Transcript

[0:01] (music)

Derek Bruff: [0:05] This is Leading Lines. I'm Derek Bruff. I am on record as a virtual reality skeptic. I'm not sure how useful VR will be over time to the field of education. I've seen too many VR pitches that focus on how immersive or engaging the VR experience is without any attention to actual student learning. And that's why I appreciated a talk I heard while visiting Cornell University last year. Astronomy PhD student, Jack Madden, shared the results of a study he and some colleagues conducted using VR to teach students how the phases of the moon work. They split the students into three conditions, a VR simulation, letting them explore the Earth-Moon-Sun system, a computer simulation of the same topic, and an old-fashion physical simulation involving a light bulb on a stick. Their findings, no difference in learning across the three conditions.

[0:56] That may not sound like an exciting study, but I think it's useful to explore these kinds of studies when making sense of new educational technologies. This past summer, I talk with Jack and his colleague, Swati Pandita about their VR study. They share what they learned through their study about virtual reality and how it might help students build mental models. And they make some predictions for the potential of VR in education. They also provide perhaps the most disciplined specific answers we've ever had to our closing question about analog educational technologies. I'm still skeptical that VR will have widespread use in higher education anytime soon. But I came away from the conversation with a better sense of just how VR might be useful in particular teaching contexts and with particular teaching objectives. I also came away with some ideas for how to study other new educational technologies and their effects on student learning. (music)

Derek: [1:47] Thank you for being on our podcast today and talking about your VR project. I'm happy to have both of you here and am excited to learn more about your work. Let's do some introductions. Can you each say who you are and what you're doing right now at

Cornell?

Jack Madden: [2:01] Okay. Yeah. Thank you for having us. I'm Jack Madden and I am a fifth-year graduate student, actually in the astronomy department, but I've been working with the physics and the communications department on a project in using virtual reality as a teaching tool in physics.

Swati Pandita: [2:20] And I'm Swati Pandita. I'm a second year PhD student in communication. And my area of focus is mainly clinical applications of VR, but when I saw the educational applications, I was really interested in that. So then I got put into this project.

Derek: [2:38] Okay. Say more about how this project came to be before we talk about the study itself and what you found.

Jack: [2:45] So we had an interesting collaboration between Natasha Holmes and Andrea Stevenson Won. So Andrea is in the communications department. Natasha is in the physics department. And this question came up about using virtual reality in physics labs. So Natasha does a lot of work in physics labs, sort of improving those. And Andrea is looking at VR in many different aspects. So there is a connection there between short of shared interests and went from there. They had a very successful proposal. And then we got some graduate students roped in. I got started because I know Natasha informally and the work I do in astronomy sort of allowed me to sort of consult on some of the astronomical aspects of the project. And I got involved in the data processing and all of that stuff too.

Swati: [3:49] He also did a lot of the modeling of the VR environment.

Jack: [3:53] Yes, the creation of the actual 3D environment. I helped a lot with, as well.

Derek: [4:00] And Swati how did you come to this project?

Swati: [4:03] For me, I was a first year PhD student at the time. And so I was just kind of looking around for projects and I came across this one. And so my expertise is running like a lot of social science experiments. So I did a lot of the like running participants and making sure that the experimental design was okay. And then when Jack got the data, making sure that that was in a usable form. (laughs)

Jack: [2:48] Double checking everything I did. (laughs)

Derek: [4:30] Nice, well, let's talk more about the study. What kind of questions were you trying to answer and how did you go about answering those questions?

Jack: [4:39] Yeah. So sort of a precipice of the whole study in general, we're looking at using virtual reality in a teaching setting. And so the environment we set up to test this was using the moon phases, which is sort of a classic demonstration in astronomy and physics classes, where the teacher sets up a light in front of the class and there's a ball on a stick and you sort of move the ball around your head and you can see how the light plays on the sphere to create different phases. And so that's a hands-on activity that's used in classrooms to teach about moon phases.

[5:17] There's also sort of a desktop version of that where you can use on your computer, where you can sort of simulate the different orientations and alignments of the earth, the sun, and the moon to see the different moon phases. So what we did was we created that similar activity in virtual reality. And now using these three different conditions, the hands-on physical model, the desktop model, and now this VR model, we sort of ran participants through with a pre-test. They went through the experiment randomly assigned to one of these three conditions, took a post-test about knowledge that they gained through that to see what the differences were and we collected a bunch of demographic data, as well to see what their backgrounds would be so we could inform on how they did.

