Accessible Interactive Simulations for Inclusive STEM Learning Video Transcript

-: Hello. My name is Ainsley Latour. I'm one of the co-founders of IDEA-STEM and together with the University of Toronto. I'm very pleased to introduce this session for our virtual symposium around supporting learners with disabilities in STEM learning.

And this particular session that I'm introducing today is going to be presented by Dr. Emily Moore and her team are an accessible interactive simulations for inclusive STEM learning.

So in this session, Dr. Emily Moore introduce teachers to the PhET Interactive Simulations projects project. And this started in 2002 and perhaps the richest resource for teachers out of this project, is that the projects website contains over 150 free science and mathematics simulations.

And those simulations are available in over 90 languages. So in addition to those simulations the PhET project also includes research around educational technology, STEM learning, and accessibility. In fact, in 2014 the project started making these simulations accessible to students with disabilities. Importantly, especially in a world where a lot of teaching and learning is happening virtually or in a combined virtual and face-to-face scenario.

This simulations are available across a variety of devices and platforms. So through this session, we are going to see some examples of simulations within the PhET project.

And we're gonna learn about some of the additional resources in that project that are available to STEM educators and that we definitely encourage you to check out. So some of his resources include a community that STEM teachers and educators can access. And that is a network of over 5,000 teachers, there's classroom activities. There's facilitation guys, there's tips and there's a few other things as well which may be of interest.

Because the PhET project is also a research project to there may also be opportunities for people to participate in research and they would get paid for it. And those people who participate in the research projects are all ages without disabilities with disabilities, all kinds of intersecting identities.

So if this is something you think would be useful in your class, or were you just curious? I think this is a fantastic resource and I really do encourage you to go to the website check them out and start a conversation with either Dr. Emily Moore or the PhET team or any of your colleagues.

We hope you enjoy the session.

Thank you.

-: Hello.

My name is Emily Moore. I'm the director of research and accessibility at the PhET Interactive Simulations project at the University of Colorado in Boulder.

The title of this presentation is "accessible interactive simulations for inclusive STEM learning". So I'm gonna be talking about our efforts in progress and expanding features for the PhET simulations to make them more accessible integrate more opportunities for inclusive learning.

The PhET project started in 2002. We were first the physics education technology project which became the acronym PhET P H E T with the Ph from the word physics. Over time we have grown to include more disciplines beyond physics.

And so we dropped PhET as an acronym and now our name is PhET Interactive Simulations. We are best known for our website which includes over 150 interactive science and math simulations or SIMs as I will often call them. These SIMs are used over a hundred million times per year around the world and are available in over 90 languages. Each SIM is a free, flexible, exploratory learning tool. And in just a moment, I will demonstrate one for you.

In addition to the simulations were also a research project known for developing a unique design approach and for our research in education technology, STEM learning and accessibility. I'm gonna demonstrate one of our SIMs John Travoltage. John Travoltage is about static electricity. It provides a way for learners to explore transfer of charges, attraction, repulsion, and grounding.

When the same opens, you see a man John, standing in a room on a rug next to a door his leg and his arm are interactive. I can rub his foot on the rug And move his arm closer or further from the door. As I rub his foot on the rug, I hear his foot rubbing and I noticed charges shown his blue spheres that appear with a pump transfer from the rug onto John's body.

As I moved John's arm, I can move it closer to the door knob and John can get zapped. As a charge is discharged from John's body. I can play around with transferring even more charge on John's body and investigate how that impacts how close or far his hand needs to be from the doorknob before he gets out.

So I just walked you through this in a very straightforward way, but as you make guess learners can take many different pathways and explore many different questions that come up as they try to make sense of the behaviors and relationships in this SIM.

Here's some of the common design features you'll find in all PhET SIMs. They are highly interactive. You learn with them through interacting with them. They provide real time feedback. Allow difficult or impossible actions. Include multiple representations. Are intuitive to use and implicitly scaffold and inquiry.

The design of the SIM itself supports learners and understanding what to do and what to pay attention to as they interact.

So you can find this simulation and many more at our website. Our website is PhET.colorado.edu. That's P H E T @colorado.edu. All of our resources are free and each of them has its own SIM webpage. And on that page you can find texts and video facilitation guides including teacher tips as SIM primer video.

And for many SIMs, that sound features video as well as classroom activities created by us PhET books and submitted by teachers around the world. You'll also find out each SIMs webpage all of the translated version that SIM.

