- **Dr. Streveler:** ***Welcome to Episode 2 of the Research Briefs podcast.***

  I'm your host, Ruth Streveler coming to you from the School of Engineering Education at Purdue University.

  The goal of Research Briefs is to expand the boundaries of engineering education research. In these podcasts we'll speak to researchers about new theories, new methods, and new findings in engineering education research.

  My guest today is Dr. Allison Godwin, an assistant professor of engineering education at Purdue; full disclosure – Allison is one of my colleagues.

  Allison will be discussing new frameworks and methods for exploring diversity and inclusion in engineering.

  And thank you Allison for being a guest on Episode 2 of Research Briefs.

- ***Could you start by saying a little bit about your background and how you came to doing engineering education research?***

- **Dr. Godwin: Ruth, thanks for having me. I also want to acknowledge all of the collaborators on the project we'll be talking about today. That includes Lisa Benson from Clemson University; Adam Kirn from University of Nevada, Reno; Geoff Potvin at Florida International University; and, I also want to especially thank Jackie Doyle who was the graduate student on the project**

from Florida International University and recently graduated with her Ph.D. She's now a postdoc at the Harvard Smithsonian Center for Astrophysics and she did all the work on operationalizing the data analysis we'll be speaking about.

So, my background is I earned my chemical engineering degree from Clemson University, and I spent a little bit of time after that in the engineering industry at a pharmaceutical company. I realized pretty quickly that I didn't want to stay in industry for the long-term; I enjoyed my job, I had a lot of great colleagues, but I just couldn't see that being kind of the future forever. And, I kind of found engineering education research through an email from my former undergraduate academic advisor. He told me about a new program that was starting at Clemson with the Ph.D. in engineering and science education and a project that my advisor, who's also a project lead on this research, was working on along with two of his other colleagues. And so, I ended up applying kind of out of the blue in a lot of ways, but tied back to my interest in undergraduate mentoring and undergraduate tutoring that I had done throughout my undergraduate years.

So, with my time in engineering education I really developed some expertise in identity development, especially looking at the transition from high school to college. But, more recently, and where this project started was expanding the definitions of diversity to some broader definitions beyond just gender and a binary gender measurement to race, ethnicity, first-generation status, sexual orientation, socioeconomic status, and other pieces of social identities and how students see themselves as engineers in

their undergraduate experiences from their first year all the way through their graduation.

So, I started here at Purdue, as you've said, in August of 2014 and have been working on those kinds of questions since then.

- ***So, I have one question to ask you, as a female engineering student in chemical engineering, did you find when you look back at that do you see how your identity work relates to your experience?***

- **I do. I think, for me, there's a lot of things I didn't think about or realize as an undergraduate student I didn't really question my place as a woman in engineering until much later. I kind of bought into that meritocratic way of thinking about engineering; if I just work hard and I do my best then it'll be just like anyone else. And, I started to notice smaller things as I got further along in my degree program through my experiences in my co-op at work on how I was treated differently than some of the other male engineers at the site. And also, just some of those small comments that got said in the classroom; I think I became a little bit more sensitive to some of those things. And that's what really spurred my research interest for my Ph.D. in looking at women in engineering.**

What I realized over the course of my Ph.D. and kind of in my first couple of years as an assistant professor was that position, in a lot of ways, was still really privileged because I didn't ask questions about my other intersecting identities, especially my whiteness. And so, when I talked about women I thought of women in general, but what I really was talking about was white

women in engineering. And so, a lot of this work kind of spanned from that starting point that I started with a real interest in women and went to a place where I wanted to understand not just gender identity but also a lot of other pieces of who people are and how that may or may not be included in engineering education.

- ***Excellent! So, one of the things that I want to talk about today is you're looking at a new approach, what you've called "Normativity," to look at diversity inclusion as well as this really new cool method, Topological Data Analysis, to be able to capture some of that quantitatively.***

  Could you describe a little bit what you would see was the existing paradigm and the existing analysis, and why you felt drawn to try to look for something new?

- ***So, the project this kind of all started on it and this idea of normativity plus the kind of new statistical type makeup, Topological Data Analysis, or TDA, for short, is the intersections of non-normative identities and the cultures of engineering, which is a total mouthful, we call it Inice for short.***

  And, what we were really interested in was understanding at the individual level how students had differences in their attitudinal profiles and if there was kind of a larger, or denser, group of those attitudes in engineering that shaped the culture of engineering and how students experience that over time.