Derek: [6:11] Okay. Swati, can you, mindful that this is a podcast, and we only have audio to work with, what would the student experience be in the virtual reality environment doing this demonstration? What is, can you try to describe that?

Swati: [6:27] So the thing about this study in particular is that a lot of students come in with the expectation that they're going to be put in a VR environment. And sometimes they come and we hand them a ball on a stick and we're like, "go for it." And so there's a little bit of disappointment. But the way in which we made the study too, was that even if you weren't put in the VR environment per se, after the post-test, you did get to kind of play around in the environment. And a lot of students were very excited for the VR condition. A lot of them haven't been in VR. So their expectations weren't totally set as to what they should see or what kind of graphic fidelity there should be or things like that. But when they were able to interact with space in particular, in the VR condition, students could essentially grab the

moon with a trigger grasp and then move it around. And essentially like change through space and time, which is really cool. And they really enjoyed that aspect.

Jack: [7:31] We did spend a bunch of time on sort of mimicking the same motions that the participants would experience in the hands-on version and then mimicking that in the VR. So if you looked at them, they would sort of look very similar. They're holding their arm out. They're moving their arm around. They're sort of spinning around on spot. We tried hard to get them to be as identical as possible, just in a virtual space.

Derek: [8:00] What kind of hardware did you use for this VR?

Swati: [8:04] So our lab mainly focuses on using consumer VR because we do want this type of software and application to be available to other people and not just doing it within the ivory tower. So we use an Oculus Rift headset. So just the standard controllers, two controllers, one headset, and actually for this one, three sensors, because we had a totally 360 environment.

Derek: [8:30] I like that too. I think one of the reasons I've been a little skeptical of VR in education is that it does seem to require a lot of hardware, right?

Jack: [8:39] Yes.

Derek: [8:40] At the higher end. And that's rapidly changing, which is good. It just means that there's more potential across education for tools like this.

Jack: [8:49] Yeah, that's a huge thing. It would be very difficult right now to create a classroom for twenty, using Oculus, this sort of setup that we had. So we had one participant at a time going through this. Using the headset that we used, it would require a computer, as well, that can run these. So nice graphics card. So you sort of have to have a computer for each student there, but they are definitely developing technologies to get around that.

Swati: [9:19] Yeah, Oculus is coming out with a quest. And actually I think our lab is on the waiting list to try that out. But yeah, we do try to also be mindful of the type of technology we're using, because in its current state, like it's very hard to roll out VR into rural areas because, you know, the software does require a stable internet connection as well, which can be harder to get along with the computers. It's a matter of data infrastructure and

connectivity, as well.

Derek: [9:48] Sure. Okay. Yeah. So you're not talking about some kind of freestanding device. You're, well-connected when you're using one of these?

Jack: [9:57] Yes.

Swati: [9:58] Yeah.

Derek: [9:59] What about, this is the other piece of VR that sometimes I think can be a lot of work and that's actually creating the virtual environment. So once you have a kind of hardware platform that you're working with. Because you guys had to create all of the stuff that the students were interacting with. Was that challenging to build that out?

Jack: [10:19] Yeah, it definitely, took a while. Definitely. One of the aspects that we were looking at as well, by sort of doing these three different conditions. The hands on, the desktop, the VR is that they do have different pros and cons. So with something like the desktop and VR, once it's created, you can easily send it around to people. Whereas the hands-on demonstration, they actually need to buy the light and the ball the proper resources for that. You can't copy and paste a stand light to someone else. So it definitely has that benefit once it is created, but it did take a while. It took about a semester of fine tuning to get everything we wanted to work right. We did also go through some piloting of different control setups, different sort of user interface setups to just get the fuel rate for what we wanted.

Derek: [11:16] So let's go back to the study itself. What were the learning outcomes that you were trying to assess in these three different conditions?

Swati: [11:23] So we were interested in seeing whether or not VR kind of lived up to its name in that, do people learn better in VR as compared to the hands-on and the desktop condition? And Jack, would you like to report our findings?

