[Intro music]

[Alison]: Hello and welcome to PhosForUs, the science podcast of the STEPS Center. For this episode, we'll be your hosts. I'm Alison Deviney.

[George]: And I'm George Hoteling. The STEPS Center is the Science and Technologies for Phosphorus Sustainability Center. We're a convergent research center that focuses on how we can support more sustainable use of phosphorus, which is turning out to be quite the challenge. The center has experts from dozens of different fields across the physical and social sciences working together to address this challenge.

[Alison]: So George, you said STEPS is a convergence research center. Can you explain to our audience what that means?

[George]: Yeah, sure. Well, it's actually the topic of today's episode. So it lies in the heart of how STEPS tries to solve the challenges of phosphorus sustainability. Convergence research is the process that drives our research direction, and it enables us to find the best and necessary avenues to take. It's actually a pretty cool concept, and being a part of a convergence research center like STEPS really gives us the opportunity to give you the inside scoop on that.

[Alison]: I agree it is cool. So let's start this episode by taking a closer look at what convergence research is, and give a few examples of how it's done. After that, we'll hear from some members of our steps community about how being part of a convergence research center has impacted the way they view problem solving in their own work as researchers.

[George]: All right. Yeah, that sounds great. Let's dive right in.

[transition music]

[George]: We'll start by explaining the concept of convergence research as provided by the National Science Foundation or NSF, which in full disclosure, is the agency funding the STEPS Center. So in 2017, the NSF began assembling a list of ten big ideas. These big ideas were kind of the original guidelines for research to better serve our nation's future. Convergence research happened to be one of these big ideas. So the NSF tells us that convergence research is a means of solving vexing research problems, especially those focusing on societal needs, as two primary characteristics. So it's driven by a specific and compelling problem, and it shows deep integration across the disciplines. So we'll get into that.

[Alison]: Okay, so that's the NSF definition of convergence research. But what does that really mean?

[George]: Right. Good question. Let's break it down. First, we'll go for specific and compelling. I actually looked up the definitions of specific and compelling. If something is specific, then it has clear definitions, right? Boundaries or objectives even. And if something is compelling, well, Merriam-Webster's tells us simply that it demands attention.

[Alison]: So let's talk for a minute about how the STEPS Center's focus on phosphorus sustainability fits the bill for a specific and compelling problem. It's specific because we're only talking about a single element, phosphorus. And Every STEPS project is centered on some aspect related to phosphorus. And as for compelling, I would say it's compelling for a variety of reasons. But one way to think about it is that phosphorus is essential to all life on Earth. So it's both a social and a biological issue, and yet it can be a pollutant in large enough quantities. So it's also an environmental issue. And since we get nearly all of our phosphorus from mining the limited deposits around the world, it's a geopolitical issue as well.

[George]: Hmm. Yeah, I see, so it's sort of odd how honed the issue is simply on phosphorus, but how global and multidisciplinary the related issues are.

[Alison]: Right. So now we can see how specific and compelling a problem it is to manage phosphorus sustainably. George, you mentioned Multidisciplinarity, and earlier we said that convergence research operates by deep integration, and it does so because it needs to. But why is that? And we should probably also explain what we mean by deep integration.

[George]: Hmm. Yeah, I agree Alison. So let's look into it. Our Center's director, Doctor Jacob Jones, actually gave us some insight on both of these questions during a previous episode called 25 in 25. So here's what he said, and it will help us understand what deep integration is and why it's so important.

[Jacob]: There's another interesting tidbit, um, of quantitative data. In a paper published in the journal *Nature* in 2018 by Marco Springmann and a bunch of other authors. And so this paper looks at environmental impacts of phosphorus in the environment. And, uh, through modeling, uh, that team calculates different types of interventions and the effect those interventions might have on environmental pressures. And if you do things like change diets of every human on the earth, you can't bring back the environmental pressure that's going to be pushing from population growth. If you do things like reducing food waste also, you can't bring it back. Um, if you create new technologies, the models show that you can bring it back to, to levels near what we had in 2010, but it's through the convergence of all of those things that you can get the greatest reduction in environmental impact. So, um, we don't think we can solve this alone with technologies. That's why we have social scientists on the team, for example, um, in fact, the disciplines across steps. And maybe this is in another question span, 28, uh, unique disciplines. So it's a great group. And, uh, glad to talk a little bit about that 25 in 25 vision.

[George]: So yeah, it's clear there's a lot of ground to cover. And deep integration is certainly needed. Now what about how it looks practically? What is deep integration across disciplines? Doctor Joan has more on that.

