- **Dr. Streveler: Welcome *to 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 on Research Briefs is Dr. Shane Brown, associate professor of civil engineering at Oregon State University in beautiful Corvallis, Oregon.

  Shane has been researching difficult concepts in engineering and has some ideas about how to approach this research that he'll be sharing with us today.

  Shane, welcome to Research Briefs, in the second season of Research Briefs. I'm glad you could be here.

- **Dr. Brown: It's a real pleasure to be here. It will be fun to talk to you, Ruth, about concepts because you know an awful lot about them also. So, I'm pretty sure we can have a hearty discussion about concepts regardless of setting. So, I really appreciate this opportunity.**

- ***To provide a bit of an introduction to listeners, could you tell me a little bit about your pathway into engineering education?***

❖ **The short version is that I got a Ph.D. at Oregon State University in civil engineering, but I agreed with the school ahead of time that I wanted to do research in engineering education before I started that Ph.D. And, I think because I was an undergraduate student there and knew people, they sort of could like understand the way that that might function. And the department chair had some interest in engineering education anyway, so it was just based on the idea that I wanted a Ph.D. for sure, but I didn't want it to be in "normal" engineering research, that's not the right way to say it. Oops. And, then I just found a place that would support that.**

- ***So, you ended up researching social capital if I'm remembering right. How were you sparked by that idea that you thought that was something you wanted to investigate?***

❖ ***That's a good question. My department chair's name was Ken Williamson and he's the one who facilitated me getting a Ph.D. with engineering education research. He essentially said, "I'll support that, but I want you to do your research on social capital," and he handed me the book "Trust," by Francis Fukuyama, which is a pretty dense extended theoretical discussion of that concept and said, "You've got to sort of frame something in this space for your dissertation."***

- ***Well that's an easy way to go about it.***

- ***It sure is, it was clear as day that's what I needed to do.***

  - ***Yes, yes. So, conceptual changes and conceptual understanding is your major focus now. How did that develop?***

- **When I completed my Ph.D. I went to work as a non-tenure track faculty at Washington State University and I had a few years to think about what research I really, really wanted to do. And, I had some interest in social capital still. But, it's a big diverse topic and it was hard for me to pin down exactly which part of that I was interested in because there's social network aspects, there's normative aspects, and I just had an increased interest in student learning and why do some students struggle, why are other students successful. When I was an undergraduate I tended to try to think of kind of concepts like conservation of energy and apply those across courses; so, I just always had this interest in learning and now was an opportunity to reinvent myself as I transitioned to a tenure-track job at WSU.**

  - ***I know from knowing you that your ideas about what conceptual understanding is and how to determine it have evolved. And, I personally think that evolution is really fascinating so that's kind of the thing that I wanted you to share with the listeners a little bit of the biography or timeline of how did you start thinking about conceptual understanding. You're in your classroom, you're teaching, you're seeing some of your students struggling and you're wondering why. How did you first think about this, and how are you thinking about it now?***

- **I would say I first thought about it in an academic way in my early years as a tenure-track faculty when I was trying to figure out which part of learning I would want to investigate. And when you talk to people in our field about learning then conceptual something is a pretty common topic and it comes up in a bunch of different ways. So, I think first maybe I learned about concept inventories and thought in some ways those were a strange device to kind of enforce so much judgment on students; because the assumption was if you're not good at these then you must not be good at school maybe, you must not be good at concepts, maybe you're not a good engineer. So, I spent a lot of thought on how all of that could come with a set of multiple-choice questions. And, I don't mean to say there's no value in those, but I thought deeply about those ideas.**

  There's a whole bunch of different language we use in our field that I was exposed to in our early years. So, there's conceptual understanding, there's concepts, there's concept inventories, there's conceptual change, there's all the language around the theories of conceptual change, and I found them very incongruent. So at first, I was thinking well maybe conceptual change is just change in performance on a concept inventory. And then I read a paper by Chi and her categorical theory of conceptual change and I said, "Well, that seems a lot different than responses to a concept inventory."

  So, I think to answer your question it was sort of seeing all the rich activity in our field related to concepts seemed like a real nice entry point into learning and it was amplified by, I think, engineering faculty's affection towards concepts as being so important and just thinking about why do we think those are so important? And, why do we think those are so important,

and why do we think that if you know those things that everything will be sort of okay 'cause you can transfer and do that. So, not only was it just interesting hearing people talk, there's a lot of holes due to the different ways people talked about it and the assumptions they make when they talked about them in those ways.