From the start of the PhET project in 2002, we've been committed to the mission to make math and science learning more accessible to learners around the world.

In the early days of PhET that meant making the SIMs interoperable so that they can be accessed on as many devices, as possible desktops and eventually laptops and mobile devices and across platforms. Then we added the ability to translate the texts that's visually displayed and provide offline access. So they didn't have to speak English or have internet access To use the SIMs.

And we also always designed the sentence to be able to be used within different curricula, across age groups and in different learning contexts, using different teaching methods. But SIMs are used from kindergarten and their college in the classroom, remotely embedded in a lecture as part of class or student group activity within homework assignments and met it in learning management system and many more.

In 2014, I began leading a project to address challenges of access in particular for learners with disabilities. At that time PhET SIM supported only more traditional input mouse, touch and track pad. The emphasis was on the visual display. There was little to no auditory display in any SIMs prior to 2014.

Because of this, the SIMs are not accessible non visually, and they weren't yet taking advantage of the many new and alternative input methods. So in my work since 2014, we've been expanding the different input and display opportunities possible for the PhET SIMs using existing web technologies and common competing devices.

I have been with PhET for over 10 years and six years ago I began leading PhET's accessibility initiative, which has since grown into a team of folks dedicated to the design implementation and research and multimodal features. Meaning different modes of display and input for interactive learning tools. My team's mission is to create the most enjoyable inclusive learning experiences available at scale.

The way we do that, the pathway we work through and the medium we work with is they're creating accessible STEM simulations. We use the process of inclusive co-designed to create new features between implementing the simulations at scale.

So they're available to all, and we do that involving a diverse team of in-house experts, that's my wonderful team and many collaborators. A few things I'd like to point out about our process of inclusive co-design. First we see disabilities and mismatch between a person and their environment.

That means we consider it as a design challenge. We seek one size fits one solutions. So our goal is flexibility so that each simulation can be adapted to meet the needs of the teacher learner or learners making use of the tool in the moment.

So the outcome is an inclusive technology. And we designed through diverse collaboration. Our process embraces diversity and includes participation by teachers and learners with a broad diversity of needs.

And we think about scale in multiple ways. We envisioned design, develop, study and publish new multimodal features for accessible and inclusive PhET SIMs for use on a global scale. And we also developed design practices and associated learning materials to share these practices. There are things like online courses, such as MOOCs.

We conduct and publish academic research and STEM education, accessibility, computer science to share widely the knowledge we're developing.

And our software development we follow web accessibility standards to be compatible with many assistive technologies and when needed we further develop software architectures within our open source code base so that others can take up not only the SIMs but also our design practices and our software code to create their own accessible interactives, and all of this has high quality free openly licensed for use by everyone.

And we do this through the efforts of my team of eight people, which includes experts in software development, web accessibility, STEM education, linguistics, music, and many other things. As well as collaborations with the inclusive design research center at OCAD University in Canada, people at Georgia Tech, including Carrie Bruce and the Sonification Lab led by Bruce Walker and the CHROME Lab at St. Louis University led by Jenna Gorlewicz. And they Embodied Design Research Lab at UC Berkeley led by Dr. Abrahamson.

We also partner with multiple consultants that bring expertise and assistive technologies, and we partner with a number of schools and outreach programs through between do some of our co-designers.

Okay. So now I've told you about PhET as a whole in our accessibility initiative. So what are these multimodal accessible inclusive features that I've alluded to? Well, what we've been working hard at for the past six years is developing new display features which includes auditory display, visual display and haptic display. As well as expanding the input capabilities of simulations how learners interact with the SIMs.

I'll talk through each of these briefly and then show you some examples of what you can do with these features in different combinations, as well as let you know what is available to you to use right now from our websites and what's in development and will be available soon.

Let's start with auditory display. This includes everything you could potentially hear from simulation. We develop non speech auditory display. That includes sound effects and Sonification. Sonification is where sounds like musical tones are mapped to the SIMs underlying model. So the sound can provide information to the learner. So a musical tone might change in pitch as a variable is increased or decreased.

That's non speech auditory display, but we also have developed a way to provide speech display that describes what's happening in the SIM, as it happens. One variant of this, we call interactive description which is description provided the risk through screen reader, software as learners navigate and use the SIM. Interacted description allows for completely non visual access to the SIMs that have this feature.