  We were interested really in if students who are more aligned with that kind

of dense group had an easier time in navigating their pathways through engineering and we also hypothesized that students who didn't match that might struggle more or may even leave engineering. And so, that's kind of where we started from was the hypothesis that there was kind of a dense group of attitudes that might exist.

And so, that kind of came about from an idea related to where research has sat for a long time on diversity and most of the research on diversity, not all, has really focused on differences between groups. So, often, students get placed into men versus women, or other underrepresented minorities versus majority students, and understanding the differences between those groups. And our concern was that by binning students into those particular groups it did allow us to understand something about them but we might continue to be spotlighting them as other or different in comparing them to the majority group in engineering in whatever analysis we were doing.

One of the other challenges, and it kind of just starts to then bleed into the statistical side of things, was that a lot of statistical tests used to do those kinds of comparisons between groups have particular underlying assumptions about the data and they don't allow for, or they do correct errors in the models so they don't take into account differences as much as kind of overall averages or distributions. And, using those techniques and reporting the average result has a pitfall of potentially essentualizing the groups to that kind of average value rather than taking into account the kind of wide variance you might see among different groups.

And so, with kind of all of that in mind we wanted to approach the idea of

diversity by saying, "What exists?" rather than going in with a lot of apriority assumptions about the groups we would find, or the differences that we would see. We first wanted to understand, kind of going by this idea of topology, what's the landscape about attitudes in engineering and how can we understand those groups and the differences among them after we allow the data and the analysis procedures to tell us what exists?

And so, that kind of leads to the statistical technique that we ended up choosing, that Topological Data Analysis allows for that emergent structure to be examined without any of those apriority assumptions; there are still decisions that the research has to make but it's a robust method to understand multidimensional data or allow us to examine a lot of different attitudes all at once. And, allow those things to emerge as we understand them.

- ***So, I thought maybe we could do a little bit of glossary work for some of the listeners who might not be as versed in the theory and the stats.***

  So, one of the words that you talked about was "binning." I wondered if you could just say a bit about what binning is.

- ***Yeah, I don't know that it's a technical term, it's a term we've used. I think of our work as maybe the flip side of the same coin to a lot of other diversity research but with a different set of lenses and how it takes the particular steps and approaches. So, when I say the word, "binning," what I think about it is in more traditional diversity research, you first put students into groups. And the researcher determines what those groups are based on***

whatever the research questions are. So, this idea of, we'll put all the women into a bin and compare them to all the men, which maybe is another bin. And so, what we're thinking about is kind of a term of grouping that is predetermined by the researcher. Again, I don't think it's a technical term, but it's a term that we've been thinking about that we place students into these predefined categories that may limit the ways in which we understand them.

- ***So, I think conceptually it's a very important concept for your work.***

  The other thing is "binary" and "non-binary." So, again, I think sometimes people that don't work in this area aren't used to those kinds of words and what they mean. Could you talk about what binary is with regards to diversity?

- **So, when we talk about gender, what we don't mean is biological sex, the sex you're born with; what we mean is how students choose to express who they are in the world. And so, often, a lot of research has looked at men versus women, and what we've really been examining is other places in which students may identify kind of with the understanding that engineering is very masculine and maybe exclusive to particular groups. So, instead of just looking at men and women, which would be binary, you know, you're one or the other, we're also interested in examining students with different gender identities, whether that's any kind of agender, or non-binary genders so there's a whole group of different gender identities that students claim for themselves. And, I wouldn't even pretend to know, or make a list of, all of them; we've actually worked on creating demographic**

measurements that allow students to self-identify in those ways. So, thinking about other options for students beyond just men and women in our data analysis. And really the goal there is to understand and provide opportunities to support students differentially in engineering.

- ***So, the final term I wanted to ask you about was, "essentializing," and so could you say what you mean by essentializing?***

❖ **When I use that word, I think of it as making claims as if, "All women are like X." Or, "All underrepresented minorities are like X." And so, I think, it's not a criticism of where we've come from, but it is a kind of recognition that there might be other ways of thinking about some of things.**

And so, I often hear claims made, "Well, women have low self-efficacy in engineering." And, I push a little bit against that and I really kind of pull from other work; I think of Amy Slaton and Alice Pauley and Donna Riley, and a host of other amazing qualitative focused researchers who say, "Well, you can't say everyone's like something." You can't say, "All women have low self-efficacy," we see differences in individuals and how they experience engineering and what their beliefs about their abilities to succeed are. And so, I think that's one of the pitfalls of quantitative research in general is that it's set up to look at differences in averages. And in, kind of by definition, an average lumps to the middle value of a dataset and so, in some ways averages automatically essentialize. And, I think in some ways it's easy to get an answer, we look at the significance, we can look at the effect size and know this is likely not due to chance and it has a large effect on the outcome we care about. But, I worry at times, does that take into account all of the

individual differences that matter to student experiences? And so, that's kind of where we started from in the whole project was thinking about those kinds of questions.