[Jacob]: The challenges underpinning phosphorus sustainability are very broad, um, from many different disciplines to many different stakeholders. Um, and you can describe it along so many different dimensions. And one of the ways in which we describe the challenges underpinning phosphorus sustainability from our perspective as a center is through link scale. Um, so we need researchers working at very small length scales like angstrom or nanometer scale, uh,

folks like myself who work in materials science, chemists, chemical engineers, we need them working hand in hand with researchers at other length scales, like social scientists and, uh, agriculture researchers. And so, uh, in order to integrate research across all of those different length scales, we need highly transdisciplinary approaches, right? Um, transdisciplinary approaches build upon interdisciplinary approaches, which builds on multidisciplinary approaches. But transdisciplinarity is really taking methods in one discipline and applying those methods in another discipline. And so we see that in many cases throughout STEPS. So to advance a vision as ambitious as 25 in 25, we need to understand at the highest level, at the systems level, understand phosphorus flows where we can intervene, how we can create solutions that will be adopt and actually make an impact in the long term. So our researchers are situated in these highly disparate disciplines. Um, and we have, uh, integration director, uh, on our team. So she's the steps integration director, and she's trained in the fields of science, of team science and integration and implementation science. And she creates structures and processes in order to facilitate our integrating across all of those different dimensions and all those different disciplines.

[Alison]: As you might have picked up on, there is a lot of intention that goes into building convergence within our center. And to help with that, we have, as Jacob mentioned, a dedicated integration director that oversees this process. So how about we explore what makes convergence research successful?

[George]: Let's see. So the NSF actually identifies four critical components of a successful convergence research project. I think listing them in the context of steps really helps identify the value and potential of convergence research. So as a broad overview, these components are one a need for convergence research two readiness to engage in convergence research three integration of knowledge tools and modes of thinking and four progressing the next generation of scientists. So let's look into number one, a need for convergent research.

[Alison]: Yeah. The founders of steps recognized that phosphorus is a complex problem that none of them were going to be able to solve on their own. So when they came together to write their proposal for a science and technology center, they made sure to include as many disciplines as they could engage at that time. And that approach has really changed how they do research. Here's how Doctor Yong Genzer, a member of that original proposal team, put it.

[Jan]: You know, going looking at at my research approach, when I started, I was always looking at the at the research from a hypothesis point of view. Right. So this is sort of NSF type proposal where you propose a hypothesis and you, you verify it or you do not verify. Go back and forth. Now when I look at the structure of my group and my research, we have moved very heavily into the mission driven research, where we have a problem somewhere out there and we have to find a solution to it. So we still do a lot of work. We do reverse engineering first, where I come up with a model and try to see if the model system works, and we can apply the findings from the model to solve the real life problems, which very often doesn't happen, but that really involves a very, very diverse group of people, uh, just because of the nature of the problem. And so it's been fascinating for me to see that you know, in these types of approaches, you have to reach

out to different, uh, different communities of scientists, different, uh, expertise. And it's a it's a constant learning experience.

[Alison]: So the founders of the Step Center recognized that we needed many disciplines and included those perspectives in the proposal process. And as Jacob mentioned, our community now includes dozens of researchers and scholars spanning 28 disciplines.

[George]: And it's still growing, which segues nicely into the NSF's second component of convergence research. The research group shows that they have a readiness to engage with convergence research. This essentially means they're going to be composed of the necessary disciplines for the task.

[Alison]: Okay, George, but a question I have is how did they know which disciplines to include?

[George]: Yeah, I was thinking the same thing and it actually has some history to it. It started with a mass balance by a soil scientist, and this mass balance illustrated the need for everything from biologists, material scientists and analytical chemists like John Genzer, who we just heard from all the way to economists and social scientists who understand things like stakeholders policy and the international phosphorus trade. Many of those disciplines were identified as the steps leadership worked through the complexity of phosphorus challenge just writing their proposal.

[Alison]: Exactly. And now we have agricultural engineers, geneticists, nanomaterial scientists, water quality experts, extension agents, people who work in risk assessment education. We even have a historian. And that list continues to grow.

[George]: Yeah. And that breadth of disciplines is what allows steps to demonstrate that critical third component, the integration of knowledge, tools and modes of thinking. This piece ensures that a group shows they have a serious game plan to couple, leverage, or co-develop their various tools and techniques like, uh, like the element of a precisely crafted charcuterie board all working together to make some really excellent flavor profiles.

[Alison]: I like that analogy. You know, this point reminds me of something else we have in steps. They're tools called boundary objects. And the boundary objects are focal points that help us work together and support that co-creation of knowledge. For example, we use a phosphorous flow diagram to help us identify where our research fits into the bigger picture. We also have locations we call triple bottom line scenario sites. Those bring research and disciplines together in specific geographic and ecological settings.

[George]: Yeah, exactly. Those are also a good place for students to learn about how their research fits into the real world. Which brings us to the final component for convergence research to be especially successful. Component number four. That involvement of the next generation of convergence researchers.

