CHAPTER 15.

FROM IMPROVISATIONAL PUZZLE TO INTEREST-DRIVEN INQUIRY

BY TIM SAUNDERS AND JEREMIAH KALIR

TIM'S STORY

I have a very vivid memory of my entry into teaching with gameful learning.

The night before I introduced *Matter Quest*—a gameful iteration of a states-of-matter unit for my fourth-grade students—I was still struggling to craft a story line. I had some broad outlines for where the story would go; a galactic threat would put the game's story line in motion, I would play a character, and the story would unfold over different levels. But I was still struggling with this main character, who would launch the adventure. I knew that I wanted to use my old Jedi Knight robe as a costume piece, and I knew that my character would be a villain.

The content was set. All of the labs were waiting online for my students to complete. The materials were set out and ready to go. The nitty-gritty of gameplay was ready for my students to start working, but the story was still in need of major depth.

The answer to that did not come overnight in a dream, and the minutes leading up to my science lesson that morning grew more tense. Because of my constant hype, my students knew that the game was starting today and they had many questions about what playing—and learning—would entail.

I decided it was time to force the issue. Hoping for the best, I handed a video camera to one of my students, leaned over, and said quietly, "Start taping as soon as I walk in the room."

"What are you going to do?" she asked.

"We'll see," I replied softly.

The kids continued to read. I walked across the hall and into the teachers lounge, where I had the robe hidden. Once I was in there I put on the robe, pulling the hood across my face, hiding it. I drew in a deep breath, still not sure what I was going to do.

I walked back into the room, turned off the lights, grabbed the classroom microphone, and started to speak to my students in a playfully menacing voice.

It wasn't smooth, and it took a few revisions as the day went along, but by 3:30 that afternoon, Creepor the Emissary was alive, and my teaching would never be the same.

Background

I came to embrace a game-based learning approach to teaching in the winter of 2012 while working toward my master's at the University of Michigan-Flint. It was actually a pair of assignments from Remi, my instructor, that laid the seed for my embrace of this method, along with the support of another professor in the program, Jeff Kupperman. I have to admit that initially I felt very cold toward the idea of working with games in the classroom, particularly with video games. I thought that the games themselves were too constraining, and that their outcomes were limited.

So who am I as an educator? And what are some of my core beliefs and tenets? First, I believe strongly in an inquiry-based approach with my students. I want them to develop a sense of wonder about the world and to have the space to follow up on that wonder to learn. I believe that all students love to learn, and I feel strongly that school should be a place of learning, and not only a place of schooling. When students have the chance to create a space for learning, they dive in. I want my students to experience their learning through direct action, not by sitting and listening to me explain something to them. I am very much a "guide on the side" teacher, even though I believe that I am good "on the stage," too. I think the best examples of those who have influenced me the most with inquiry-based learning are Neil Postman and Michael Wesch.

I also want my students to be autonomous. With much of human knowledge at our fingertips through wireless devices, I encourage my students to become self-directed learners. As Wesch argues, "This new media environment can be enormously disruptive to our current teaching methods and philosophies. As we increasingly move toward an environment of instant and infinite information, it becomes less important for students to know, memorize, or recall information, and more important for them to be able to find, sort, analyze, share, discuss, critique, and create information. They need to move from being simply knowledgeable to being knowledge-*able*" (para. 2).[1] I want them to have a desire to know something new and have the ability to discover that information themselves. I don't see my role as a gatekeeper of knowledge, but as a facilitator, helping my students become critical thinkers who can sift through the endless knowledge at their fingertips.

Finally, I want my students to work within a community of learners. Naturally, this means with their fellow classmates, but I see this expanding like a ripple to other groups within our school, community, town, state, country, and globe.

TIM'S GAMEFUL LEARNING

For the past six years, I've taught fourth grade at Wealthy Elementary in East Grand Rapids Public Schools. Before that I taught third grade in Kentwood, Michigan, fifth grade at Arrowhead Elementary in Aurora, Colorado, and second grade in Coopersville, Michigan. My classroom averages

1. Wesch, M. (2009). From knowledgable to knowledge-able: Learning in new media environments. Academic Commons, 7. Retrieved from http://www.academiccommons.org/2014/09/09/from-knowledgable-to-knowledge-able-learning-in-new-media-environments/

24 students, and in addition to teaching math and language arts in my homeroom, I also teach three sections of science. Within the science grade-level standards, I teach four units: adaptations and ecosystems; the relationship among Earth, the moon, and sun; states of matter; and energy transfer. This chapter is about how I've worked to transform my teaching of science—and, more important, my students' engagement with scientific inquiry—through gameful learning.

Defining and Designing "Gameful Learning"

When creating *Matter Quest (MQ)* and *Intergalactic Jury (IJ),* my emphasis was on designing gameful learning experiences through which my students could engender playful attitudes, experiment with different selves and ways of being, and pursue questions and curiosities. What do I mean by "gameful" learning, and how might my approach be different from other game-based learning efforts described in this book? The two learning experiences featured in this chapter were not video games produced by a company, designed for some imagined or prototypical elementary science class, and then adopted into my teaching. And did you notice I called *MQ* and *IJ* "learning experiences?" That's because despite having many gamelike features, from the tools students used, to their problem-solving processes, to the "mechanics" of play, neither one is a video game like *Portal* (a popular video game that can be used to teach physics; see Cameron Pittman's chapter) nor a tabletop board game such as *Pandemic.* That's why I call my approach "gameful learning." I believe that designing for learning practices, such as inquiry, can be accomplished using a variety of media and methods.

So what made *MQ* and *IJ* gamelike? First, both featured teams collaboratively solving problems. Problems were grouped based on difficulty, and they were designed to introduce complex content knowledge for students to engage in shared inquiry procedures. Because the process was highly scaffolded, students were able to learn through trial-and-error methods, helping them compromise as they thought flexibly. Second, both required that students deftly use a variety of digital and physical tools, from lab materials such as graduated cylinders and pipettes to digitally mediated processes such as recording podcasts and authoring in our class wiki. Third, character role-play was an important way to introduce and sustain creative activity, and our role-play included me and my students; we all experimented with new selves and identities. I played the main character in *MQ,* while in the *IJ,* the students had the opportunity to adopt different identities during presentations.

My ability to design *MQ* and *IJ,* and my students' willingness to "play along," also required something familiar to any game player, a particular kind of gameful attitude. Whether in *World of Warcraft* or dominoes, playing a game means voluntarily accepting a certain set of rules that are meaningful within that particular "world" of activity. Golf wouldn't be golf, for example, if players raced down the fairway dribbling golf balls to see who slam-dunked his or her ball into the hole first. Agreeing to use tools such as golf clubs in particular ways, and to follow rules about sand traps and tee order, might appear absurd to an outsider, but to the golfer, these rules are voluntarily agreed upon to enact gameplay. This attitude—of accepting what might appear to be absurd rules in order to play—not only characterizes any game (see Suits's "lusory attitude"),[2] but it also certainly characterizes how my students agreed to play *MQ* and *IJ.*

I also understand gameful learning to be more than the sum of its parts. Let me explain.