Building on interactive description. We can use that description to create simulations that are self voicing. So simulations that provide description of what's occurring without using screen reader software. This description self voicing description is provided directly to the browser. So you don't have to know how to use a screen reader to make use of this description. This feature makes description available for use by those with and without visual impairments and could benefit students with learning disabilities cognitive impairments, or anyone who enjoys auditory display.

Next we have visual display features. PhET has over the past 20 years refined our approach to visual design. But in my work we have developed Pan and Zoom capabilities and also implement in a way to allow users to select if they want to view a focus highlight or not on objects as they're interacting. Focus highlights are very important if you're navigating by alternative input methods, but some of the work we have done also allows those using mouse or touch input to be able to opt in to seeing these focus highlights as well.

Pan and Zoom capabilities and always visible focus highlights can benefit learners with low vision and anyone using a SIM on a small mobile device.

For haptic display, we have been working on vibratory haptics on mobile devices. Learning how vibrations can support learners with and without visual impairments and understanding what's on screen and what's happening during interaction.

And a vibratory haptics enhanced John Travoltage using your mobile phone you can feel vibrations his charges transfer onto John's body. And when those charges discharge shocking, John.

And now we're to alternative inputs. we've expanded our open source code base to now support traditional alternative input. Things like keyboard and switch devices, as well as the use of mobile voiceover which is a screen reader software to control custom objects. If you're familiar with screen reader software, this feature enables unusual objects like for way, to rag about objects that we haven't PhET SIMs to be accessed through an iPhone using the native screen reader.

And we're also currently researching the use of alternative gesture and put in custom tangible inputs. And I'll talk more about these a bit later in the presentation and give you some examples which will help you make better sense of what these are.

So each of these features comes with their own strengths as part of a learning tool and their own limitations and challenges. As well as unique design research and implementation structures and communities.

I'd be happy to talk with anyone interested about any of these in particular, but to understand the true power of having these features in interactive learning tools. I like to demonstrate them in combinations. So I'm going to now is walk you through three examples.

One highlights, the use of features we have the longest experience with and the most simulations published with. The next highlight, some of our newer features in the last example is about our newest avenues of research. And while we don't have any SIMs published with this last example, set of features, I share it here because I think it helps indicate what we're moving towards in the vision of inclusive learning tools that we have and are trying to bring into being.

So, as you go about your work as educators, I hope that with our first example, you're able to make use of these sorts of features in your classroom right now. And as we get towards the later examples, that these sorts of ideas can help inform what you imagine for your classroom and your learners, and when you advocate for and come to expect from creators of educational technologies.

So on my first example, we have interactive descriptions traditional alternative inputs. I'm gonna use my keyboard to interact, and we'll also have sound effects and Sonification. With these features, the result is non-visual access with common screen reader software as part of our design and publication proxy process.

We test with NVDA, voiceover and JAWS. I'm gonna demonstrate this combination of features using the SIM ohm's law. And this SIM there's an interactive equation in circuits. This allows you to investigate relationships between current voltage and resistance in a circuit.

I'm gonna first navigate through the SIM using a screen reader, as you might navigate through a webpage. And we'll hear a brief description of the SIM. It's about 150 words, and I'll let listen in.

Voiceover: Heading level on ohm's law. Ohm's is interactive SIM. It changes as you play with it.

It has a play area and a control area. In the play area you find the equation for ohm's law

V equals I times R and a circuit voltage and resistance sliders allow changes to the equation and circuit.

In the control area, a button allows users to reset the SIM. Right now list with three items. Bullet voltage V is 4.5 volts. Bullet resistance R is 500 ohm's. Bullet current is 9.0 mA out of list.

Look for voltage and resistance sliders to play or read on for details about equation and circuit.

If needed, check out keyboard shortcuts under SIM resources. Heading level two play area. Heading level three ohm's a lot of equation. Voltage V is equal to current I times Resistance R. In equation letter V is much, much larger than letter I and comparable to letter R. Heading level three the circuit appear of wires connected resistant to a series of batteries. In circuit, list with three items bullet batteries, supply 4.5 volts. Bullet resistor shows a medium amount of impurities. Bullet very small arrows indicate a current flowing clockwise at 9.0 mA out of list. Heading level three slider controls, voltage and resistance sliders allow changes to equation and ser-

-: From that description, which someone using the screen meter could listen to in full or jump around or skip entirely. We get a quick summary of what's on screen and available in an interaction hint for where to start with the sliders. And then as the description went on, we heard more about the current state of the equation and circuit.