[Alison]: Exactly. So we talked with some of our step scholars. Those are the undergraduate and graduate students, as well as postdocs working in steps to get their perspectives on this. Let's

listen to some of their comments, because I think it really shows the impact that convergence research has on the next generation.

[Shwetha]: This is Shwetha - I'm a research assistant for Dr. Anna-Maria Marshall, and I'm a Scholar. So for me, uh, being part of a convergence research center gives me the opportunity to interact with other research areas that I normally would not have interacted with at all. Um, and it gives me a way to, um, translate my work to people outside social science. I'm a social scientist. Um, so it helps me. Um. Not simplify, but it helps me translate my work. I think that's the easiest way to say it and make it more legible to an audience. That's not in sociology, and I found that really helpful.

[Alison]: I just want to note that, as Shweta said, there are social scientists which even among the different disciplines and the steps community, is a bit of an outlier. This idea that involvement in convergence research has enhanced their ability to communicate is a key benefit of being part of the step center, and the benefits have been recognized by those with natural science perspectives as well. Here are Doctor Jessica Deaver, who is an environmental engineer and postdoc at North Carolina State University, and Lucas Crain, a graduate student at Arizona State University. Both of them work in the broad realm of urban wastewater management.

[Jessica]: So one of the things I was thinking about when looking at these questions is that it being a part of a convergence research center really incentivizes the…going beyond your discipline or your area or your group, maybe your department. If you're in academia, in order to try and reach people in other disciplines, both within academia and outside of academia. And so it allows us the freedom, the space, and potentially even the expectation that we should be going beyond what is in our bubble in order to try and bring new perspectives to the research that we're doing and the challenges that we're trying to address.

[Lucas]: Um, I wanted to sort of go off of what Jessica was saying, where, um. In many ways, being in a conversion research center and getting to interact with the people who are from different disciplines, who can provide different perspectives and can really, um, harness their knowledge in different ways for your own research, in many ways, for me has enabled additional research. Um, and without it would not have been able to do. Um, uh, one really good example of this is when we think about stakeholder research. Um, I'm a urine researcher. And so we work a lot with these urine diversion systems and these buildings. That requires lots of input from building managers, from plumbers, from the users. Um, but, you know, us being environmental engineers by discipline has, uh, our ability to interact with those stakeholders comes from very different perspective. Um, and so working with, uh, say social scientists, but, uh, even any other discipline that we have here in the Step Center has really been able to provide different perspectives and allows us to leverage the opinions of, say, all of these different stakeholders in a much more efficient and more effective way.

[George]: Those are some great perspectives, and I really appreciate that example from Lucas of Convergent Science in Action. I think what Jessica and Lucas have said really ties back to that main idea of engaging, diverse perspectives. And to wrap up this idea, Doctor Kim Born sums it up nicely.

[Kim]: I'm Kim Born. I am a postdoc scholar with, um, the convergence integration team in STEPS in terms of I have a I feel like I have a very unique perspective on what it means to be in a convergence center, since that's directly, um. What I'm researching. And I think one of the things that really strikes me is part of. The reason I was interested in this position is what a lot of others have touched on is this interest across the board in academia and different subject matters, and really cultivating that sense of curiosity about the world, how we create knowledge and how all of the pieces fit together. And I think, especially as a scholar, having that culture of co-creation of knowledge and epistemic humility really creates this breeding ground for that natural curiosity that got me interested in academia and graduate school in the first place. And it's been a really wonderful experience to, um, really be immersed in that once again.

[Alison]: I totally agree with Kim, but she mentioned something we haven't heard before in this episode: epistemic humility. George, can you explain what she meant by that?

[George]: Yeah, totally. So epistemic humility is a term we use in steps to acknowledge that even though we have our own expertise and experiences, none of us can know everything. So practicing epistemic humility is one of the individual habits of mind that steps researchers embrace in order to work together. By questioning our own assumptions and being open to this perspectives of others.

[Alison]: I think that says a lot about what it means to work in a convergence research center. And personally, I feel that being part of steps has allowed me to both contribute to, but also learn from all this important work. In fact, it seems like being exposed to all these different disciplines has actually enhanced my own sense of belonging in the science community. Shweta had something to say about that as well.

[Shwetha]: Yeah. When you said belonging, it made me, uh, think about when I first came here. Um, I thought when I first joined last year in 2022, um, I thought I would stick out like a sore thumb. Um, it would be strange for me, uh, being in a science community. Uh, but now I do feel like I belong. Um. And I think that's because it's a convergence research center. Um, and I do still stick out just because I am doing social science, uh, in a sea of natural science people. But now it feels like I'm sticking out just as a thumb and not as a sore thumb, if that makes sense. Um, like I'm there. I'm present, you know, or as a six finger in a hand of five fingers, if that makes sense. I do feel like I belong, uh, in a very unexpected way.