2. Suits, B. (1978/2005). The Grasshopper: Games, life and utopia. Ontario, Canada: Broadview Press.

Yes—collaborative structures for problem solving, a diversity of material objects and digital tools, role-play, and a playful attitude are all important features of *MQ* and *IJ.* However, what is most important to me—and what I hope to illustrate in this chapter—is that creating and enacting gameful learning fundamentally changes how I *think* and what I *do* as a teacher, and so too how my students *think* and what they *do* as they learn. This "gamefulness" is also possible, albeit to a much lesser degree, when I adapt "off-the-shelf" video games. After all, my science students do like *Food Fight,* and there is a time and place for that type of play, too. But here, I'd like to describe a more robust vision of gameful learning that accompanies students' interest-driven inquiry, something that doesn't happen when creating "game guides" for *Food Fight*.

Gameful learning is something that requires more than individual play in a shared setting (i.e., my students sitting side-by-side at computers), or coplay in a shared virtual world. For my students and me, gameful learning is most dramatically—and effectively—evident when our shared curiosity and improvisation emerge. In what ways are my students (and me too, for that matter!) asking questions and pursuing information that reflects genuine curiosities? If our classroom is loud and messy, and the expression of any group's insight unpredictable, how might that be both acceptable and productive to learning about matter or the solar system? When different pathways to different representations of expertise emerge, how do I help my students, their families, and my colleagues understand that this breadth of *doing* and *knowing* reflects both state standards and the "state" of authentic scientific inquiry? These are the types of questions and opportunities that characterize my design of—and my own professional growth from— "gameful learning."

III. FIRST TAKES

In this chapter I describe my experiences designing, implementing, reflecting upon, and iterating the games *Matter Quest (MQ)* and *Intergalactic Jury (IJ)*. My story is unique for a number of reasons; here, I describe two learning experiences, created and enacted across multiple school years, with nine classes of fourth graders (more than 225 total students!), aligned with varied disciplinary content and curricula, and as influenced by a number of people and resources. To help clarify the elements of my narrative, Table 1 summarizes my gameful learning and design timeline, noting key units, related science content, design phases related to *MQ* and *IJ,* and key design events. Classroom teachers and administrators will be pleased to learn that each unit aligned with various Common Core and Michigan Grade Level Content standards, including: comparing and contrasting the characteristics of the sun, moon, and Earth, including relative distances and abilities to support life (Earth, moon, and sun); comparing and contrasting the states of matter, including solids, liquids, and gases *(MQ);* and writing opinion pieces on topics or texts, and supporting a point of view with reasons and information *(IJ).*

Table 1. **Tim's gameful learning and design timeline.**

Time Period	Unit	Design Phases	Design Events
Nov 2011 – Jan 2012	Earth, Moon, and Sun	First "I Wonder" questions and student research	Conversation with Michael Wesch
Feb 2012 – April 2012	*Matter Quest* (Take 1)	Creation and first implementation; Gathering student feedback; Ongoing reflection; Conversations with colleagues	Conversation with Amanda Pratt; Read Lee Sheldon's *The Multiplayer Classroom* (2012)
Nov 2012 – Jan 2013	Earth, Moon, and Sun	—	Co-designed *Intergalactic Jury* with building principal Anthony Morey
Jan 2013	*Intergalactic Jury* (Take 1)	Creation & first implementation; Gathering student feedback; Ongoing reflection; Conversations with colleagues	Initial implementation "on-the-fly"
Feb 2013 – April 2013	*Matter Quest* (Take 2)	Second iteration	Introduction of riddles, student-crafted story finale
Nov 2013 – Jan 2014	Earth, Moon, and Sun	—	—
Jan 2014	*Intergalactic Jury* (Take 2)	Second iteration	Great number of students contact living scientists, "set" calendar introduced at outset of game

Prelude to Gameful Learning

Before *Matter Quest* and the States of Matter unit, I attempted to significantly revamp the Earth, Moon, and Sun unit from the Battle Creek Math and Science Center (BCMSC)[3] by moving away from students' use of paper-based workbooks to authoring in Google Docs, before changing again to a wiki-based platform. A wiki-based platform, such as Wikispaces.com,[4] allowed my students the opportunity to create text and data tables, add pictures and links, create and share videos and podcasts, and share their work more easily with their classmates. Students maintained weather observations for the month of December and used tables to document their data, and then they logged daily moon observations in the month of January. Developing the skills and comfort to author in online environments, such as wikis, proved invaluable when implementing both *MQ* and, later, *IJ*.

At the beginning of the Earth, Moon, and Sun unit, I encouraged my students to write "I Wonder" poems concerning what they wondered about space and the cosmos. This was designed as a means for the students to delve into their own questions and wonderings about the universe and their place in it, as well as a way for me to gauge the students' broader interests. Students then posted their poems to their individual wiki pages, with the vague promise of an opportunity to explore and research some of these questions on their own. See Figure 1 for an example of how a student attempted to format and

3. https://www.bcamsc.org/

4. http://www.wikispaces.com/

answer some of her selected questions. Although I didn't know it at the time, these "I Wonder" poems became the seeds for *IJ* the following year.