Now let's interact with the sliders and find out what happens.

Voiceover: Voltage slider 4.5 volts.

-: Notice how we learned that we're on the voltage slider and what its current value is. Let's move a slider and find out what changes.

Voiceover: 5.4 volts. As letter V grows letter I grows. Current now 10.8 million times.

-: Notice how we hear the change in the voltage value and also the resulting outcome for the equation. Let's keep interacting with this lighter and the resistance slider.

Voiceover: 6.3 volts as letter V grows letter I grows. Current now 12.6 mA. 7.2 volts, as letter V grows letter I grows. Current now 14.4 mA. 8.1 volts as letter V grows letter I grows. Current now 16.2 mA. nine volts as letter V grows letter I grows. Current now 18.0 mA. R resistant slider, 500 ohm's. 401 ohm's as letter R shrinks letter I grows. Current now, 22.4 mA. 302 ohm's as letter R shrinks letter I grows. Current now 29.8 mA. 203 homes as letter R shrinks letter I grows. Current now 44.3 mA.

104 ohm's as letter R shrinks letter I grows. Current now 86.5 mA. 10 ohm's as letter R shrinks letter I grow. as a lot current now 900.0 mA.

-: And there, we found that at the maximum voltage and minimum resistance, the current becomes huge. If we navigate it back to the descriptions we heard initially, they would tell us about the current state of the simulation as it is now.

That information updates is and learner changes the SIM. So they always have a place to go back to that provides a concise description of the state of the SIM as a whole. And it's always up to date and accurate.

Also notice we had the sound effects and Sonification on. So we also heard a looping sound that changes in pitches as the current increases. The SIMs we have available now with all three of the features

I just demoed the interactive description, sound effects and Sonification and alternative input. Our friction, gravity force lab, gravity force lab basics, John Travoltage, molarity, molecules in light, ohm's law, resistance in a wire. And we also have a publicly available prototype for soon to be published. Some called ratio and proportion. Additionally, the simulation balloons and static electricity, has interactive description and alternative inputs. And we'll soon have sound effects and Sonification, but it doesn't have that yet. Faraday's law has alternative input and Sonification and coulomb's law has alternative inputs.

You can find all of our published SIMs with multimodal features on our websites. SIM filter page filtering by accessibility feature. And you can find all of our prototypes in published SIMs with multimodal features at the website phet.colorado.edu/en/accessibility/ prototypes.

And my second example, I'm gonna demo John Travoltage with the new self voicing feature. This is the semi walked you through at the very beginning of the presentation.

Now I'm gonna let the SIM tell you about itself and what's happening as I interact with it. First, I'm gonna listen through different options in the quick access menu.

Voiceover: Read me bottoms and speech controls shown. John Travoltage is an interactive SIM. It changes as you play with it. It looks like John is leaving the house, facing the door. He strikes a pose on the rub. John has hand close to door knob and he is ready to swing his leg to rub his foot on the rug. Swing John's leg to rub his foot on the rug. Self voicing quick menu hidden.

-: Now, I'm gonna start interacting with John.

Voiceover: Leg swinging, rubbing a few electrons on body. Rubbing, rubbing, rubbing, rubbing a large amount of electrons on body. Leg swinging foot on rug. Arms swing, hand pointing a upper door, close to door knob a large amount of electrons discharged with hand. Just about door knob.

-: We have multiple SIMs being instrumented with a self voicing feature right now. These include friction, John Travolta, to gravity for slab basics and the new ratio and proportion. Look for public prototype links in the next month or so. And the regular published versions of these SIMs to come out with this feature later this year.

And now we've made it to my final example, our newest investigations. These new investigations involve the use of object tracking. By developing the capability to use your computer or phone camera, to track objects. Things that you move your hands, a piece of paper or any physical object, can become an input mechanism for a SIM. If you couple this with a self voicing feature that I just demonstrated we now have the ability to have completely screenless emulation experiences.

We have a brand new simulation called ratio and proportion built in collaboration with the Embodied Design Research Lab at the University of California, Berkeley. We built this simulation from scratch to be born inclusive. Simultaneously with the design of the visual display. We have created the auditory display and various alternative input mechanisms. If you were to use this simulation like a typical PhET SIM on a tablet device using touch, for example, if you were viewing the screen you would see two hands that could be moved up and down. As you move the hands up and down you get feedback, visual and auditory if you have sound on. When you are near or at a specific ratio of hand heights, for example a ratio one to two, where the right-hand is twice as high as the left hand. You can change the target or as we call it in the SIM, the challenge ratio and learners can explore moving the hands and finding heights that correspond with the challenge ratio.