And then the final piece is, I spent some time thinking about the contextuality of concepts for a lack of a better term. We did a little study where we interviewed engineering faculty and practicing engineers and asked them about transportation concepts. And, one of the things we asked them about was sight distance which was just how far down the road you can see; it's pretty straight forward. Faculty would use sort of textbook answers, "it's how far down the road you could you see," practicing engineers would say, "it's how far down the road you could see, but that's not really what is important, is it night, is it day, are there obstructions, are you going over a hill, are you going around a corner." And so, context was important to them more so than the concepts. And that led me into this space of, well maybe for example, the way the concepts are presented in an inventory is a way of presenting them, but that may not be universally applicable depending on what you're trying to accomplish with that concept.

- ***And, I know you also had practicing engineers take concept inventories, right?***

❖ **Um-hum.**

- ***And, what did you find out?***

❖ **A little self-promotion here, we just published a paper in the *Journal of Engineering Education* on this finally, which is what all faculty say I think, and we found that in almost all cases students perform better than practicing engineers on concept inventory questions. We also found that the categorization of concepts, that sometimes we use factor analysis to see how the concepts cluster, was different for engineers than for students. And, we think that might be based on the interpretation of aspects of the problems that are different than the original developers intended. And, we found in some cases that engineers will do much better than students on particular questions, but we think it's because something resonates with the engineer about the meaning of that question.**

So, for example, there's a concept inventory question on the fluid mechanics concept inventory about water flowing through a pipe, and they talk about a smooth pipe. Engineers know that there's no such thing as a frictionless pipe, so they interpret that as low friction; students interpret that as no friction. So, there's a big discrepancy in their performance because of the way that small idea was interpreted by them.

- ***So, in engineering education we're often saying that we're preparing students to be professional engineers, or practicing engineers, and you're finding that, "Wow, we give them these tests that supposedly measure their understanding but the practicing engineers can't perform well on that test," it kind of blows that whole assumption out of the water that***

we're really preparing them to be in practice.

- **It's sort of the idea that you have just presented is the reason why I wanted to do this study. It's to begin to question the role that concepts play in applied settings. I would say that your interpretation is a reasonable one and I'm very glad that you ask about it. In my discussions with sort of experts in the field there is a contingent that would argue that just because practicing engineers can't perform well on that question doesn't mean that they don't know that concept just that it's an invisible part of brain operations that is not part of their conscious process.**

  I think that's probably a fair argument, but we've interviewed practicing engineers about their understanding of these concept inventory questions and they frequently say things like, "That's an academic problem, I don't think about this in that way. I haven't seen it represented in that way since I was in school. I'm going to have to go get my textbook." And sort of a long list of that the context matters. So, I would sort of deny the idea that it is part of some invisible cognitive processes. I think that conceptual understanding is very contextual. And so, I think it is a little problematic that we may use concept inventories, or even more broadly academic representations of knowing, to say that those are the pathway to being good in this discipline.

  - ***So, when you say, "context matters," you gave a couple of examples about that of the engineers thinking about sight distance, and is it raining, is it daytime, what's happening," can you say a little bit more though about other kinds of context that seem to matter from what***

you're finding?

- **I can. We did, and these results will come from an ethnographic study we did of the engineering workplace to look at concepts related to roundabout design. And we found that there were several ways of that workplace setting that influenced concepts and that sort of were the life of concepts in that particular application. And so, for example, we found the concepts were relegated to sort of non-human applications like software applications. So, you may not have to know certain concepts because they're so embedded in the software applications that you either don't know them, or you know them in a way that's represented very specifically within that software. And you might argue, "Well, you have to know the concepts, it can't be a black box," and that's a sort of naïve way of thinking about it. They have a way of knowing it, it's just really related to that particular application.**

  We also found, for example, there's a meeting with 10 people in the room talking about sight distance for a roundabout and they were worried about some obstructions. And, in that hour-long meeting nobody used the word sight distance. They drew pictures, they had diagrams, they had figures, they talked about equations, they put the ruler on the drawing and said that's the distance between here and there. So, even when we pick a word we think would universally sort of meaningful and utilized by a setting it's not always true. So, they have multiple complex representations of that concept depending on the setting.

  We also found that the meaning is socially negotiated over time in relation

to a particular application. So, sight distance to this project meant something kind of different to, for example, a highway project where a speed limit change, or maybe there's a deer crossing, or something like that; you would think about sight distance in that setting much differently than you would in a roundabout design.