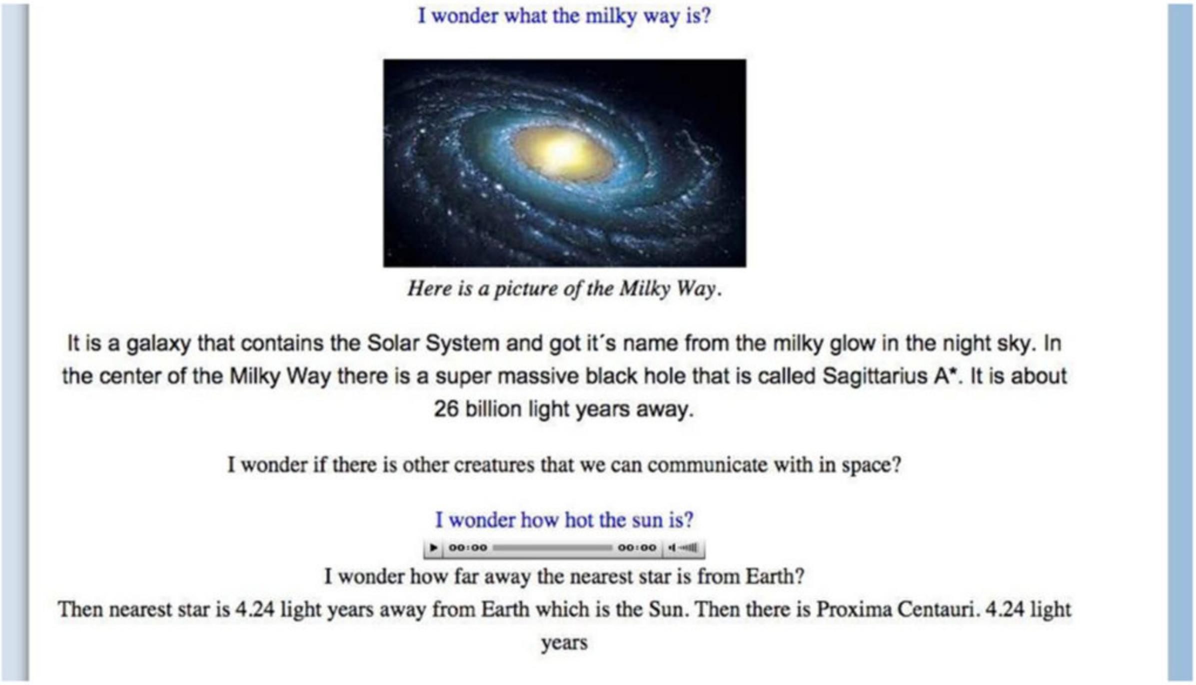

Figure 1. An early example of students' sharing text, pictures, questions, and audio on a wiki.

The inspiration for greater student-driven inquiry came from a conversation with Dr. Michael Wesch, anthropology professor at Kansas State University. Wesch cites Neil Postman and Charles Weingartner's 1969 book *Teaching as a Subversive Activity* as inspiration for his work,[5] particularly in asking students to be deeper, more critically minded inquirers into the world. Wesch has developed these ideas further—first, by engaging the ubiquity of information available through wireless and mobile devices, and second, in considering the implications of access for education. Wesch states, "We just have to stop pretending that the walls separate us from the world, and begin working with students in the pursuit of answers to real and relevant questions" (para. 19).[6] In our conversation in December of 2011, Wesch expressed his curiosity about the Earth, Moon, and Sun unit that I had just completed, particularly the "I Wonder" poems collected on student wiki pages and some hands-on activities demonstrating the orbital relationship of Earth, the moon, and the sun. This led to a deeper discussion about mixing analog and digital pedagogies, and I began to consider ways to make that happen in my next unit.

Matter Quest

My Earth, Moon, and Sun unit had concluded, and I was eager to design new ways for my students to engage in learning about states of matter. I also wanted to incorporate more analog and hands-on experiences. Whereas Earth, Moon, and Sun was predominantly abstract and conceptual in nature, the States of Matter unit provided a chance to blend analog and digital experiences for the students.

5. Wesch, M. (2008). Anti-teaching: Confronting the crisis of significance. Education Canada, 48(2), 4-7.

6. Wesch, M. (2008). A vision of students today (& what teachers must do). Encyclopedia Britannica Online. Retrieved from http://blogs.britannica.com/2008/10/a-vision-of-students-today-what-teachers-must-do

After all, it's difficult to experience the birth and death of the universe in comparison to the length of time it takes ice to change from a solid into a liquid. With their developing skills on the wiki platform, I thought that my students would continue to be engaged sharing their work online. At the same time, Earth, Moon, and Sun featured a lot of teacher-driven instruction, as opposed to student-driven exploration. I was looking to spend more of my time as a learning facilitator, rather than a direct instructor, so I considered what I could use that would provide a framework for more autonomous exploration.

The answer came, in part, from Amanda Pratt, a North Carolina educator and my research and writing partner in the University of Michigan-Flint's Global Program (a design-focused educational technology graduate program with international residencies and partnerships). She recommended Lee Sheldon's book *The Multiplayer Classroom*.[7] In his book, Sheldon examines how his teaching of video game design classes improved once he adapted the process of gamification to his courses. The implementation of points, quests and side quests, badges, bosses, guilds, and other "mechanics" parsed from board and video games were wrapped around a story line specific to his classroom. After reading the book and discussing these ideas with Amanda, I was excited about incorporating aspects of Sheldon's approach in my States of Matter unit.

What came next was *Matter Quest,* a 12-level "game" whereby students worked in guilds (groups) to help Creepor. As the antagonist of *MQ,* Creepor serves as an intergalactic emissary heralding a planetary invasion of Earth. (While I initially thought *MQ* was a game, as I discuss in my reflection below, the experience was more an "improvisational puzzle"; now I consider both *MQ* and *IJ* designed "learning experiences.") In *MQ,* students were "forced" to work for Creepor as he had abducted their grades. My role-play of Creepor is captured in Figure 2.

7. Sheldon, L. (2012). The multiplayer classroom: Designing coursework as a game. Boston, MA: Cengage Learning.

Figure 2. Tim as Creepor the emissary introducing students to Matter Quest.

Playing the Matter Quest—Creepor's Demand

As *MQ* began, students quickly formed groups and set to work on experiments. Directions for laboratory experiments, such as Gases Quest, an exploration of whether gases have volume and take up space, were posted on the class wiki. Each of the 12 levels corresponded with a different experiment. Advancing from one level to the next was not possible until all students in a guild shared their wiki updates with me, as each level was also password protected. Students would receive the next password once they had successfully demonstrated their knowledge and understanding, or mastery, of each level. The unit took almost three months to complete. Table 2 summarizes *MQ*'s 12 levels, the learning objectives I adapted from BCMSC, a brief description of the lab, lab materials and digital tools that featured prominently in that level, and—for fun—the password or riddle that contributed to Creepor's story.

Table 2. Matter Quest **levels, curricular objectives, lab descriptions, tools, and either the password or riddle for a level.**

Level	BCMSC Objectives	Brief Lab Description	Materials and Digital tools	Password/Rddle (Take 2)
1 – Matter Quest	Classify the three states of matter	Students classified 7 items under 6 categories (texture, color, etc.)	Materials: golf ball, jar with air, jar with water, wooden cube, bean bag, rock Digital tools: netbook, wiki page, tables	Password: pogo Creepor video*
2 – Mass Quest	Construct a simple balance to measure the mass of various objects	Students build a balance to measure the amount of mass in a variety of objects	Materials: paper cups, ruler, paper clips, masking tape, large nail, 1-gram cubes Digital tools: netbook, table	Password: Skywalker Riddle 2**
3 – Solids Quest	Identify and give examples of matter as a solid, and describe the properties of solids	Students observe displacement of water to find the volume of solid objects	Materials: graduated cylinder, clay, marble, screw, dowel Digital tools: netbook, wiki page, tables	Password: Mordor Riddle: At night they come without being fetched, and by day they are lost without being stolen.
4 – Liquids Quest	Describe the properties of a liquid	Students explore the properties of liquids, and understand the metric connection between water, mass, and volume	Materials: graduated cylinder, containers, water, pipette, cup Digital tools: netbook, wiki page, tables	Password: Wilco Riddle: I'm the part of the bird that's not in the sky. I can swim in the ocean and yet remain dry. What am I?
5 – Gases Quest	Describe the properties of gases; compare and contrast the states of matter	Students attempt to add water through a funnel to a 1-liter bottle with a rubber stopper	Materials: 1-liter bottles, water, rubber stopper, funnel Digital tools: netbook, wiki page, tables	Password: Spock Riddle: My tines be long, My tines be short, My tines end ere My first report. What am I?

