PLU STEM Institute Offering

Presenter(s) and Affiliation Brandon Hendrickson, Science is WEIRD Cathy Kim, Pacific Lutheran University
Presentation Title Teaching Science through Quests: Using Stories and Technology to Make Each Lesson a Riddle Wrapped in a Game (3rd–8th grade)
STEM Categories addressed As students engage with science content, they often bring with them preconceived ideas of how things work, yet we don't always push them to make those ideas visible or confront them as they explore and learn our specific content goals. *Wonder* is part of a scientist's job. How can we catch students' attention to steer them into real scientific thinking? This session will integrate the forwarding of science inquiry with collaborative discussions around riddles in a game-like format using digital tools to support student thinking and knowledge construction over time. Science: NGSS SEPs (particularly 1 and 7) English Language Arts: CCSS.ELA-LITERACY.SL 3.1 / 4.1 / 5.1 / 6.1 / 7.1 / 8.1 Comprehension and Collaboration OSPI WA State Technology (ISTE): Knowledge Constructor; Global Collaborator
Description Within a conceptual framing of how we learn and personalize science understanding (versus memorize facts) teachers in this session will consider strategies to support student thinking, surface alternative conceptions, and change ideas and reposition technology as a means of facilitating and documenting knowledge construction and collaborating with others. We will experience and build off of a way to gamify science content — enlivening students with the power of questioning and games. As we devise a lesson together, you'll learn how to make science *matter* to all students, particularly those who have struggled to pay attention.
Objectives and Expected Learning Outcomes: Post session, teachers will be able to: ● Support students in confronting their own ideas as they learn new content ● Craft riddles that stick in minds

- Locate the emotions hidden in content
- Drop tantalizing hints
- Plug kids into the epic story of science

STEM Career Connections:
This session is focused on how to engage students with content and help them internalize and make the learning more relevant. While participants will experience these ideas through science, strategies can be applied to any content. The process of doing so involves developing a variety of skills that are applicable to a number of disciplines/career choices, in STEM, as well as media/communications, advertising/marketing, human resources/public relations:

- communicate complex ideas (e.g. producing or improving new technologies; learning from the findings of others; sharing information with the public)
- how to know when you don't understand something (e.g. entering a new career)
- how to keep a group's attention (e.g. giving a presentation)

Explicit attention to DEI & culture:
Some of these strategies for teaching science, while designed for students with executive control difficulties, support the learning of all students. They are especially helpful for students with ADHD because they do not assume high working memory.

The framework emphasizes starting with student ideas - what they know, building upon it, and facilitating their sense-making. This not only makes teaching and learning more engaging, but more relevant as well. Students are not memorizing facts, but considering ideas and drawing on their own lived experiences to make personal and collective sense of the new information they confront.

Details on next page -

Overview and Plan:

Section	**Description**	**Time**
Part I: Participant and Content Introductions		
Introductions	Digital warm-up/entry task and whole group share-out as baseline for the session.	10 min
Inquiry	How students come to know and understand science; eliciting student ideas and supporting them to confront them in light of new information. [Science AND technology conceptual frameworks + planning for meaningful technology use and a concrete classroom example that will align the two. A pegagogical grounding for tech use will be introduced beyond just "a tool" so that end results are not just increased engagement but evidence meeting technology standards (e.g. facilitate student use and reflective inquiry to construct, evaluate, and analyze learning over time)].	25 min
Imaginative Education (IE)	How IE sees learning differently (specific tools, and worksheet explanation)	10 min
Gamifying a lesson and becoming a giant brain	Goal: answer riddle Finger code example Timer: 10 seconds per response Thumbs: how we engage	5 min
Part II: Sample Gamified Lesson, Team Analysis, Whole Group Discussion		
A sample lesson	If you lose weight, where does it go? [Content + Technology]	40 min

