsequent work should include additional interviews with students, faculty, and institutional leaders across multiple types of universities and disciplines to further establish the themes observed in this study. For example, interviews with faculty could be conducted to explore their perceptions of disciplinary culture and the ways in which these perceptions influence how and what they teach in the classroom. Institutional leaders could discuss overarching visions for the university and further describe the underlying culture within an institution. While not explored in the present study, additional analyses that integrate findings from future interviews are necessary to further explore the influences of nuanced institutional characteristics (e.g., research intensive versus predominantly undergraduate; public versus private; and commuter versus residential) on perceived culture. From this body of work, we can gain a better understanding of where and how disciplinary, institutional, and national cultures are intersecting to educate the next generation of engineers.

### **Acknowledgements**

This paper is based on work supported by the National Science Foundation under Grant EEC-1329224. 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. The authors would like to acknowledge Dr. Homero Murzi, Dr. Ryan Cook, and Dr. Paige Horst for conducting the initial data collection and analyses for the early phases of this study. Authors Agrawal and Groen contributed equally to this work.

## References

- [1] A. Biglan, "The characteristics of subject matter in different academic areas.," *J. Appl. Psychol.*, vol. 57, no. 3, p. 195, 1973.
- [2] T. Becher, *Academic Tribes and Territories: intellectual enquiry and the cultures of disciplines*. Buckingham: SRHE/Open University Press, 1989.
- [3] J. G. Donald, *Learning To Think: Disciplinary Perspectives. The Jossey-Bass Higher and Adult Education Series*. ERIC, 2002.
- [4] H. A. Klein, "Cognition in natural settings: The cultural lens model," in *Cultural ergonomics*, Emerald Group Publishing Limited, 2004, pp. 249–280.
- [5] J. Bradbeer, "Barriers to interdisciplinarity: Disciplinary discourses and student learning," *J. Geogr. High. Educ.*, vol. 23, no. 3, pp. 381–396, 1999.
- [6] D. D. Nulty and M. A. Barrett, "Transitions in students' learning styles," *Stud. High. Educ.*, vol. 21, no. 3, pp. 333–345, 1996.
- [7] G. L. Downey, "The Normative Contents of Engineering Formation: Engineering Studies," in *Cambridge Handbook of Engineering Education Research*, 2014.
- [8] E. Godfrey, "Understanding disciplinary cultures: The first step to cultural change," *Camb. Handb. Eng. Educ. Res.*, pp. 437–455, 2014.
- [9] G. L. Downey and J. C. Lucena, "Knowledge and professional identity in engineering: code-switching and the metrics of progress," *Hist. Technol.*, vol. 20, no. 4, pp. 393–420, 2004.
- [10] G. L. Downey and J. C. Lucena, "National identities in multinational worlds: engineers and engineering cultures'," *Int. J. Contin. Eng. Educ. Life Long Learn.*, vol. 15, no. 3–6, pp. 252–260, 2005.
- [11] G. D. Kuh and E. J. Whitt, *The Invisible Tapestry. Culture in American Colleges and Universities*. ASHE-ERIC Higher Education, Report No. 1, 1988. ERIC, 1988.
- [12] A. E. Austin, "Institutional and departmental cultures: The relationship between teaching and research," *New Dir. Institutional Res.*, vol. 1996, no. 90, pp. 57–66, 1996.
- [13] M. J. Pifer, V. L. Baker, and L. G. Lunsford, "Local Cultures in Institutional Contexts: The Functions of Academic Departments in Liberal Arts Colleges," *J. Study Postsecond. Tert. Educ.*, vol. 1, no. unknown, pp. 233–252, 2016.
- [14] T. Becher, "Towards a definition of disciplinary cultures," *Stud. High. Educ.*, vol. 6, no. 2, pp. 109–122, 1981.
- [15] C. J. Groen, "Advancing from Outsider to Insider: A Grounded Theory of Professional Identity Negotiation," Doctoral Dissertation: Virginia Tech, Blacksburg, 2017.
- [16] J. S. Stark, "Classifying professional preparation programs," *J. High. Educ.*, pp. 353–383, 1998.
- [17] J. M. Braxton, "Disciplines with an affinity for the improvement of undergraduate education," *New Dir. Teach. Learn.*, vol. 1995, no. 64, pp. 59–64, 1995.
- [18] E. A. Lee and D. G. Messerschmitt, "Engineering an Education for the Future," *Computer*, vol. 31, no. 1, pp. 77–85, 1998.
- [19] G. Salvendy, *Handbook of human factors and ergonomics*. John Wiley & Sons, 2012.
- [20] B. L. Yoder, "Engineering by the Numbers," 2016.
- [21] N. LeGros and F. Faez, "The Intersection Between Intercultural Competence and Teaching Behaviors: A Case of International Teaching Assistants.," *J. Excell. Coll. Teach.*, vol. 23, no. 3, 2012.
- [22] G. Hofstede, *Culture's consequences: Comparing values, behaviors, institutions and organizations across nations*. Sage, 2001.
- [23] A. W. Astin and M. J. Chang, "Colleges that emphasize research and teaching: can you have your cake and eat it too?," *Change Mag. High. Learn.*, vol. 27, no. 5, pp. 45–50, 1995.
- [24] E. T. Pascarella, T. M. Cruce, G. C. Wolniak, and C. F. Blaich, "Do liberal arts colleges really foster good practices in undergraduate education?," *J. Coll. Stud. Dev.*, vol. 45, no. 1, pp. 57–74, 2004.
- [25] J. J. Lee, "The shaping of the departmental culture: Measuring the relative influences of the institution and discipline," *J. High. Educ. Policy Manag.*, vol. 29, no. 1, pp. 41–55, 2007.
- [26] D. Riley, A. E. Slaton, and A. L. Pawley, "Women and minorities in engineering.," in *Cambridge Handbook of Engineering Education Research*, Cambridge: Cambridge University Press, 2014, pp. 335–356.
- [27] R. K. Yin, *Case study research: Design and methods*. Sage publications, 2003.
- [28] Indiana University School of Education, "Carnegie Classification of Institutions of Higher Education," 2017. [Online]. Available: <http://carnegieclassifications.iu.edu/>.

- [29] H. G. Murzi, "Understanding Dimensions of Disciplinary Engineering Culture in Undergraduate Students," Doctoral Dissertation: Virginia Tech, Blacksburg, 2016.
- [30] M. Prince, "Does active learning work? A review of the research," *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, 2004.
- [31] M. J. Prince and R. M. Felder, "Inductive teaching and learning methods: Definitions, comparisons, and research bases," *J. Eng. Educ.*, vol. 95, no. 2, p. 123, 2006.
- [32] G. L. Downey, "The engineering cultures syllabus as formation narrative: Critical participation in engineering education through problem definition," in *U. St. Thomas LJ*, vol. 5, Cambridge: Cambridge University Press, 2008, p. 428.
- [33] D. H. Jonassen, "Engineers as problem solvers," in *Cambridge handbook of engineering education research*, A. Johri and B. M. Olds, Eds. Cambridge University Press, 2014, pp. 103–118.
- [34] A. Kolmos and E. de Graaff, "Problem-based and project-based learning in engineering education," *Camb. Handb. Eng. Educ. Res.*, pp. 141–161, 2014.
- [35] S. Lord and J. Chen, "Curriculum design in the middle years," in *Cambridge Handbook of Engineering Education Research*, Cambridge: Cambridge University Press, 2014, pp. 181–199.