6 – Air Quest	Observe that air takes up space	Students explore how air takes up space by submerging a plastic cup full of tissues underwater without getting the tissues wet. Students also use straws to blow water out of a cup and demonstrate that air takes up space	Materials: water basin, water, straw, plastic cup, tissue Digital tools: netbook, wiki page, tables	Password: woookiee Riddle: I will die if you give me water, but if you give me food I will live.
7 – Volume Quest	Compare and contrast the states (solid and liquid) of water	Students investigate how the volume of an ice cube changes as it phase changes into a liquid	Materials: graduated cylinder, water, pipette, ice cube Digital tools: netbook, wiki page, tables	Password: volume Riddle: Before I'm counted, I'm not known. Boy, will you miss me, When I'm all flown! What can I be?
8 – Phase Change Quest	Explain how the arrangement of the small particles in substances differ in solids, liquids, and gases	Students observe the phase change from solid to liquid	Materials: plastic plate, hand lens, pipette, water Digital tools: netbook, wiki page, tables	Password: Bowie Riddle: What do people love more than living? What do they fear more than dying? What do poor people own, and what do affluent people need? What do all people take to their coffins?
9 – Melting and Massing Quest	Describe how the mass of a solid object remains the same after a phase change	Students place an ice cube in a plastic bag and measure its mass as a solid and again as a liquid	Materials: resealable plastic bag, balance, gram cubes, ice cube Digital tools: netbook, wiki page, tables	Password: melt Riddle: I have a lot in my belly, Wood on my back, Nails in my ribs, For feet I have nothing. What am I?
10 – Physical Changes Quest	Observe changes of a liquid to a gas, and gas to a liquid	Students taped a resealable plastic bag with a cup of water to a window in the classroom to observe condensation	Materials: plastic cup, resealable bag, water, tape Digital tools: netbook, wiki page, tables	Password: bag Riddle: I am a wingless bird, flying even to the clouds. I give birth to tears of mourning in pupils that meet me, even though there is no cause for grief, and at once on my birth I am dissolved into air. What am I?

11 – Combining Solids and Liquids Quest	Investigate the freezing point of different liquids	Students filled baby food jars with dish soap, water, rubbing alcohol, and vegetable oil to investigate if there would be a difference in the time it would take for the liquids to freeze	Materials: baby food jars, dish soap, rubbing alcohol, water, vegetable oil, freezer Digital tools: netbook, wiki page, tables	Password: cold Riddle: My thunder comes before the lightning; My lightning comes before the clouds; My rain dries all the land it touches. What am I?
12 – Escape!	End-of-unit assessment	Students individually complete district standardized unit test	Materials: test	*MQ* take 2: Students use riddle answers to guess what Creepor's intentions are on last page of assessment

*Creepor video: https://vimeo.com/59710772
**Riddle 2 video: https://vimeo.com/59964733

A Day in the Life of* Matter Quest*ors

What did a typical day look like when my students were playing *MQ?* I teach three sections of science a day, all of them after lunchtime. Students in my first class walk through the door at 12:20, and they come from my colleague Winona Tinholt. Winona also studied with Amanda and me in the University of Michigan-Flint Education in Technology Global Program, and her students regularly play around with new ways of learning. The following are interesting events that happened as we moved through the unit.

Death by an overzealous janitor. As they line up outside my room, the 27 nine- and 10-year-olds lean against the lockers making small conversation with each other. Their enthusiasm is evident.

"Is Creepor coming today?" asks Andrea. "He hasn't been here in forever."

"Ah." I stall for the right words to explain Creepor's disappearance. "Creepor's had some … difficulties lately."

Creepor's disappearance from class stems from an innocuous enough reason. A fifth-grade teacher in my building was retiring. I was hiding the Creepor costume in the staff lounge across the hall from my classroom. While my room is spacious by most standards, it's smaller by half than the other classrooms in my school, and cabinet space is at a premium. To preserve the thin illusion that I may not be Creepor, I decided to keep the costume hidden outside of my classroom.

The problem arose when the retiring teacher placed her Valentine's Day materials in the lounge after the holiday party. She typically did this after each holiday party or change in season. More often than not, these materials and knickknacks would lie unclaimed for weeks on the lounge tables. Another colleague, however, decided to dispose of the unclaimed material after a few weeks, and despite the costume's being hidden under a table in an adjoining room, it too was tossed with the holiday junk.

"I know he's really you," Andrea said, giving me an out from her line of questioning.

"I don't know what you're talking about," I said with a grin.

Creepor's identity was an open secret at this point, but the reason for his disappearance was not. Despite the "death" of Creepor, his presence in the class left a definite footprint, and his return was not yet out of the question. As my homeroom students left for Language Arts, I continued to field questions from the students.

"Are we playing Matter Quest today?" asked Jeff.

"Dude, what else would we do?" David laughs back at him. "There's no sub here today." (Sub days are a mixed bag in fourth-grade science. Most kids are bummed that Mr. Saunders is gone, but watching a Bill Nye video is a solid consolation prize.)

"Will you check our level?" asked Edith. "I think we're done."

"Sure," I answered. "Catch me once we begin. You guys can head in."

Creating a class of interdependent learners. Kids stream into the room. Some take a seat, set their netbooks up on their desks, and turn themselves in the seats toward me. Others stand over their seats with one hand on their desk and the other on the backrest, rocking toward the two large gray tubs that hold all of the beakers, graduated cylinders, and other materials they'll need for the unit. There's a low chatter as the students wait for the totality of my whole-class direct instruction for the day.

"If you can hear my voice clap once," I say into my microphone. A handful of kids, but not all, return the single clap. It sounds rough, with more than a few kids clapping earlier or later than the bulk of responders. While not everyone claps, all voices either stop or grow silent.

I milk the silence and their anticipation for a moment or two, surveying who is here today and who isn't. All the seats are filled.

Drawing a short breath before delivering the entirety of the whole-class instruction, I finally utter a single word: "Go."

The silent room explodes into a blur of movement, activity, and purpose. Some flip open their netbooks to check over lab materials for their level that day. Others spring from their seats to open the tubs and gather materials. Edith's group reviews its work from the previous day before checking in with me about moving up to the next level. A few walk over to the bookshelf to work on some reading. Members of one group chat and laugh for a minute before one of them calls them back on task, at which point they all get to work setting up jobs for the day. Another group walks straight out of the room and heads to the teacher's lounge to check if its liquids froze in the freezer overnight. Students in the last group walk into the hallway with their netbooks to set up shop for the next 45 minutes and get some space from the other groups and the hum of noise. They have a podcast to rehearse and record. No one asks me what he or she needs to be doing right now.