Team activity	Analysis of teacher moves and strategies per team thinking with sample worksheet	10 min
Whole Group Discussion	Unpacking observations from Team Activity. Explanation of strategies definitions, and how to craft them. Steps: ● Teacher initial ideas ● Research ● Tool decisions ● Drawing/Webbing/Organizing	15 min
BREAK (9 min)		
Part III: Teamwork		
Breakout groups: Brainstorming and Planning a Sample Lesson	In teams, use IE tools to plan a lesson on A) the seasons or B) why clouds float or C) other content of choice. Participants will craft ideas, choosing from the following tools: a riddle, a weird insight, a metaphor, a story, a somatic act, a role-playing task, a simple question, a bit of nonsense, a mini-game, a definition of a term, an experiment, a quick draw, an evocative image, an emotional binary, a further mystery. Examples of tech + IE: quick draw on tablets; make-a-guess drawings + sharing student drawings, allowing students to engage with and respond to each other's ideas; finding and sharing quality science videos that go beyond defining words; scaffolding images, metaphors, mysteries	20 min

	to confront ideas and challenge perceptions.	
Lesson Presentation and Feedback	In groups, present planned lessons to another team. E.g. Team A will present their lesson to Team B, and vice versa. 10-minute presentation time with 5 minutes allowed for verbal evaluation from the other team (evaluation criteria provided). Was the lesson engaging? Consider technology goals *with* content ones? Did it further your understanding? Did it make use of the planned tools/strategies effectively? Whole group takeaways. In teams, participants will be using Jamboard to elicit students' initial ideas, their ultimate conclusions, and their further questions.	35 min
Part IV: Next Steps and Evaluation		
Closure	Revisiting Warm-up/Initial Task Digital Exit Slip (can have paper option) One Word whip around	10 min

Materials on last page -

Supporting Material and estimated cost for materials:

Projector

Possible laptops available if participants do not have a device?

Worksheet printing

**Request that participants bring a device and/or tablet

Dotted (not lined, or blank) journals — one per participant

- https://www.amazon.com/Teskyer-Journal-Notebook-Journals-Travelers/dp/B08D9HBRRR/ref=sr_1_3?dchild=1&keywords=teskyer%2Bdotted&qid=1619280690&sr=8-3&th=1
- Note: the default option (lined) won't work — please scroll to choose the "dotted" option!

THE LOST TOOLS OF SCIENCE TEACHING

Teaching science: the agony and the ecstacy

Why is it so hard to share the love of science?

It seems like it shouldn't be. Maybe you're like a lot of us: we went into teaching because we experienced firsthand how fascinating science is. And yet it can be *so terribly hard* to spark this fascination in our students. (Just look at all our students slouching in their desks, or the teen on Zoom who we're only 90% sure isn't a looped video…)

It's not that we thought this would be easy. We've all experienced dry science teaching, but we don't make the mistakes our teachers did. We don't give dull lectures; we try to make our lessons interactive, hands on. We've studied the teaching methods that promise to develop real understanding in kids.

And yet, the *thrill* isn't there. We see students going through the motions, but not engaging their minds. **The learning may be hands-on, but it's not brains-on.**

Which, goodness, can be dispiriting. We have high standards, and when we fall short of them, we sometimes fear that the problem is us. Our students need better than we can offer them. Sometimes, when we're at our most frustrated, we wonder if the problem is the students: maybe they just don't have the capacity for scientific wonder.

I'd like to suggest a different hypothesis: the problem isn't us, and it's not our students; it's the way that our culture understands learning. **There's something important missing from how we think about learning science — and we can add it back in.**

Imaginative Education: a new way to think about learning

I've been a teacher for more than a decade. **I currently focus on helping 2e (twice exceptional) students** — kids who are both gifted, and have a learning disorder, typically ADHD.

I love working with this population, and *boy* can it be challenging! Gifted kids usually overflow with curiosity, but find the basics boring. Kids with ADHD often struggle to find *anything* academic interesting.

Put them together, and what do you get? Well, when I began teaching science, **I had lessons bomb so profoundly that I lost all control of my classes.**

And then I began applying the insights of Imaginative Education. Imaginative Education (IE) is a theory of teaching and learning that comes from Vancouver and flows from the writings of Kieran Egan, an educational philosopher at Simon Fraser University.