Jack: [11:40] Yes. So yeah, we did look at all sorts of stuff. We collected a lot of data on the pretest, so the pretest with sort of a knowledge test about moon phases. Like where does the moon rise each night? Like if, if you see a full moon, what is the phase? If someone's on the other side of the earth, what do they see? So sort of questions like that. So that was the

pretest. They went through the experience and the post-test had very similar questions with a bunch of demographic information, as well.

[12:12] So the main thing is like, what is that pre to post-test score difference for these three different conditions? What we found across conditions was there was no significant difference in the learning gains for these three conditions. We found that students really preferred the VR experience way more. About 80% of people said they preferred VR, no matter what condition they had been in originally. So it was interesting to see that, you know, despite which ones they prefer, they actually still learn the same across these different conditions. And as Swati was mentioning before, a lot of students didn't really have experience with VR before. The experience wasn't set up super optimally. So it's kind of interesting that even under like non-ideal conditions and something they were unfamiliar with, they could actually still learn just as well as a more traditional method and something they're more familiar with like a computer or laptop.

Swati: [13:17] Yeah, one thing with the controllers, especially, is that even though we introduce the controllers outside of the headset and we're like, "here's a trigger, here's the grip," a lot of people that are new to this and don't really have that much experience interfacing with controllers that much, you're telling them, "here's how to use this now put on a headset, blind yourself and just like figure it out." So despite that, the fact that the learning outcomes were similar is actually pretty amazing because they had to learn not only how to use VR and navigate around with VR, but also the concepts of moon phases.

Derek: [13:53] So it sounds like a takeaway might not be that, hey, this, there's nothing here, right? Like it works just as well as anything else. I mean, on the one hand, you did no harm. That's good, right? They didn't learn less in the VR environment. But it sounds like you may be arguing that if students have a little more experience using those tools, then in fact they might learn more in that environment.

Jack: [14:18] Yeah, perhaps. And I think even just whether they would learn the same amount was still an open question. There's sort of a thing that it's going to be too distracting. There's going to be too much going on in the VR thing. It's going to be too new. They're gonna learn less. They're not going to be as focused. It's sort of like too flashy. So there's sort of that camp that would've expected they would learn less. So it was kind of interesting to know that they would do just as well.

Derek: [14:47] When they were in one of the three conditions, did you give them specific tasks to carry out or questions to try to answer or were they just kind of invited to kind of play around with the light or the simulation or the triggers?

Swati: [15:02] So they were given guided questions, each condition had about ten questions that ask them like, "what moon phase would you expect at this time of day?" and things like that. And they were all multiple-choice too. So yeah, they had like ten questions per each condition.

Jack: [15:22] Yeah, they were sort of prompted to explore the environment, to answer those questions and then proceed to the next question. So it was like, you know, I think the first question is, what, which direction does the moon orbit the earth if you're standing above it? And so we then prompt them like, you know, you can move the moon around to see which way it's going. And when they see that the time counter is going up, when they move it counterclockwise than they're supposed to intuit that. That's going to be the counterclockwise answer. Hit that. That's correct. And then move on to the next question.

Derek: [16:00] Did, in all three conditions the students were interacting, right, in some fashion?

Jack: [16:07] Mhhm.

Swati: [16:08] Mhhm.

Derek: [16:09] Yeah, it sounds like you, you didn't do a more passive exposure to this content. But did you consider something like having one group of students just watch a three-minute video on the phases of the moon?

Jack: [16:20] That, yeah, that would have been interesting. We did look at, some of the studies that we pulled the questions from, had done more traditional sort of classroom style lectures on moon phases. And so we were sort of roughly comparing our learning gains to those. And they were similar. We were really focused though on like the interactivity and the hands-on versus sort of simulation aspects of VR and how it compared to the other options.

Swati: [16:59] The main purpose of also using VR is the fact that you have the affordance of engagement, right? So we wanted to make sure that we amplify the amount of interactivity a

participant or a learner could have within the environment. And sometimes giving instructions is the best way.

Derek: [17:18] Yeah. Well, and one of the reasons I bring this up. It's kind of an artificial question because as I look at the science education, research literature, right? Like I don't think we're at a stage now in 2019, where you want to compare a passive exposure to a textbook or a video to some type of interactive engagement approach, like we've seen that the interaction works better almost all the time, right? So to kind of show again that in fact, when students interact with stuff, they learn better. Like I don't know that we need that, right?