Edith and the Science Girl Guild. Instead of sitting back and savoring the scene, I immediately jump from group to group, checking in on what they're doing. Edith's group, the Science Girl Guild, is ready to share its level. As with all the guilds in all three classes, the students name their own guilds, and Edith's group of three was no exception. The three of them stand across from me, netbooks in hand, wiki page cued and ready to share. They've just finished a level on volume and water displacement.

Scanning their pages, I note that each has created a data table showing the volume of several objects (see Tables 3, 4, and 5).

***Table 3.* Edith's volume data table.**

Object	Volume of water without object	Volume of water with object	Volume of Object Volume of water with object -Volume of water without object Volume of object
Marble	50 ml	51 ml	1 ml
Screw	50 ml	51 ml	1 ml
Clay	50 ml	67 ml	17 ml
Dowel	50 ml	59 ml	9 ml it floats

***Table 4.* Anna's volume data table.**

Object	Volume of water without object	Volume of water with object	Volume of object
Marble	50 ml	51ml	1ml
Screw	50 ml	51ml	1ml
Clay	50	67ml	17ml
Dowel	50 ml	60	10ml **It Flouts!**

Table 5. Erin's data table

Object	Volume of water without object	Volume of water with object	Volume of Object Volume of water with object -Volume of water without object Volume of object
clay	50 ml	67 ml	17 ml
marble	50 ml	51 ml	1 ml
screw	50 ml	51 ml	1 ml
dowel	50 ml	59 ml	9 ml

"How come Anna has a different mass for her dowel than you and Erin?" I ask Edith.

"Um, I don't really know," Edith answers.

"Well, when I measured it they both thought that it was closer to 59, and I thought it was closer to 60," Anna answers.

"I see," I said. "I guess that makes sense. Your pages don't have to be identical, and it's OK to disagree about results as long as they aren't really, really different."

The girls stand and nod quietly, waiting as I scan their work to see if anything else needs attention.

"How were you able to determine the volume? How were you able to figure it out?" I question them.

"Well, first we filled a graduated cylinder with 50 ml of water," Anna answers.

"Then we dropped in one of the things, like the screw. After that we looked to see how much the water went up."

"Yeah, then we subtracted it," Edith added.

"Subtracted what?" I ask.

"We subtracted it from 50," Anna answers.

"From 50?" I ask.

"No, I mean," Anna hesitates. "We subtracted 50 from how much the screw was."

"Why did you do that?" I ask.

"Well, the water goes up by how much the screw is," said Edith. "There was already 50 in there, so we subtracted it to find out how much it went up."

"I see," I replied, nodding. "What is volume, then?"

"It's how much space something takes up," Edith says as Anna and Edith both nod in agreement.

The girls wait again quietly as I scan their summaries.

"OK," I finally say. "This looks good. Do you want the next password?"

All three girls grin and nod their heads quickly. I lower my voice to barely a whisper and give them the new password. Each of the girls clicks the link to the next level and adds the password. They then scurry off and start reading what is to come in the next level.

This interaction highlights my new role as a science teacher. While the rest of the class is engaged working on their labs together, I have the opportunity to speak with a small group of students to gain a better sense of their understanding. For example, during their lab time I was able to visit with the Science Girl Guild while they were working on their lab exercise and question them directly on what it was that they were doing. These informal assessments allowed me multiple opportunities to check for understanding, offer feedback, and redirect if needed well before they approached me with a final draft of their wiki information.

Becoming the Ultimate Guide on the Side

This is what my science class is now: a cycle of overlapping evaluation, observation, questioning, and engagement. It's not altogether different from what the students experience, although my cycles are overlapping with six different groups of students.

In addition to the challenges of mastering the content, there are a host of interpersonal and social skills that the students engage. They are learning to organize, compromise, and collaborate in ways that they haven't done in my science class before. These challenges affect students and groups differently. Some groups thrive in this environment, and some struggle; accordingly, my instruction is as much about scientific content as it is new ways of doing schooling, teaching collaboration, and listening to and learning differing ways that students understand and make sense of what's happening around them.

Reflecting on the First Matter Quest Iteration

While there was engagement in *Matter Quest*—and sure, my students enjoyed the "improvisational play" I performed as Creepor—I still thought that I didn't quite hit the mark. That is, when originally redesigning the unit, I envisioned students' demonstrating robust means of inquiry: being more productively confused, asking more questions about their interests, and creating new ways to shape their learning. They weren't there yet. While they were constructing science knowledge from the hands-on activities in the labs, *Matter Quest* wasn't providing a place for them to move beyond the curriculum. Contrast this with the simple activity the students did at the start of the Earth, Moon, and Sun unit, when they wrote and posted "I Wonder" poems detailing their questions about space and the universe. The simpler "I Wonder" writings immediately pushed the students to question their interests beyond the Earth, moon, and sun.

In addition to my observed concern, I was starting to wonder if *Matter Quest* were even a game. In reflecting upon my first implementation of *MQ,* I thought about a distinction my former Global Program graduate instructors Jeff Kupperman and Gary Weisserman made about gameplay; a game is something that can be replayed over and over again with uncertain outcomes. A puzzle, however, has a set outcome and does not have as high (or any!) replay value once solved. Think of a crossword. Once you've finished it, you don't erase it and start over again. You might want to find a different crossword to complete, but the one you've completed doesn't have any meaningful replay value.

MQ felt similar to a crossword. My students enjoyed it thoroughly; however, they had no interest or intention to complete it again from the beginning. And there was no need to; they had finished it. I'm sure they would have jumped on the chance to complete, say, "Energy Quest," if I had continued the same format with the next unit. However, I held off on creating another iteration in the same style without first reflecting on the practices and learning I share with my students. I did have some ideas for ways to improve *MQ,* but as the calendar cycled around toward the start of the next Earth, Moon, and Sun unit, a new idea began to take shape. It turned out that those "I Wonder" poems were going to be pretty important.

Intergalactic Jury

I'm fortunate to work in a building with a very supportive principal, Anthony Morey, especially when it comes to taking risks pedagogically. Not only is he supportive of the ideas of his staff, but he is also a wonderful partner in developing ideas to bring them to life. During a meeting in late 2012, I expressed some of my frustrations with the qualities of student inquiry in *MQ.* He described an activity that his former middle school social studies class did with the controversy related to President Andrew Jackson's involvement in the Cherokee Trail of Tears. In Anthony's teaching, half of the class argued against President Jackson (and even called for his impeachment!), while the other half argued in favor of Jackson's decisions. As a part of their inquiry, his students examined multiple historical documents and perspectives, constructed arguments either for and against impeachment, conducted a trial, and then voted on whether or not to impeach the president.