For me, IE has a rich source of insight into the minds of learners. It's a complex theory — it doesn't fit neatly into the usual educational dialogue of educational traditionalism vs. educational progressivism. But **I'd summarize the most helpful insights of IE as follows:**

> **1. Emotion is key**
> We're not Vulcans, we're humans — emotions are what our brains use to weigh how much something matters. If our lessons don't provoke emotions, students will struggle to pay attention, to care, and to remember.
>
> **2. Students' emotion flows from *our* emotion**
> We can't just add emotion into a lesson. Real emotion flows out of our interaction with the content. In order to pass along emotion, we have to first experience it ourselves when we're trying to understand what we teach.
>
> **3. Emotion can best be shared through certain "tools"**
> There are certain tools that make it easier to pass along the emotion we feel. These tools aren't new (people have used them to pass along information throughout history). Sharing the excitement of science means giving a lesson through these tools.

What tools? There are lots of them — Egan and his community have found a few *dozen*. **But let's start simple.** In my experience, there are a handful in particular that, when woven together, work again and again to communicate the love of science:

Start with a **riddle,** wrap it in a **game,** and **puzzle out** the answer together — sprinkling in **metaphors, experiments,** and **images** as hints. Then culminate with an **insight** that upends how students understand the world.

What might this look like? Let's unpack this.

Start with a riddle...

A riddle is a question — **but it's not just any kind of question.** A riddle is a question that (1) students *feel* that they could solve, and (2) they really *can* solve. A *good* riddle also (3) forces students to see the world in a new way.

Questions are everywhere in school, but riddles are rarer. "What is the capital of Afghanistan?" "What is seven times eight?" "What's the organelle scientists call 'the powerhouse of the cell'?" None of those are riddles — they're just questions.

For a question to be a riddle, **students have to already know the answer — they just can't know it's the answer!**

One of my favorite riddles is "What's the room immediately behind your toilet?" The answer is, obviously, going to be something they already know — another room in their building. But to figure out *which* room, they'll need to re-imagine the layout of their home. They'll need to start thinking like a plumber.

Why are riddles more powerful than ordinary questions? An ordinary question is one that students might feel expected to answer. There's no emotional tension, and the only students likely to raise their hands are the ones who think they know the answer.

But a riddle is something that virtually *no* students know the answer to. The only way to get to the answer is to think outside the box. **Everyone can participate in a riddle.**

Which is good, because the whole lesson that follows will be an attempt for the class to answer it.

Examples, please!

Bad examples of riddles:

- What are the different names for clouds?
- Who named the clouds?

Good examples of riddles:

- What's a cloud made of?
- Why do clouds float?
- What causes it to rain?

...wrap it in a game...

In order to solve the riddle, I tell the class, they need to become a *giant human brain*. But that's easier said than done — **it's hard to get a group of strangers to work and think together.** So we turn the lesson into a game.

What's the trick to making a game? You might think that a game is a chance to relax, shrug off the rules, and just *play*. But the truth is nearly the opposite.

Ian Bogost (author of the book *Play Anything*, which has taught me a lot about game design) points out something funny about games: **they're defined by *limits*.** Think about golf: the goal is to get a white ball into a small hole. If that was all, then it would be boring: you'd just take the ball, walk straight to the hole, and plunk it in. The rules, though, limit what you can do:

1. You can only touch the ball with a stick
2. You can only touch it as little as possible

Compare basketball: you need to get the ball through the hoop, but the hoop is very high up, and you can't walk with the ball, and other people are trying to simultaneously do the same thing in a *different* hoop.

Or compare hockey: you need to get the puck into the net, but you can only touch it with a stick, and also there's a person sitting in the net to block you. Also, you're on ice, and you fall down a lot. (Also, other people knock you around, and sometimes punch you? I'll admit I don't really understand hockey.)

So I turn the lesson into a game by imposing limits on the kids, and **policing those limits *ferociously*.** I tell them their goal is to figure out the answer before the class is over — but that I won't tell them the answer. I'll limit myself to giving hints.

At any point they can take a guess, or ask a question, or make a comment — but each of those can only be 10 seconds long. And the second I call on someone, I start counting down from "ten" with my fingers!

Tension. A ticking time bomb makes a good frame for a movie; as teachers, we can learn from that.