[17:55] And so your study comparing three different modes of interaction. And what are the differences? I'm reminded of a study I saw years ago in the classroom response system literature, clickers. And they were, they had this kind of fake lecture environment and they would intersperse it with these questions they ask of the students. And in all three conditions, the students were asked questions, right? And asked to respond to these questions. It was just the response method that was different. And in one case, they did a show of hands. In another case, they did a little index card. And in the last case, they used clickers.

[18:26] And the study was really interesting because you started to see some of what the clickers provided that the other two interaction methods did not. And so that was Stowell and Nelson, 2007. And I still remember that because it was one of the first studies that started to tease out, well, how does this interaction technique different than some others? Because we know they need that kind of feedback in class. And so I guess I'm wondering in your case, it seems like to me that if a student has a really robust mental model of the earth, the moon, the sun, and how they move around and they can answer all those questions. And so are you able to detect anything in any of the three interaction modes that you studied that would help support that mental model development? Or do you think, again, they kind of all did that the same way?

Jack: [19:16] That's a good question. And yeah, you're right they were looking at these three different, very different ways of interacting. I think we're hoping to see that these different ways of interacting are going to be better for different types of situations. So something like the moon phases, where you do sort of have to build this 3D spatial model that evolves in time over timescales that you're not used to. Something like that might lend itself better for VR. Whereas there's another study that looked at, that used VR, but it looked at something

much more conceptual. It's like electromagnetic fields. So that's a spatial space and a time-space. That's also not what you're used to, but it's something that's a lot less concrete than looking at the moon, looking at the sun. It's like entirely, you know, mock images of field lines. There's so many different types of lessons that might lend themselves better or worse to the different types of interaction.

Derek: [20:37] Here's a question and I'll tell you in a minute where I'm getting this question from, but in the three different conditions, were students able to both kind of take a first-person perspective like I'm here on the Earth and I'm looking up at what I see? And then also kind of an outside perspective where they're looking at the whole system as it interacts? Could they do that in all three conditions?

Swati: [21:03] In the VR condition, we definitely have that.

Jack: [21:06] The desktop did.

Swati: [21:08] Yeah, the desktop condition you could as well. However, in the hands-on condition, you essentially were the earth and then you are holding the moon. So one could also argue that there's a little more embodiment happening in that condition. Which to kind of circle back to your mental model question earlier, how does thinking about the next segment of or the next phase, of this study in which we're kind of looking at, okay, is embodiment, is that going to affect people's mental models of how they think about the earth and the moon and the sun system? And so we decided to look into that in terms of embodying students within these astronaut suits, as well as like incorporating a social aspect to it. So now you have a partner in which you're learning moon phases about. So we're definitely interested in exploring different mental models and different modes of learning. But yeah, in terms of figuring out how to give different perspectives, it's very easy to do in anything that's like PC based. But I'm wondering now like in the hands-on condition, how can we give them that perspective? Unless someone is there giving them a demo.

Derek: [22:25] Right, if I have someone else be the earth and then I can move around and then tell the earth what to do. Well and one of the reasons I ask, a few episodes back in the podcast we had on a guy named Max Seidman from Dartmouth and he does game studies. And he told us about a game that was designed to teach people about herd immunity. So like we should all get vaccinated because the more of us get vaccinated, the less risk there is for the people who don't get vaccinated, right? And so they had designed

this game, that was, it was kind of like a little bit like the board game Pandemic. Like you're, you're trying to prevent this outbreak, right? And so, and you're cooperating to try to do this. And they had two versions, regular and zombie version, it was fun.

[23:26] But one of the findings they had is that their participants tended to learn about herd immunity better. And they had some, some metrics that they were using. The participants learned about herd immunity better when they played the board game versus a digital version of the board game. And the conjecture is that when you're playing, and I will say the digital version was not on a big screen, it was on a little screen. It was a tablet, I think. And so the conjecture is that when you're playing the digital version, you're not getting that big picture of how the parts of the system interact. You're looking at your part of the system and how you interact with the things around you, right, which is sufficient for playing the game well, but it may not be good for teaching a system concept like herd immunity, right?