As Anthony was describing this format, my mind kept coming back to the "I Wonder" poems that the students had written at the start of the Earth, Moon, and Sun unit. What if the students had an opportunity to research one of their "I Wonder" questions? What if instead of researching Andrew Jackson, the students researched one of their "I Wonder" questions? At this point the questions were coming fast and furious in my mind, and I began to hash out some ideas with Anthony. Eventually, we settled on an idea for the game *Intergalactic Jury.*

Forming an Intergalactic Jury

The students would form interest-driven groups based off their "I Wonder" questions from the start of the unit, and I would then look for common themes that appeared in a large number of poems. I found a strong number of students who had an interest in Mars colonies, Moon colonies, exploring life on other planets, black holes, or asteroid shields. Once I formed their groups, I explained the learning experience to them, along with the twists and constraints.

I delivered the story line role-playing Carl Sagan, the famed astrophysicist. As Sagan, I told my students that NASA was looking for a new decade-long mission, and that it needed a goal. The purpose of this mission was decided by an intergalactic jury. Coincidentally, NASA had chosen students in each section of fourth-grade science at Wealthy Elementary to serve with distinction on the jury.

Students were placed in their interest-driven groups and then had two weeks to research their topics. As they delved deeper into their topic, they began to craft a mission proposal to share with the jury. One of the areas that I tried to encourage the students to develop in their research and presentations was a sense of wonder and awe that their mission could inspire among jury members. This proposal could be no longer than 10 minutes, and students could use any visual aids or relevant materials to help sway the jury. Finally, on the last day and after much critical consideration, students would vote for their favorite proposal.

While this initial structure was good, a few twists were needed to connect the students to their research personally, as well as to include deeper critical reasoning. Students would have an opportunity to "fantasy draft" a famous astronomer or explorer to give "expert testimony" during their presentations. Another twist would be to have each group give a short rebuttal presentation against another group; that is, a second group would argue against a first group's proposal, articulating reasons why the original proposal should be viewed skeptically. Before the presentations, each group would have an "evidence exchange" that would allow each group to see the presentations of the opposing group in advance. And at the end of *IJ,* on the day of the vote, all groups would be given no more than five minutes to give a "final word" on their topics, synthesizing and rebutting criticisms faced in the counterarguments from other groups and from the jury of their peers. Figure 3 shows the complete calendar for *Intergalactic Jury* that students could access through the class wiki. Wednesdays were days that the classes didn't meet for science, as the students attended their "specials" classes of art, music, and gym.

Monday	Tuesday	Wednesday	Thursday	Friday
20 Research	21 Specials	22 Research	23 Research	24 Research
27 Snow Day	28 Specials	29 Research/Rehearsal	30 Research/Rehearsal Writing	31 Research/Rehearsal **EVIDENCE EXCHANGE**
3 Research/Rehearsal	4 Specials	5 Presentation Day **Mars Colony** **Black Hole 2**	6 Presentation Day **Solar System Exploration** **Space Animals**	7 Presentation Day **Asteroid Shield** **Black Hole**
10 **"Spiff Up" Day** This is your day to work on responding to what other groups said	11 Specials	12 Last Day Final Word Vote	13 Review	14 **Test**

Figure 3. Intergalactic Jury calendar found on class wiki.

Connecting to Outside Experts—An Activity of Intergalactic Proportion Within Our Solar System

This was my initial plan for *IJ*. And, as with much of teaching, I revised *IJ* as it was first implemented with my students. For example, the fantasy draft was a bit of a bust. That is, until one of my students—Elizabeth, who was studying interstellar travel with the hopes of exploring extrasolar planets for signs of life—asked if she could email Dr. Debra Fischer of Yale University. And we were both surprised to hear back from Dr. Fisher with a quick and detailed reply, as you can see in Figures 4 and 5.

Mail | Properties

From: [redacted]
To: [redacted]
Subject: Fwd: My School Project On Space

Sunday - October 12, 2014 4:05 PM

On Tue, Jan 29, 2013 at 4:48 PM, [redacted] wrote:

Dear Mrs. Debra Fischer,

Hi! My name is [redacted] and I'm in 4th grade at Wealthy Elementary, in East Grand Rapids, Michigan. In my Science class we are doing an activity called Intergalactic Jury. We are split up into groups and make presentations about our subject. We are competing against the other groups in my class for a blank check from NASA (fake). My group is doing a project on Interstellar Travel. Everyone had to pick an astronomer to study and I chose you! I was wondering if you have an opinion or information on Interstellar Travel? If you do, could you please share it with me? My teacher would be really pumped to hear that I emailed you. Thank you in advance for trying to help me!

Sincerely,

[redacted]

P.S.

Your email might possibly be shown with my presentation to my class.

Figure 4. Elizabeth's email to Dr. Fischer.

Mail | Properties

From: [redacted]
To:
Subject: Fwd: My School Project On Space

Sunday - October 12, 2014 4:05 PM

Dear [redacted]

It's great to hear about your exciting project! Intergalactic jury, eh?

I think it's a big mistake to try to send human beings for interstellar travel. The distances between the stars are enormous! If we sent a crew at 10% the speed of light, it would still take 40 years to get to the nearest star system. We'd have to pack in 4th graders - you guys would be adults when you arrived at alpha Centauri.

If we tried to send humans even faster, there are two problems: (1) we don't know how to accelerate space craft to those speeds and (2) the radiation fields become blue-shifted to wavelengths that are hazardous to our health.

We really should travel to the nearest star system, but we should send little nanobots. Once they arrive, they can phone home and send us pictures. I think that this may well happen one day!

With best Regards,
Professor Debra Fischer
Yale University

Figure 5. Dr. Fischer's reply to Elizabeth.

How great was this? I'm well aware of the cultural and institutional challenges women confront when pursuing STEM-related interests and careers. And I've seen the negative effects of stigma and stereotype manifest as early as the fourth grade. For varied reasons, I know Elizabeth and I were thrilled to receive a response from one of the world's leading experts on extrasolar planets.

As an educator, I found it was a powerful experience to witness. This was a moment that I had not anticipated nor planned for, and it highlights a need for being open to student input and action while implementing these sorts of learning experiences. Indeed, the unpredictability of receiving contributions from leading disciplinary experts—and having experts "play along"—is part of what distinguishes, and deepens, inquiry in gameful learning.

Final Jury Presentation

Another aspect of *IJ* that changed during play was the final juried presentations. There were only a few constraints about the form of students' presentations, such as time. During the course of the presentations, I was excited to see how students would argue their points. With the classes split into six different groups with four students in each group, it was time to see what the groups had to argue. Topics consistently presented across all three classes included interstellar travel, extrasolar planets, asteroid shields, and black holes, among a few others.

Mars and moon colonies were also popular in each of the classes, and they were among the first groups to present. Figure 6 shows a sample slide from one of the presentations, highlighting a mix of practical considerations and an appeal for glory.