…puzzle it out together…

The rest of the lesson is **a wild scramble, a hyperactive idea playground.** I've planned out the tools (e.g. images, metaphors, experiments) ahead of time, but I can modify the order to fit with their guesses and questions.

The overall effect is to have **the whole class emulate a creative mind.** Creativity is often nonlinear and frenetic: our brains make guesses, try half-baked ideas, narrowly avert disaster. And that's what it's like to be in a lesson like this: we play with ideas at lightning speed, making mistakes and always learning.

Nonsense is valued; lateral thinking is the rule. Because, goodness, science is bizarre. It's so delightful to see kids beginning to push against their categories, re-think how they see the world, and suggest a ridiculous idea that they're 90% sure isn't true. (It's even more exciting when that idea is *precisely right*.)

The goal, overall, is to help students move away from being repeaters of old information, and get them to be explorers of a new mental landscape. The students drive the class forward (and backwards, and side to side); **as the teacher, I merely steer.**

…sprinkling in metaphors…

In a curious way, every metaphor is a lie. A metaphor is when we pretend that one thing is something else — that something new and unexplained is really just the same thing as something old and understood.

Life isn't *really* a tree. An atom isn't *really* a ball (nor is it a bunch of balls whizzing around each other). A hydrogen bond isn't *really* a chain.

Should we avoid metaphors, then? It's important that we understand that metaphors are wrong, and actually dangerous for a full understanding of the world. But then, once we understand that, it's important to carry on using metaphors — and in fact use them *more*.

Because it turns out metaphors are essential. It's possible that we literally cannot do without them: some cognitive scientists think that metaphors are our brain's One Weird Trick, the fundamental way minds make sense of the world. It may be, in fact, that when we say "students should understand science", **what we're actually saying is "students should have a vast library of metaphors".**

But metaphors really aren't as risky as I'm making them seem, because as teachers, we have a secret weapon: **we can prompt students to ask whether a given metaphor is really true.** The answer is never simple, and will always involve looking carefully at specific aspects of a metaphor. (Life *is* like a tree in that species generally split off from one another, and don't combine. Life *isn't* like a tree in that, well, sometimes they *do* combine; and in fact some single-celled organisms swap genes like Pokémon cards.)

And when we don't know the deeper story, we can always arch our eyebrows, and stage-whisper: *That has been a great scientific mystery.* (It's is a great way to get kids interested in higher-level science classes — and it's easy, too!)

When we stock students' minds with metaphors, and help them question those metaphors, we equip them to puzzle through new phenomena for the rest of their lives.

Examples, please!

Examples of metaphors:

- H_2O = a magnet shaped like Mickey's head
- A water droplet = one billion Mickeys loosely stuck together

Questions to ask:

- Is an atom *really* a ball?
- Is a water molecule *really* a magnet?
- Is light *really* a wave?

...experiments...

Before I say anything about this, I need to confess something: **my memories of doing experiments are universally bad ones.** I have vivid recollections from my high school Intro to Chemistry class:

1. Teachers told us what to do
2. We tried to copy it
3. Everything went terribly wrong

Later, reading the Potter books, I had a lot of empathy for Neville in the Potions class scenes. Conducting experiments actually lessened my scientific curiosity — and probably contributed to why I avoided science in college.

And yet, of course, **experiments really can be a powerful source of understanding and wonder.** (Fun fact: we get our word "experiment" from an Old French word that could mean both "practical knowledge" and "enchantment"!)

When we can get kids to do experiments, we must.

I teach over Zoom, and can't depend on students to have much equipment, so I keep experiments as simple as possible. More importantly, I **frame them not so much as "experiments" as "challenges":**

- Can you create a cloud on the side of a glass?
- Can you create one when you open the freezer?

The goal in framing them as "challenges" is to ramp up the emotions. Another way to do this is to **have kids guess what's going to happen:**

- What will happen when two drops of water touch?
- What will happen if you plunge a sock in a bucket of water?

...and images as hints....

Are images important in science? Yes, obviously! This is hardly news: science books have had illustrations since the Middle Ages. And we've gone further: nowadays, videos are common in classes.