Next, you can challenge learners to try to maintain the ratio as they move their hands from low to high on the screen. We've done this with learners across age groups and it's a wonderful example of embodied mathematics learning. Where learners have the opportunity to really feel the one to two ratio or any ratio you choose. As they have to figure out how to move one hand twice as fast as another to maintain the ratio during motion. Where they computer efficient and self voicing capabilities. Learners can experience this SIM away from the screen.

In this example, we have printed out paper markers that software use with the SIM tracks. We attach these paper markers to two children's blocks and now learners can hold the blocks up in front of the camera and move each up and down. This is controlling the hands on the screen and the SIMs if you're watching them. But if you're not watching them, you could be looking at a peer or a teacher who's working with you or just experiencing non visual access to exploring ratio and proportion.

The auditory display provides the information helping you locate and maintain the challenge ratio. As we explore the capabilities of this SIM couple with self voicing and object tracking, we got even more creative.

Remember, PhET team cutout tracks in a diaper box and put this up in front of a computer camera creating a cardboard physical vertical slider setup. Where you move to small handles, similar to baby food pouch lids up and down to explore ratio with this SIM.

The paper markers are on the backside of the sliders facing the camera. The learner would sit in front of the cardboard and move the physical handles up and down individually or with a partner.

And another example, the paper markers were attached to too long cardboard strips and sat on top of a table. Learners on either side of the table, coordinated together how to move the cardboard strip so that the markers were at the challenge ratio heights. And then coordinated together how to get those markers moving while maintaining the challenge ratio.

These are just some of the ideas we came up with and are exploring. It's tools like these that we're really excited about for the future of inclusion.

We imagined with SIMs like ratio and proportion, teachers and learners have a wide variety of options for how to experience the SIM and can have the SIM work for them on many different devices with many different assistive technologies.

They can customize the visual and auditory display as they like and can get creative for fun or to address a specific access need for an individual or group to allow effective and enjoyable exploration and learning with the SIMs. We found the creative use of existing web technologies and commercial computers and phones that are so many ways to make truly inclusive learning tools right now.

By building these examples and sharing them with the world. We were working to advance screen optional, flexible collaborative learning tools that are effective and enjoyable for all teachers and learners who use our SIMs, including those with sensory mobility or cognitive disabilities.

We believe each learner brings unique gifts to the learning experience. And we want to create tools that enable these gifts to be used and valued in STEM learning, classrooms and beyond.

If you have any questions about what I've shared in this presentation or about PhET in general, please reach out to me.

My email is emily.moore@colorado.edu. That's E M I L Y . M O O R E @colorado.edu.

If you have technical questions or access issues with any SIMs, you can let me know or send a message to PhET help at Colorado Tech EDU. And that's P H E T H E L P at Colorado Tech EDU.

I'd also like to personally invite you to get involved. Please contact me if you or someone you know would be interested in being a research participant. We have paid research participant opportunities in our ongoing studies.

Each opportunity typically takes about one to two hours in total. It can be done remotely from within and outside the U.S and we have opportunities for people from grade two up to adults with and without disabilities.

I also invite you to join the PhET teacher community which is now 500,000 teachers strong. You can make a free account on the PhET websites and when you do so you can opt into subscribing to the teacher email list.

Through this list, we send out notifications of new simulations, research opportunities and occasionally surveys to get your input on new features.

You can also follow us on Twitter and Facebook and if you have an interest in doing so you can donate to PhET through the PhET website. There's some link in the header.

We very much appreciate every dollar donated to us and use it to support the making of new SIMs and SIM features.

And just like that, we've reached the end of my presentation, a few parting notes.

Our website is Phet.colorado.edu that's P H E T at Colorado EDU. You can find all of our SIMs there.

You can find all of our SIMs with multimodal features published and prototypes that I talked about today @Phet.colorado.edu/en/accessibility.

And I'd like to acknowledge the National Science Foundation the Hewlett Foundation and the University of Colorado Boulder for their financial support of this work and the PhET team and our collaborators for contributing their skill and expertise and their time.

And I'd like to thank you very much for listening.