[24:11] Which I thought was kind of interesting. And so that's why I'm wondering, in your case, right? You are, you're trying to teach a system concept, right? They need to have kind of a model of how all these things piece together and so that study would indicate that the physical condition, where they're not able to kind of step above it all and look at all the pieces, you might see lower learning gains in that case. And you didn't. But that just makes it all this more interesting.

Jack: [24:39] We did actually look at. So getting back to, seeing if we can figure out how they're building a model. We looked at sort of four months later, I think we asked them, we sent out a survey about, you know, sort of the similar questions and seeing which groups you know retained that knowledge more, if they had built a stronger model. We didn't get super high response. I think we only got about twenty people per condition. So it was like borderline, but we didn't see any noticeable difference between the three conditions and their knowledge retention. So that sort of makes me believe that maybe there wasn't a super-strong model.

[25:28] But the thing for me when I was actually making the simulation, I've taught these sort of lessons to groups of undergrads a lot and as an astronomer, I've sort of taken these classes a lot, as well. And my mental model for the moon phases that I use, even though I learned about it hands-on with the light source and the ball and the stick is something a little more realistic where I'm sort of above the earth and moon. And when I actually built the simulation and when in it, I was like this is how I've always seen it in my head. And so if we

can get it to sort of it's final evolution faster for the student, maybe we can increase the pace at which they pick it up. So I think maybe spending some more time for students to spend more time on this, they only had roughly ten minutes, I think. You might see something there.

Swati: [26:28] Yeah, and that's one of the downsides of VR too, is you can't really keep people within the headset for more than like 15-20 minutes, just in terms of, dizziness and disorientation is definitely a factor. It's getting a lot better now. But even in terms of the comfort of the headset, you know, people come out and it looks like they have like a little like sunburn, they're just like red and flushed and stuff and you're like, "okay, that's enough VR for you."

Derek: [26:59] It does get me thinking though about like the kinds of learning that we're trying to foster and how the, you know, the modality that the students experience may sometimes be quite relevant, right, in terms of the effectiveness. And it also gets me thinking about kind of you said your students kind of preferred the VR, which is great. But we know from the literature and learning styles that people have lots of preferences for how they learn, but that doesn't necessarily mean they learned better that way. That often it's the modality that matters. It's the modality content match that seems to matter more than the modality learner match. And I think your study kind of shows that to some degree. So what's next for the study? You mentioned astronauts suits and some social pieces, but are you doing more iterations of the study or more explorations along this line?

Swati: [27:51] We're definitely doing more iterations. So I'm very interested in questions of like avatar embodiment. So if you are embodied in an avatar, you know, there's certain questions about it. Like the demographics of the avatar, is that going to affect how well you perceive yourself in the virtual space, how present you feel within the virtual space? So a lot of questions regarding embodiment for a future, future study. But currently we're interested in the social aspects of VR and learning.

[28:23] So one of the things I mentioned earlier is that VR can afford this social learning. You can have two participants, you can have multiple participants. And so right now we're piloting to see, do you learn more when there's someone else in the environment with you? And earlier you had also asked about the guiding questions. We're kind of curious, we're like well, you can also be explorative in VR. So we decided to take out the multiple choice aspects of the questions and just give them these like open-ended questions to see like do they actually

discuss them? And some people, some pairs actually do. We were pretty surprised. We were just thinking, we might get like some clickers that are like, "I'm just ready to get out of here." But no, people are really interested and engaged in social VR and like, it's fun to see other students helping each other learn. So yeah, in terms of avatar embodiment, they do have these pretty snazzy astronaut avatars that were a pain to rig. And by rig, I just mean like allow them to move within space. No anti-gravity features just yet, but maybe we'll get there one day. (laughs)

Derek: [29:35] So no flying around yet? (laughs)

Swati: [29:38] Not yet, although I really wanted them to float, but the physics of that is crazy.

Derek: [29:46] Well and this reminds me of something else that Max Seidman said, the game studies guy, is that in some cases they found that games that had a more narrative component seem to engender more learning or social change, right? The kind of abstract game in some cases was less effective than the game that had a lot of story to it. And so I think even in the epidemiology game, there was a little more positive reaction to the zombie theme to the game. The game structure was the same, but they just kind of put some color to it and that seemed to help some aspects resonate a little better. So I think there's the narrative piece that is probably different than the embodiment piece and the VR situation?