- ***Now, I recall some earlier work too that you did with looking at how the problem itself is represented: is it a picture, is it a line drawing; and I think you found some differences even there too didn't you?***

- **We did. The best example I could think of on the spot is two of the fluid mechanics concept inventory questions are a pipe expansion or contraction. So, there's four versions: there's one where it goes from a bigger pipe to a smaller pipe horizontal, there's another one where it goes from a smaller pipe to a bigger pipe also horizontal, and then those same two applications in a vertical setting. And, they ask you, "How does the pressure and the velocity change as the water flows through there?" And, the answer is related to Bernoulli's equation, is that you have three forms of energy, elevation, pressure and velocity and if one goes up the other one must go down. So, for example, in the horizontal pipe if there's an expansion then the velocity has to go down because you're moving the same amount of water in a bigger space and if the velocity goes down the pressure goes up. That's weird a little bit because you might think, "Well, the water has a lot more space now there must be less pressure and be pretty happy about that."**

So, to get back to your question, we ask engineers about that and a large

percentage of them get that problem wrong and they say things like, "Well, the pressure goes down because there's more space and there's more space for the water to occupy." And, they don't go back to the fundamental idea of the conservation of energy. That's compelling. We are currently postulating, "Maybe that problem has no significance to pipe designers," because that's who we asked the question of. We are suggesting that you might design a pipeline system to have a maximum pressure of 100 psi but the pressure that's in that pipeline might be 30 at any given time, so you're not even close to the capacity of the system. So, when you show them a contraction that's vertical, horizontal, I think the answer is, "Who cares?" It just doesn't matter.

- ***It's never going to happen.***

❖ **Right. And it'd be compelling, as I think about this, if we could pick applications to ask them about that do matter, then would they go back to the fundamentals and get the right answer. Is it really more about the importance of getting it right or is it the importance of the actual concept?**

- ***So, one question I'd like to ask too that I know I hear people struggle with when they're starting to do the research is like picking a theoretical framework. And, I know in conceptual understanding there's the popular frameworks and there are the not as well heard of frameworks. And, I know that you've negotiated between that a bit. Could you speak to that a bit about how you decided on frameworks, and what your reaction was, and just how you use frameworks in your research?***

- **I would love to. I'll start off by saying to all you listeners out there, if we mischaracterize theoretical frameworks, please don't comment because there's a lot of different ways of thinking about a theoretical framework. Thank you for listening. ((laugh)) I would also say that there is a lot of dissension in the cognitive science field about the different theoretical frameworks for conceptual change.**

  My short, and semi-flippant answer is, we just need to spend more time thinking about all of those because there's been a group of people who have done some research in conceptual change but even within that group there's not a lot of articles in our notable publications, in all the journals of engineering education that try to understand these theories in our setting. So, that didn't exactly answer your question. I struggled a little bit because all of the three prominent theories, and there's more than that, so Chi's theory, diSessa's theory, and Vosniadou's theory; I consider those to be the three big ones, are unbelievably complex and have 100s of pages written on each of them and are a little bit inconsistent over time. And, when I say inconsistent, I think they're all trying to make their theories more robust and think about them.

  - ***Yeah, they're evolving as well.***

- **Yeah, that's a better way of saying it. So, it's hard to pick three big theories; to pick one and then to pick like kind of which version you want to work with, and then which subtlety or aspect of that version you want to work with in your study. Which is why I think we would just benefit from starting to do that.**

So, I just picked one that happened to be really obvious to me that it was a relationship between knowing and the setting; and that's Vosniadou's Framework Theory because she talks about, as an example, the presence of a globe in a classroom setting and the effect that can have on student's beliefs about the flatness of the earth. So, going back to our earlier conversation, me having the approach that context is important, that resonated with me really well.

I don't want to infer that diSessa or Chi don't account for context, it just happens that that application of context I found particularly resonant in thinking about people's understanding in the relation to their surroundings.

- ***And, what has been the reaction for you choosing a framework that isn't quite as popular in engineering education?***

❖ **Here's my silly part and then I'll get to a better part. My students don't care because they haven't heard of any of them until I tell them to start reading them, so they are great to talk to about it because there's no defiance.**

There's a little bit of academic posturing that's sort of has occurred in conferences and submissions to journals about, "That's not the right one, you should pick this other one." There's been some kind of hallway discussions along the same lines, you know, "Maybe that's not the best one." I would go back to the idea of, if we had 50 publications in engineering education that looked at different pieces of these theories, that maybe is the time to start beating people on the head a little bit. But, when

we we're just starting to explore this phase, I'm not sure the confrontational approach is the best one to do.

I think like well-reasoned arguments amongst people are quite helpful to our field. That's a little different than saying, "Why did you choose that one, I don't think it's very good."