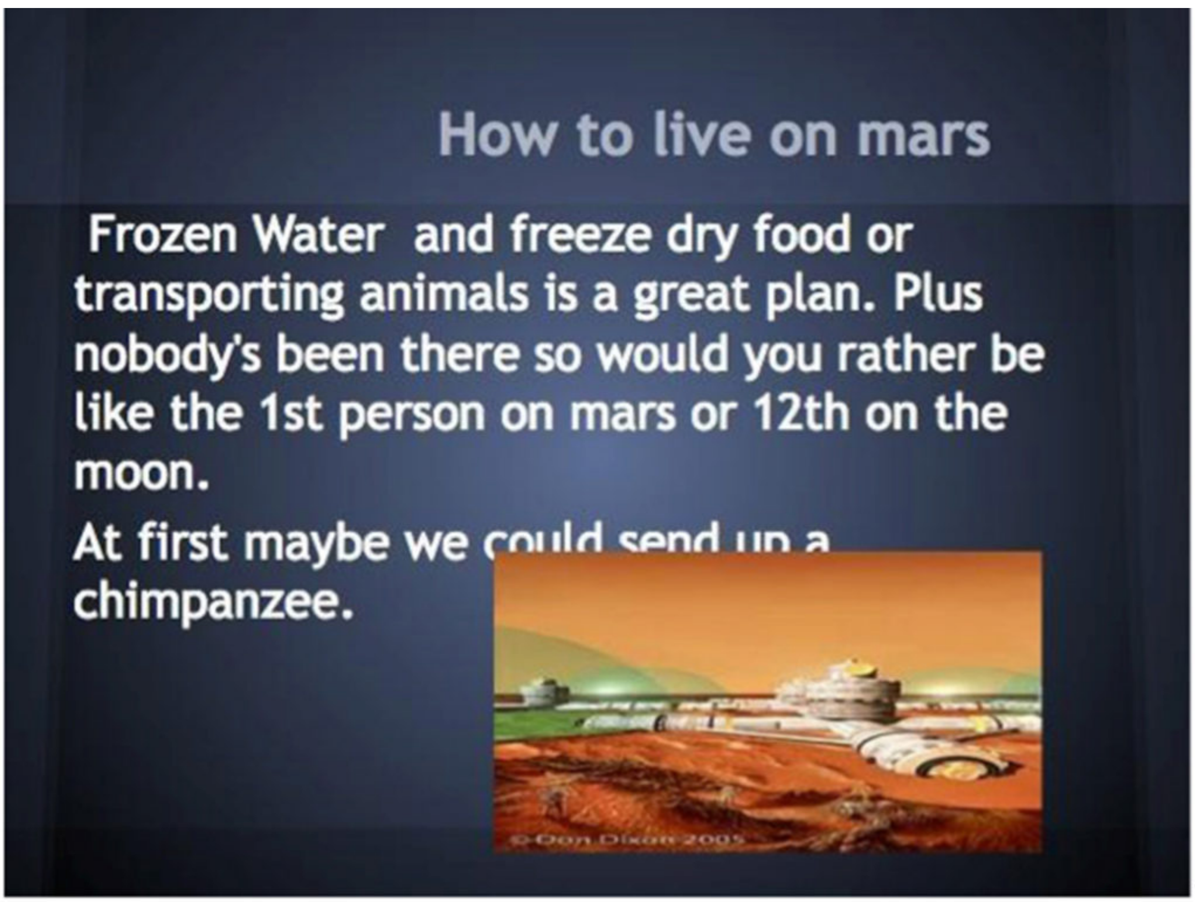

Figure 6. Student slide in support of a Mars colony.

Without exception, students used Google's Slides application to share their presentations, although some used additional models and drawings to help make their case. Some models were made from

Legos, while others were made from Styrofoam. Others took advantage of the Google Drawing feature and created a digital rendering, as seen in Figure 7.

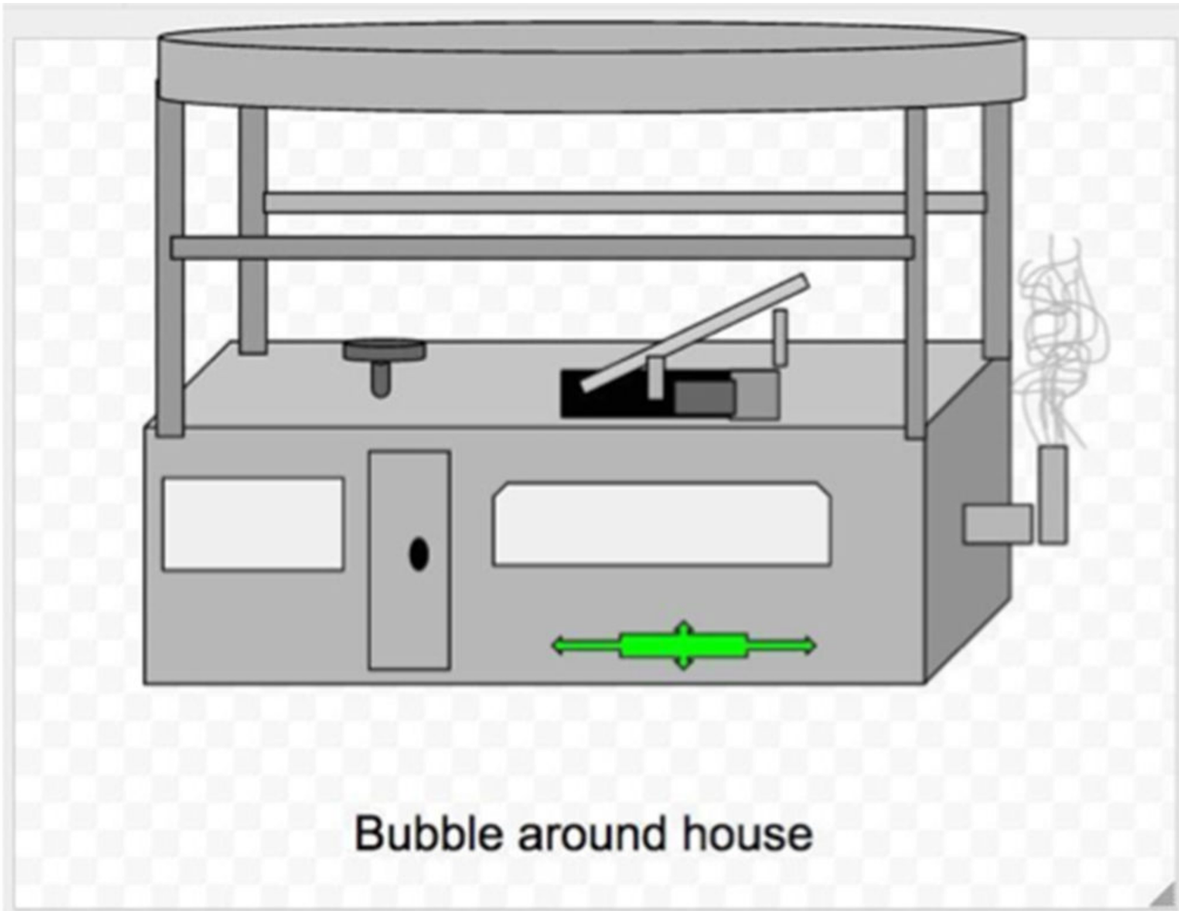

Figure 7. Digital rendering of a Mars colony house.