Swati: [30:27] Correct. Yeah, that just gets me thinking. I think I was listening to a couple of podcasts in which, you know, a lot of our information used to be orally transmitted through stories. So our brain is just kind of, it's sensitive to storytelling and gaining knowledge that way. So I think if we incorporate maybe a narrative piece.

Jack: [30:48] A mission assignment.

Swati: [30:51] Another Apollo mission. (laughs)

Derek: [30:53] (laughs) I like that. I like that. Well, let me ask you to do a little future casting since you guys know more about VR in education than most people I talk to, if you look out, I know five or ten years, what would you like to see for VR in education?

Jack: [31:10] What would I like to see? I mean, I can sort of start with where the technology is

going and then sort of where it might land in a classroom. So we mentioned before the Oculus Quest, which is sort of a standalone headset, which is something that probably could have ran our simulation, but it doesn't have any wires, it doesn't have any sensors, but it has the controllers as well. So it's something you may, you wouldn't need a computer for, which is actually the biggest cost of VR set up right now for Oculus is the actual computer with the proper hardware. So with that you could have multiple headsets in a classroom that is much more affordable. So you could have a few people in a classroom using those at a time without the need for a computer sort of in a shared space, perhaps.

[32:09] We actually tested those. We went to one of their conferences. We tested it. There is actually a shared, it's all, it's, a lot of the development is in video games right now. So it was a video game, but there were multiple people, sort of in the same space working together. So that's sort of more of what a classroom might look like. But I think a lot of, you know, we sort of think of education and we go to the classroom and the, you know, middle school, high school, college age groups. I think there is a lot of learning that is taking place outside of those age groups, and outside of classrooms. You know individuals are learning a lot through online resources, which is something that an individual with a headset without a computer has like you could actually run what we just did. So there's sort of space for both.

Jack: [33:09] I think there still needs to be a lot more study of where it's going to be benefiting the most, you know, an entire semester in a headset may not be the best. I definitely, I think we can say now, it probably wouldn't be the best for most subjects. But a lesson or two, where you want to get the student to that very high-level mental model, as quickly as possible. And you can just show them right away and they can explore it themselves without distractions of it being very artificial. So we can make it look realistic. You could see some benefits there hopefully.

Swati: [33:52] So to carry on with that, I think I have a lot of aspirations for VR in the future, just because so much is being done now that maybe not a lot of people are aware of. I wasn't even aware of this, but there are a lot of clinical applications of VR for like medical students teaching them not only, you know, simulations in which they interact with 3D organs and such and practice surgery but also like bedside manner type skills. You know, what do you do when you are interacting with a potentially aggressive patient? So those types of things are very important. There are also, I'm sure you've seen, there's so many like public speaking, like VR type apps out there now.

[34:39] So a lot of soft skills as well as more technical skills. But I think when I think of VR in education as a learner myself, I do think of the fact that it can amplify your ability to introspect and kind of learn in a more private space where a learner might feel less judged. So you're afforded this, the wonderfulness of anonymity and you can kind of just learn as you go and no one needs to know. On top of that, as we were talking earlier, VR is becoming less tethered. So I would love to see like kids coming home with like VR headsets and still be engaged in wanting to do homework or learning or things like that and not have it be more of a chore. And also if you think of potentially for lower income students or students whose parents may not have the financial needs to be there, at least that's a remote way that students can continue learning. So VR can really foster distance learning as well. I think it can really help equalize educational inequalities if done correctly.

Jack: [35:59] Yeah, I think it also, it's making me think also about how VR, we might be using it in a classroom to learn, but it may also be someday used as a tool in research in different aspects of work. So you might have students learning how to use VR to then use it as a tool later on. So we use our computers, we use them to learn, but we also use them as tools for the things that we're learning towards. So you can sort of imagine, you know in Star Trek, they use the Holodeck to solve problems. They're using it to research things. They're creating complex situations. So you might be using VR to enter a space where you can do your research more effectively.