- ***Right, right. So, one of my aspirations with Research Briefs is to help people when they feel like their being coerced into groupthink maybe and it's like, "Well, you've got to use this method because everybody does," or, "You've got to use this framework because everybody does," to be able to have the courage to be able to resist that a bit. So, what contribution do you think your life experience with having that happen to you can help inspire people to be able to withstand something like that if they encounter it themselves?***

- **I'm an ultra-pragmatist, so I would say as this being surviving in our field, you want to think about where you are in your career and the things you need to accomplish to get tenured and promoted. And, I don't mean necessarily be subjugated to all the whims of that process, but I mean, if you can more easily write a paper or two and do some nice contributions to our field within the normative paradigm, I think that's probably an okay idea. I think it would become problematic if you, I think the saying is, "If you cut off your nose to spite your face," if you make those argumentations to say, I'd rather make this approach and that leads to you not being productive in a way that's valued by academia, that's problematic, it's career suicide. So, I think people need to be really conscious of what they need to get done in**

that time in their life and I try to, as hopefully almost full professor, realize that I'm in a position where I get to talk about these things quite freely, take a position, feel confident about it. But, I didn't feel this way when I was in the first couple of years into my academic career.

I would also say I hope that as a field we can start to embrace these seemingly defiant views; like, "I don't want to do that thing, I'd rather take this approach," and have more space for that to occupy because I think it's healthier when maybe you're not as constrained by what everybody's telling you to do. It's a fine line that we walk in terms of kind of survival I think, in terms of being an accepted part of the culture we're within, and then also hanging onto our identity and what we believe in and what we think the right approach is.

- ***So, one question I want to ask you, and I know this is a really hard question and you weren't prompted to be thinking about it, but absolutely I get your idea and concur with it of don't be defiant to be defiant, particularly as you're starting out your career, it's likely to have a bad effect. But then there is that place of, don't cut off your nose to spite your face, so how do you think you'd know if you're uncomfortable with a particular method or theory just because you're being stubborn or because it's really not productive for you. Do you have a sense of how people could think about what that difference might be?***

❖ **I love your question. I have, even more so in recent years, encouraged my students that their sort of pathway to privilege and recognition within our field is just knowing an awful lot about the thing that they're arguing about.**

So, to answer your question, I think if a student wanted to argue over a conceptual change theory or about a qualitative methodology the first thing they need to do is just go read, read, read, be smart, get in engaging conversations with people who know, so they can really be up to speed on that. Because your worst position is not knowing and just coming from it from an uneducated view. And, one of the positive aspects of being a graduate student is you have time to just go read and get smart about something. So, I would say that's maybe one of the most important things you could do is become knowledgeable. And I think you could also be very evaluative of your own approach. So, if we take positions of advocacy that's different than positions of intellectualness and then I'll be an advocate for these particular reasons, but I'll also be honest with the people I'm talking to that there's pros and cons of each of these approaches.

So, my overview answer would be, you just have to be really up to speed on the arguments that are embedded in your approach versus this other one. For example, if you run into somebody at a conference and they have a differing opinion and they start to say, "You're doing it the wrong way," you need to be able to reason through with them and maybe ideally you've read some papers and thought about some things that they haven't and then you have a little bit of a position of authority on that.

- ***So, just really do your homework about it, think about it deeply, have good reasons for your arguments and kind of take it from there. And, again, check yourself and say, "Am I just being stubborn? Am I just want to be rebellious? Or, do I have a good logical reason behind why I think***

this approach is better or maybe this theory works better for a framework than theory B does for me."

- **Right, absolutely. And, I think also recognizing that in our field, much like many others, the theories that are presented to us like for motivation, or conceptual change, or self-efficacy, are somebody's ways of thinking about it. And there's never going to be a black and white phenomenon where one is obviously perfect and the other one will never work. So, it's all grey space that you just have to get committed to, feel good about it, do your best with that thing. I think sometimes people in any science-y field get beholden to a particular set of theories just because that feels good and then the new people in that field think, "Well, it's very binary, it's very clear that one's better than the other." Whereas, for that expert that clearly came from years and years of thinking about it and maybe personal advocacy and funding and those sorts of things. So, I also think it's just recognizing that it's not the "best" one, it's just one that will work, that happens to be somebody's reasonable interpretation of a phenomenon.**

  - ***Well, Shane, is there anything else you'd like to say to the listeners about your work?***

- **One final thing is I would be excited if there were many new, young scholars in our field who would begin to explore this big space of conceptual whatever, conceptual change, understanding, knowing, learning because I think there's a lot of opportunities to do so that are helpful to students, that are related to normative ways of knowing, which are related to power and privilege, which is something that's very important for our field. And,**

certainly there's a lot to be done related to our goals of preparing students to be good engineers in the workplace. So, I think we need more people thinking smartly about this to be useful to the students, which is really what we're trying to accomplish here.

- ***Thank you. I've as always enjoyed talking to you. Hopefully that comes across here.***

❖ **This was a wonderful opportunity and I very much appreciate it. Thank you, Ruth.**

- ***Thank you.***

Research Briefs is produced by the School of Engineering Education at Purdue.

- ***Thank you to Patrick Vogt for composing our theme music. The transcript of this podcast can be found by Googling "Purdue Engineering Education Podcast." And please check out my blog, RuthStreveler.Wordpress.com.***