- ***Well, thank you for that.***

  What I wanted to do now was kind of take you back to the journey of having the sense that you wanted to find a way to express individual differences and how did you find out about TDA, and where did it come from? I know you said you're using it for social science research, implying that it wasn't developed for that. So, could you just talk a little bit about that?

- **Sure, so we started with some of these kinds of questions around what would it look like to define normativity based on what students respond rather than our own ideas? And we started from the point of saying, how could we move away from this average way of modeling, or doing representation, in the statistical side of things?**

  And, actually this idea came from a TED talk that several of the researchers had seen; it was a TEDxSpokane talk by a man named Muthu Alagappan. And, he had been consulting with a Palo Alto startup group named, Ayadsi, who has proprietary software that does topological data analysis. And it was actually founded by the statistician who really kind of pioneered the mathematical underpinnings of the technique, Gunner Carlsson, and it's a relatively new technique. I mean, some of the first kind of groundbreaking papers were coming out in 2009; so, it is relatively new. And they'd used it

for all sorts of things; they've used it for brain mapping and genome mapping and monitoring and those kinds of things. The TED talk was inspired by the analytics movement in the NBA actually, and Alagappan was talking about how he had used the software to take basketball stats and how successful players were playing in the NBA and redefining the positions of basketball. So, instead of thinking about a point guard, or a forward, or the other positions in the ways that we usually describe what they do on the court, what he was doing was saying, "How are they actually playing, and what kinds of different ways is basketball played by successful players?" And he defined a lot more positions than actually we typically talk about in basketball; and, talked about different ways you could be successful on the court even when you didn't match the traditional styles that were defined previously. And so, that was kind of, "Ah-ha!" Like this seems like a really interesting idea to move forward with in a really different kind of context than social science research and engineering education but with some of the similar kind of ideas of what are the data saying, are there certain kind of underlying ways in which performance happens that looks different than what we originally think about.

And so, we thought about this and we kind of had to deal with a lot of challenges of then using and actually building the analysis procedures from scratch. So, there's this company and we could've probably worked with them to do the work, but as a part of kind of academic side of things, there's published papers and some open source Python code that was available on the internet. So, we spent a lot of time doing research and thinking through what was the kind of underlying mathematics and statistics of topological data analysis and then using that code as a starting point to then work in R

which is the statistical software our group uses to build an algorithm to do what we wanted to do.

- ***And, I think you were saying that Jackie Doyle was the person that really did the heavy lifting.***

- **She did. We did a lot of the work in doing the reading and thinking together, but she is the one who did the coding and the project is really successful in a lot of ways because of her excellent work. And so, I definitely want to give some acknowledgement and recognition for all of that; and really a core part of her dissertation.**

  There's a lot of pieces that went into this and researcher decisions which I think I talked to you about earlier of how to slice through the data, how to determine what is a group, what isn't a group. And it's not unlike cluster analysis in the sense that, you know, researchers have to give input into where, say in a hierarchical agglomerative model do the groups start to emerge, or with a software that randomly seeds the starting points for building groups; it's similar in that way that there is that researcher input or kind of starting point input. But, what's nice about TDA is that it has less assumptions and allows for more types of data to be used but has a really similar approach to a cluster analysis in developing emerging groups from the data.

- ***So, as a cluster geek, I was really fascinated by the way the data looks and here's where I think our listeners are at a bit of disadvantage since this is an audio recording, but we do have on the website a paper that***

shows some of the analysis and for folks that may want to look it up this is something that's called, "Board 9 Characterizing Student Identities," and it is Figure 2. So, for those of you who have access to that you might want to pause the recording and bring that Figure 2 up, but for those of you who aren't going to do that we're going to try to describe it a little bit.

We have it open here on our laptop and I'm going to show it to Allison who probably remembers exactly what this looks like without having to look at the graph anyway.