So what is there to add to this? I think the full possibilities of images have yet to be brought into classrooms. Let's divide images into two types: (1) **cartoons** and (2) **evocative images.**

Cartoons

A cartoon is a picture that's *too* simple. It ignores some details and emphasizes others: a smiley face, for example, or a stick figure.

Does it seem odd to use cartoons to communicate the complexity of the world? I agree! We might even say that our goal as science teachers is precisely to get students *away* from a cartoon image of the world.

And yet, the world is just too complicated. The psychologist William James imagined that the world appears to a baby as a "blooming, buzzing confusion", and I think the same is true of our students, and of us: even when we're looking at something simple, there's just too much to take in. Our brains give up, and we miss what's right in front of our eyes. In some way, we're stuck with only seeing the world with cartoons. **Drawing cartoons, therefore, help us perceive reality by stripping away some details to focus on others.**

And the wonderful thing is that students usually *enjoy* drawing them. (Some of them may already be drawing cartoons in class!)

In class, I lead students in "Quick Draws": I draw a cartoon as fast as I can, and make them follow along as fast as they can. The goal isn't to draw something beautiful, but just to finish at the same time I do.

For this, **I give students dotted notebooks** — a place to take notes and draw pictures throughout the year, so they can refer back to what they've learned. These also become places for students to write down our riddles, and pose their own questions. It might be a relevant point that I choose high-quality notebooks, objects that I can imagine them keeping for years afterwards. (How different from the flimsiness of spiral notebooks!) Following an ancient tradition, we call these “commonplace books”.

But a cartoon isn’t the only kind of image that’s useful in teaching science.

Evocative images

An evocative image triggers an emotional reaction. This is common in teaching social studies. Think of the photo of the nine-year-old girl running from the napalm attack in the Vietnam War, or of the photo of the man standing in front of the tank in Tiananmen Square. These needn’t be photographs: if you’re American, you probably recognize the painting “Washington Crossing the Delaware”, even if you haven’t seen it in years. Go ahead and look around it for a few moments:

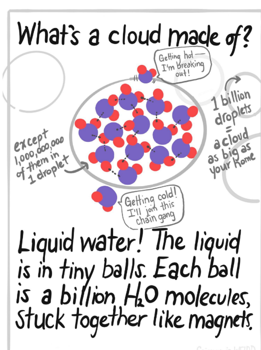
These provoke different emotions in different people. Maybe the painting makes you roll your eyes; maybe it makes a feeling of togetherness well up in your chest. The point here is just that it triggers emotions.

These are much rarer, I think, in science teaching. They shouldn't be! Images, researchers tell us, are cognitively privileged: they're easy to remember. Some psychologists, in fact, think that they are the basic currency of cognition; they (and not words) are what we think with. (These theorists think that images are even more fundamental than metaphors: a metaphor is when we link a *new* thing to an *old* image, previously stored in the brain.)

Insofar as this is correct, we should be amassing a library of powerful images that will burn themselves into students' memories — photos and paintings and videos they can't un-see, which they can reflect on for the rest of their lives and use to make sense of the world.

Examples, please!

Cartoons:



Evocative images:

- Fog creepily rolling out over a lake
- Amateur video of a violent downpour in a backyard
- A plane flying into a gorgeous, towering cumulus cloud
- The house from Pixar's *Up* lifting into the air

...Culminate with an insight that upends how students understand the world.

I love **science facts,** and try to drop as many of them into a lesson as I can (the weirder the better!). But the goal of these isn't to impart new facts.

I love **big science words,** and it's my joy to help kids get an appreciation for what they mean (I even explain Greek and Latin roots). But the goal of these lessons isn't to get kids comfortable with terminology.

The goal for every lesson is to turn students upside down. It's to make them realize that they've gotten some aspect of the world backwards. It's to get them to dismantle their model of a phenomenon, and replace it with one that's better.

When this works well, at the end of the lesson, students' eyes go wide. Sometimes their mouths literally drop open.