[George]: Shwetha makes an interesting point there. And it also reminds me there are definitely some challenges associated with trying to do convergence research, especially as it relates to phosphorus sustainability. We've touched on why phosphorus is a critical issue, but how do we communicate that either to other researchers working on their own compelling problems or to the public at large? Both are scholars, and faculty share their thoughts on those challenges as well. Here's what Lucas and Kim had to say.

[Lucas]: I think that this is sort of the the challenge of doing academic research is how do you get people to care? How do you get people to care about something that doesn't necessarily show up in their daily life? Um, and in general, you know, there's there are there are lots of

different established structures within every single discipline of how you, you know, disseminate your work, how you publish, how you, um, get things out to the public. Um, but I think that the, the, the best way to reach people, um, and to get them to care about your research in many ways comes more from the beginning of your process rather than the end of your process. If you. Work with the people that you're trying to reach early on to, um, figure out what their issues are, and you develop your research such that it addresses their problems, then I think that they would have much more reason to listen, and then you can really communicate it in any way, in any media that you might want.

[Kim]: I was thinking about, you know, how do we combining linking the two questions of the convergence and the communication? And I think in a lot of ways, um, they're really linked in terms of having a convergence center. We're always having to think about the ways we communicate with each other and unveiling the words that I know because my background is environmental engineering. But, you know, Shwetha might be like, I have no idea what you're talking about. Like, I need you to define a few terms before we're ready to understand what each other are saying, and, you know, vice versa. Um, and so I think that has really made a difference in the way I communicate with other people, because I have a greater awareness of kind of what the base level of knowledge is. And not only that, but like a breadth of knowledge to share kind of what might be most interesting to different people. Like, now I know a lot more about the economic systems involved in phosphorus.

[Alison]: So it sounds like convergence is not just about bringing different disciplines together to do research, but it's also about bringing the different perspectives together to better understand things like how the world works and what people need, and how to apply what we learn.

[George]: Mhm. To a certain extent I think that's right. One of our steps, faculty doctor Jay Rickabaugh at Appalachian State put it this way.

[Jay]: My name is Jay Rickabaugh. I'm an assistant professor of public administration at Appalachian State looking at collaborative governance for P sustainability. Uh, one of the other things that I do in my role with steps is that I'm one of the co-lead instructors on a class that teaches convergent science to undergraduate students here at Appalachian. And some of what Trevor was talking about resonates with what we've done in the class, thinking about how we translate different ideas to folks from different disciplines, how we might get social scientists thinking about some of the more natural or biological or physical components of the world, and then recognizing the ways in which theories that exist about natural, biological, physical sciences have their parallels in the social world. So one of the examples that I come to fairly frequently when I'm working with Stem faculty is punctuated equilibria and punctuated equilibria. In the biological context, when there's a major change in the environment, there's all sorts of genetic mutation when and similarly, like they were talking about with translating, thinking about what that looks like for policy, where if there's a major shift in the environment, say, like a major global pandemic, there's a huge mutation and adaptation in the policy world that happens as a result of that. Um, as a result of that change in the environment. So we're trying to try and identify in a convergent way, what are some of the larger transdisciplinary ideas that can

influence the way we think about the physical, biological, social, you know, and and natural world?

[Alison]: I like the way he put that in a bigger picture context.

[George]: Yeah, I agree. And with that, I feel pretty satisfied that we've illustrated what it means to be a convergence research, and I hope we've done that for you.

[Alison]: I'd like to conclude with one final comment from Doctor Christine Hendren, who is our integration director, that I think sums this up nicely.

[Christine]: You know, not every element is integral to life. Not every element is part of our DNA, is part of every living being. Um, you know, this is what makes this one element really special and important to care about. Um, I think that and using that as a tracer, because since I'm more of a team science convergence researcher, the idea that you can take the very smallest thread possible that is, um, able to, you know, attract all these different disciplines to have something to do with the puzzle of it. Um, that's a pretty tiny thread is one single element that you choose, you know, to isolate. So I think that that has helped me. Um, but it was also because I just had to convince myself because I was not a phosphorus researcher specifically. I was like, wait, what? Why do we care about this? And, um, and I think just holding on to the things that made me realize that this was at all an interesting topic and amplifying those. Um, has been helpful.

[George]: So that's it in a nutshell. I mean, it's hard to believe, but when she puts it that way, it's so clear that we're all tugging on this single thread together.

[Alison]: Well, I hope you've enjoyed this episode of phosphorus. We'd like to thank the National Science Foundation for funding our center. And the music that you heard is from pixabay.com. Keep an eye out for future episodes. And with that, have a good one and we'll catch you next time. Thanks for listening.

[Outro music]