- **So, the figure that we're referring to is really the results of the topological data analysis on 2,916 first-year engineering students across four U.S. institutions. So, that's the starting point and all of the decisions that went into that process have been documented in a lot of our work. But, we affectionately refer to this thing as, "The Worm," because it is kind of this long structure that has towards the end of it branches that come off of it. It is shaded by density so the beginning of it is a darker red and it goes to a lighter orange at the end where the branches start to emerge. And that's really how close together those attitudinal responses are across the multiple dimensions that we measured. We measured a lot of different things. We measured identities in STEM, we measured personality and motivation, and some of these other pieces that we know are important and have been highly researched when we start to talk about attitudinal characteristics in engineering.**

And so, if you move down the worm, there's these branches which we're

starting to call non-normative groups, and then there's a few little clusters that are not even connected to the worm; also, non-normative groups. What's also really interesting is that there's a lot of little tiny individual, or kind of dyad dots along the outside of the map which we're calling the disparate group. So, they're really different than the normative group or the non-normative groups, and really different among themselves.

And so, the way we interpret this is that the dense starting point of the graph is where a lot of student attitudes are tightly clustered together and where we don't see a lot of differences between them. And, as we start to move out in the graph, we start to see these branches or groups coming off where we start to see significant differences, not across all the dimensions but across certain parts of those dimensions that we looked at in the data analysis. And so, we're calling those, in comparison to that dense group, the non-normative groups; and the dense group the normative group. And, really those are defined in relation to one another not based on our definitions of what those might mean.

I work with physics education folks, both Geoff and Jackie are physics education people, and so they like to talk about it in terms of a spiral armed galaxy. So, there's this dense core, and then as you move away in distance, thinking about this as a multi-dimensional distance, you start to have these arms coming off that are less dense, and similar to but different than the other parts; and then as you move further out you might have more individual stars or clusters further away from that dense core. And so, that's how we've been thinking about it kind of as a metaphor for the ways in which the map kind of maps to something we can conceptualize in three

dimensions rather than 13.

- ***One thing I find really exciting about this is that normativity is defined by the group and it certainly is dynamic and it's not saying that three years from now normative might not look different.***

❖ **Right. And, it's not a part of this project to map that quantitatively over time, but what we have done is we've actually sampled out of the different groups that we see in our map, and we've been longitudinally interviewing those individual students for the last two-and-a-half years with plans to continue to do another two interviews this year. So, we have basically kind of this longitudinal data of stories of these student's pathways but where they started from and how that's affected how they've navigated engineering and how they've experienced that culture, and where they've had the bump ups against that, and where it's been pretty easy or smooth. And so, that's been a really interesting piece to round out the statistical side of things with the richer storytelling part of it as well.**

- ***The next thing I'd like to ask you about is how the community has reacted and could you remind us, just so we can put this in context, when did this group start publishing about this so we have a sense of how long this has been out there?***

❖ **So, the project was funded in September of 2014 and really the first publication started coming out, mostly conference proceedings, early on in summer 2015. And, we've been working on some journal articles, but we've been a little bit slow in really testing the robustness of TDA in really building**

out the story for that. And so, we do have some emerging things coming out hopefully in the next year, year-and-a-half. There's a special issue of *Physical Review*, it's titled "Physics Education Research for the Focused Collection on Quantitative Methods in PER: A Critical Examination." And so, they're questioning the fundamental paradigms of traditional quantitative research and asking for novel techniques as part of that special issue. And we thought, what a great space to try to fit our work into.

- ***That sounds perfect.***

- **It's been great. So, we've put in the abstract for that; that's been accepted and we're working on the full paper really documenting the analysis and decision-making process. And that's being led by Jackie, so I'm excited to see that come out. But, we've documented a lot of the process and steps along the way in other publications since summer of 2015.**

  I think the community, there's kind of two parts of this: the kind of normativity and redefining what we're talking about when we talk about attitudinal diversity; and then there's the analysis itself. And I think both sides of that have received some mixed reviews. I think anything that's new and starts to try to change the ways we think about things are challenging. And so, we've been really careful to try to talk about this as a complementary way of thinking about diversity in engineering education, but we have had some folks react to this kind of work thinking it's a replacement for the other fantastic diversity research that has occurred before. And, I'll say again, I don't think that's the case. I see this as the opposite side of the same coin. I think it's still incredibly important to

challenge the structures in engineering that privilege certain groups, and the culture of engineering that maybe for certain kind of students that fit gender and racial norms in engineering education. So, I think that's incredibly important work to be doing.

We were just interested in flipping this down to the individual level of how students are experiencing that and are there students that may not demographically look like they match into the structures paradigms but have other ways of experiencing engineering education.

And so, there's been some reactions to that both positive and negative in the excitement around a new idea in thinking about this as kind of a different perspective on the same larger issue. And then, there's been some concern that maybe if you took this to the far extreme this could be used as a way to find the "right," and putting that in quotations, the "right" kinds of students for engineering and excluding everyone else and that would be a real kind of perversion of the original ideas and foundations of this work. But, there's been some concerns raised in conversations with other researchers in this space.