A lot of my science-loving friends are aggravated that so many modern people still believe in young-Earth creationism. *Scientists have known the age of the Earth for more than a century*, they say, *it's not that these folks are off by a little — the planet is a MILLION TIMES OLDER than what they think!*

I guess that bugs me, but I'm more bothered that **this type of non-understanding is actually the norm across *all* the sciences.** Does that sound too extreme? Let me give some examples.

1. **The atmosphere is an ocean:** we live at the bottom of it. Once we understand this, it makes perfect sense why our ears pop when we go on an airplane, and why clouds float. But most people (even those who know terms like "air pressure") don't see this.

2. **Our great-grandparents were fish:** if we're willing to say "a bird is a type of dinosaur" then we should be willing to say "humans are a type of fish". Once we understand this, it makes perfect sense why embryos form in a liquid sac, and why we have jaws and spines and hands and eyes. But most people (even those who know terms like "phylogenetic tree") don't see this.

3. **Cats are monsters:** almost every feature of their bodies is fine tuned for killing. Once we understand this, everything falls into place: their round, baby-like heads are arches that crush, their teeth are keys that pop open vertebrae, their whiskers are canes that feel where prey is, when it's too close to see. But most people (even though who know terms like "obligate carnivore") don't see this.

4. **Trees are made of air:** they take the "C" out of CO_2 and use it to build themselves. Once we understand this, it's easy to understand why burning fossil fuels (ancient buried trees!) is dangerous; we can even understand where fat goes when we "burn" it (into the air, and into

plants). But most people (even those who tell pollsters they think climate change is a serious issue) don't see this.

The mass of us — even those of us are science literate — still see the world through a sort of folk physics, folk chemistry, and folk biology. **Helping students "upgrade" their imaginations** — sharing the mind-bending wonders that modern science has discovered — **can be at the center of a science education.**

To what end?

I've been cobbling together this model for the better part of a decade, and have been honing it since the beginning of the pandemic, when I was forced to take my teaching online and needed more powerful tools to connect with my students. I'm only beginning to figure out what we can do with it. What I can say, from this far on, is that it does a great job helping people experience **excitement, deep understanding, and meaning.**

How does it help students experience excitement? Emotions are put at the center of the lesson. The riddle triggers a desire in the students, and the insight/answer promises a reward. The nonsense and wild puzzling make it fun, and the game rules enhance the feeling.

How does it help students experience deep understanding? Metaphors and images are the "real deal", the bricks out of which students construct understanding. Better yet, because the class is pursuing the answer together, they're proposing and discarding ideas, modifying them to better make sense of the world.

How does it help students experience meaning? There are other tools that Imaginative Education has championed; one that I didn't include here is stories. By encountering the stories of some of the brilliant/wacky/tragic human beings who first wrestled with these topics, students get infected with the joy of *figuring stuff out*. Science becomes not just ideas to be understood, but a quest to be joined.

Why do I care? When I was growing up, there was a lot of talk about innovation speeding up — discoveries and inventions were coming along faster than ever before. These days, most thinkers believe this has stopped, and that we're facing a "great stagnation" (a phrase coined by the economist Tyler Cowen).

I wonder if the way out of this stagnation is to infect the imaginations of kids with the beautiful basics of modern science: help each student personally construct an accurate model of the whole world, from atoms to galaxies, littered with oddities, deep mysteries, and pressing problems that need solving.

More than this, though, there's just a tragedy in how science is too often taught without much emotion or a sense of how weird the world really is. We can do better, and make our professional lives more gratifying while doing it. All we need is a method — a recipe — that takes into account how minds really work.

How to go deeper

The Imaginative Education community has written a *lot* of books. The most immediately practical is probably *An Imaginative Approach to Teaching*, by Kieran Egan.

If you love educational theory, however, I recommend *Getting It Wrong From the Beginning: Our Progressivist Inheritance from Herbert Spencer, John Dewey, and Jean Piaget*, also by Kieran Egan. It points out the basic limitations baked into both educational traditionalism and educational progressivism, and suggests how we might beat a new path to the schools worthy of our students.

If you'd like to start playing with some of these ideas, let me know what you're up to! I'm at brandon@scienceisWEIRD.com, and I'm always *delighted* to help people think through new ways to reach kids with the wonders of the world.