Derek: [36:47] Yeah. Well, and I'm looking behind you on our video conference session and whiteboards serve that purpose, right? But I can imagine there could be a time for certain purposes, like the whiteboard doesn't give you what you need and you have to move into this VR space with your colleagues to manipulate or brainstorm or figure something out.

Swati: [37:06] Exactly. That also speaks towards accessibility. So individuals that might not be able to go to certain places, like if you were having a field trip to the aquarium or something like that, might not be feasible if you're, you know, bed sick with a chronic illness or something like that. So I think VR's ability to teleport people and also give this notion of presence is super helpful in a very rich environment.

Derek: [37:35] Yeah, yeah. Well, speaking of tools, I have one last question for you. We ask this question of all of our guests. We spent a lot of time on Leading Lines talking about digital educational technologies. And your study just makes me really want to ask this question. What are some of your favorite analog educational technologies?

Jack: [38:00] I know this, go ahead.

Swati: [38:02] Oh no, you go first.

Jack: [38:05] Mine came immediately. I love the, you can buy like little diffraction gratings, which are like $0.20. And you can bring these to students of all ages and you just show them how to use them. So what it does, is it sort of creates a rainbow and it's this little plastic sheet and it has all these fine lines on it and it, if you look at a light source, you sort of see the spectrum of it. And this is, it's such a big concept in astronomy, is like looking at the light because that's sort of all we have. And so, when I can show a student, a spectrum is created by looking at a light, it's this scientific instrument now. And it just, it immediately gets across how useful light is. And you can buy tons of them, you can buy them by the hundreds. And so I'll give them out to students and, and they can take home this scientific astronomical instrument and look at just random lights. They'll look at street lights and see like different sodium lines and some of them it like really hits them and they sort of really love that. So I love diffraction gratings.

Derek: [39:25] That's a really great answer. I love that so much.

Swati: [39:28] Well, I raise you one implement that is cheaper. Mine is a piece of white printer paper and let me tell you why. So my background is in visual perception. And when I learned that our two eyes basically take two separate images and combine them together to make a 3D space, that just blew my mind. And one easy way to show that is if you take a piece of printer paper, roll it up into a tube as if you're like a pirate looking through a telescope. And all you have to do is keep looking through that tube, one eye open, the one eye that is looking through the tube and then the outer eye is closed. Then you put your left hand, or whichever hand you're not holding the tube with, to the center of the length of the tube. And if you open, like when you open your eye, you'll see that there's a hole in your hand. Because your brain is like how do I put these two images together? And so when it does that, you can see that you are actually combining two images together because, you know, every day our perception seems to be seamless. So if you haven't tried that yet, it's called the "hole in the hand illusion." Definitely my favorite.

Derek: [40:47] So you just break that seamlessness in this one small way and then all of a sudden you realize, oh, my brain is doing this thing all the time that I don't even realize. That's really awesome.I love it. Those are the two most discipline-specific answers we've ever

received for that question. And I love that. I love that. Thank you so much for talking with us today. This has just been a lot of fun.

Jack: [41:07] Yeah, thank you.

Swati: [41:08] Thank you for having us. (music)

Derek: [41:12] That was Jack Madden, doctoral student in astronomy and Swati Pandita, doctoral student in communication, both at Cornell University. Thanks to Jack and Swati for taking some time to talk with me about their VR study. Thanks to Cornell physics professor, Natasha Holmes, for connecting me with Jack and Swati. If you'd like to know more about Jack and Swati and their work, see the show notes for links to their individual websites, as well as the virtual embodiment lab at Cornell University. You will also find in the show notes a link to Leading Lines episode 48, featuring my interview with Dartmouth's Max Seidman, the game designer and researcher I mentioned in the interview today.

[41:18] I see a lot of parallels between the ways games can foster learning and the ways that virtual reality can create learning experiences for students. I expect we'll explore a few of those parallels at the Learning at Play event we're hosting at Vanderbilt on November eighth. And I expect we'll have some highlights from that event in a future episode of Leading Lines. Leading Lines is produced by the Center for Teaching, the Jean and Alexander Heard libraries and the associate provost for education, development, and technologies. This episode was edited by Rhett McDaniel. Look for new episodes the first and third Monday of each month. I'm your host, Derek Bruff. Thanks for listening. (music)