With the methodological piece of it there's some challenges and some really good conversations that I've had with other researchers. One of the things that is particularly challenging about this technique is that there's no way to account for measurement error in the technique. So, anytime we deal with people and survey responses for attitudinal data there's measurement error, and certain kinds of techniques can account for that. Think of structural equation modeling or Latent Class Profile Analysis allows for

those kinds of things to be accounted for, that start to allow for groups to emerge, but one of the challenges is our data are so highly dimensional and so correlated that those techniques have other underlying assumptions that make them somewhat problematic for this kind of work. And, I go back to the fact that generalized linear modeling and cluster analysis and other kinds of advanced modeling techniques also don't account for measurement error; and so, I don't see it as vastly different than those two things.

The other thing I think we've run up against in engineering education is, I think there's this process of explaining the validity of your work and I think there's been a great recent shift in the community around moving away from using rigor as a tool to bash each other over the head with to questions around quality. And, we've benefitted from that as a part of the process of developing and using new techniques. But, there's also been a lot of questions and things we have to really unpack and explain as a part of introducing new methodological techniques to engineering education.

- ***So, the final question I have, I'm hoping through these podcasts that people may become inspired to push the boundaries a bit, so my question would be if there are people out there thinking, "Ah-hah, now I'd maybe like to try something new. Allison has inspired me." What advice would you have to people that are thinking about adopting new methods?***

❖ **I think one of the things that was really essential in the process, was an interdisciplinary team. Having people with different kinds of skills that they brought to the table to build a bigger and better picture of what we could do I think was really essential to this project.**

I think one of the other things that we really benefitted from was a really careful documentation of the decisions we made, why we made those decisions, where that might affect the quality of the results; and really that documentation has then gone into all the ways in which we talk about the results and also how we're presenting the technique with its strengths and weaknesses were opportunities for improvement to the community.

So, I think both of those things were really essential to the success of using and adapting something that had not been used in social science research before. I think there's also this aspect of being patient and working to publish things in a way that explain rather than use a lot of "jargony"?? words that people may not understand or buy into. So, there's a bit of having to do that process of educating and buy-in building with new ideas and new techniques that I think we've really had to grapple with as well.

- ***So, you talked about having to be patient. Are there other attitudes that you think are important for a person that is going to be pushing the boundaries?***

❖ **That's a great question. I don't know that I've thought about it a lot. I think, in some ways there is a little bit of being willing to step out and be a little bit bold. We've tried to really balance this idea of not apologizing for questioning the status quo with also acknowledging that there's a lot of quality in what we've been doing. And so, I think we've tried to navigate that tension. So, being bold in the sense of we're proposing something new and explaining why, but also, there's some need to be gracious in the sense**

that like, "I'm not scrapping everything else as well." And, I think our team is really committed to trying to do that because we've learned a lot in the last 20-30 years about diversity inclusion and about new methodological techniques that really set us up to do this work and if we didn't have all that work we wouldn't be asking the kinds of questions we're asking now.

- ***So, I will ask you one final thing because I am privileged enough to see what your office looks like, and I know there's piles and piles of data in your office, so can you just leave us with what some next steps are going to be working with those piles and piles of data?***

❖ **Sure. So, this project has really started and spurred on a lot of other ideas and one of them is my career grant. And so, that project is really focused on expanding this work from underlying attitudinal measures and profiles to a more expansive set of underlying characteristics which I'm calling "Latent Diversity." So, adding in students' ways of knowing their beliefs about where knowledge comes from, problem solving skills, and innovation, and other pieces that wouldn't traditionally be considered attitudinal. So, expanding that to really capture a really wide set of underlying characteristics and also expanding to a national level. So, I've recruited, with my team on that, close to 35 U.S. institutions and, you're right, I have piles and piles of data, over thousands of surveys waiting to be digitized. So, we're really excited to see when we add in those more dimensions and a larger set of data how we understand the kind of topology or landscape of engineers in their first year on a national level.**

- ***Well, I'm excited to see your results and I'm excited about where your career is going and very happy to be your colleague. And, thank you for being on Research Briefs Podcast.***

❖ **Thank you, for having me, Ruth.**

- ***You're very welcome.***

- ***Thanks to TJ Wharry for producing this Episode. Patrick Vogt composed our theme music.***
- ***Reminding our listeners that you can find the papers we talked about today, as well as the transcript of this episode by Googling "Purdue Engineering Education podcast."***
- ***Also, check out my blog at RuthStreveler.Wordpress.com.***