A Case of Cosmic Intervention

I had to be careful not to give into my own biases in helping students lock down their research and hone their presentations. While there were some fantastic and wonderful ideas that the students presented, my heart was set on one of the three classes voting for an asteroid shield for the Earth. Unfortunately, not one class selected the asteroid shield as the winning idea. One class selected a project based around sending animals into space, another class voted for interstellar travel, and the final class voted for a Mars colony. The great coincidence was that a day after the final votes, the Chelyabinsk meteor exploded over Russia quite unexpectedly. In a show of hands, asteroid shield was a unanimous winner in all three classes in a short revote.

Reflecting on the First Intergalactic Jury Iteration

What was surprising among the first rounds of presentation was the level of questioning by the jury members. In most classes and with most students, the questions from the jury were focused on clarifying specific details from the presentations. The students were demonstrating that they were listening carefully to their peers and were thinking critically about what groups were presenting.

The jury members, for the most part, were genuinely interested in knowing more about what was shown. The outliers to this were few and far between, but I recall intervening when one student asked, “Did you really think this idea through? I mean it’s not like this is even possible.” While there was some gamesmanship involved in torpedoing other groups’ presentations (and thus making your own presentation look better by comparison), I still had to be on guard to keep tone and attitude polite and scholarly. While there were a few students who had their knives sharpened and who were out to ask pointedly mean questions, the overall tone of the questions was nuanced and intuitive regarding what was presented. For most students, this was the first time they had an opportunity to argue and defend their ideas. Most questions were specifically focused on the topic being presented, as, for example, during the Mars colony presentation when one of the students asked about the process of sending a chimpanzee to Mars ahead of humans, or what kinds of animals would be sent to Mars to assist with colonization.

TAKE 2: A SET OF SECOND GAMEFUL LEARNING ITERATIONS

A Second Matter Quest Iteration

Immediately after the first implementation of *IJ,* my students started the second iteration of *MQ.* While I spent significant time working to create a more inquiry-driven model with *IJ,* my revision of *MQ* was primarily centered on refining more of the story line. I thought that the meaning of the *MQ* storyline wasn’t as strong as it could be. Why was Creepor the emissary interested in my students, and for what reason did he need them to complete the levels and labs? To strengthen *MQ*’s narrative, I added more layers to Creepor’s involvement by having him (me!) leave a riddle at the beginning of each lab level for groups to solve. Together, all the riddles explained that Creepor’s ultimate intent was world domination!

The first level to feature this narrative flourish was Level 2, Mass Quest. In Mass Quest, Creepor makes a video appearance and asks students, “What is once spoken, then broken?” Creepor performs as his usual self, a cross between the emperor from *Star Wars* and Strong Bad from *Homestar Runner.* Working together in their guilds, students attempted to solve the riddle. For the first three or four riddles the students worked hard in their groups to solve them. Eventually, students in one of the groups figured out that if they “Googled” the riddle that they could solve it much more easily (I had, after all, “borrowed” the riddles straight from a website!). After that, I changed the wording of the riddles to make them more difficult.

During the course of *Matter Quest,* the students would save riddle answers to try to discover what it was exactly that Creepor intended to do with the students. At the end of the *MQ* unit, during the district-mandated standardized postassessment, I added a page to the test that listed all of the riddle answers, and I asked for the students to guess what Creepor’s plans were. By “mashing up” a standardized test with *MQ*’s narrative, I provided my students with an additional creative outlet. Including a more free-form *MQ* ending within a summative assessment supported my students’ voice and demonstration of knowledge as the unit concluded.

Undoubtedly, adding riddles to the *MQ* levels and allowing students to interpret Creepor’s message were wins. Yet even these positive steps forward appeared too narrow given curricular boundaries. Was this the unintended consequence of a more traditional gamification model? Or perhaps I wasn’t going far enough adapting gamification to my specific circumstances? I'll admit to owning a PlayStation 3, but interest in it lies purely with playing football games. I don't play current quest-based video games. Was I at a disadvantage not knowing the finer features of narrative, plot development, and play mechanics? While I could start playing these sorts of games to support my own design efforts, I must admit to finding little time or interest in doing so.

Another unexpected development in *MQ* concerned grading. In the end, I completely dropped the idea that students' grades had been captured by Creepor. I didn't feel comfortable pairing students' motivation to earn points with their grades. While I did tell students playing the first *MQ* iteration that Creepor had abducted their grades, I walked away from that throughout the unit. Instead, I wanted the inherent engagement and enjoyment of the labs to be students' biggest motivator. Also, once it became apparent that every student would finish *MQ,* most students lost interest in the points as a motivator. Reflecting upon the first iteration, I recognized *MQ* as an improvisational puzzle. Now, having taught the unit twice, I recognized that interest-driven learning—even within the guise of an improv puzzle—is most effective when students are inherently motivated. The external rewards promoted by gamification, such as points, didn't appear to be a meaningful catalyst for inquiry-driven learning in my science classroom.

A Second Intergalactic Jury Iteration

The second round of *IJ* extended the ways in which my students helped codesign the first iteration. For example, the fantasy draft of astronomers and explorers was refocused after our communication with Dr. Deborah Fisher the year before. Now, many students began contacting leading experts in their respective research areas. We found—to our delight!—that some scientists were very happy writing to fourth-grade students. Along with Dr. Fisher, Dr. Jill Tarter at the SETI Institute also provided a similarly detailed, appropriate, and encouraging reply to students who wrote to her. Some students continued to research historical figures, but there was a general shift toward living experts once the allure of sending and receiving an email spread through the classes.

Students were assessed in a variety of ways during the second *IJ* iteration. One notable change was how I observed students during their research and presentation days. Well before the first presentation, I gave each student a rubric from the National Council of Teachers of English (NCTE) that highlighted Common Core–aligned standards for fourth-grade oral presentations.[8] I scored each student during his or her first presentation as a trial run and handed the rubrics back to the students for feedback. This allowed them the opportunity to learn and grow from their initial presentation, and it gave them specific feedback while rehearsing for their final presentation to the class on vote day.

In addition to new assessment methods, I greatly improved my ability to pace the second *IJ* iteration. I had developed, in other words, more clarity about how, and for how long, students would play. Practically, I included a calendar for the students on our class wiki pages that outlined when presentations would happen and the end date. That was very different from my first time implementing *IJ,* when pacing was open-ended and I made up our schedule as we progressed. The first time, for example, I could tell that the research phase was dragging on too long, and only then

8. http://www.readwritethink.org/files/resources/printouts/30700_rubric.pdf

did I establish time for the final presentations. Ultimately, my attention to pacing was important for student learning; I was better able to attend to their needs just-in-time, I knew when and for how long they should engage particular activities, and we both managed our time inquiring more effectively.

Having some of the older *IJ* presentations to use as examples during the second iteration also helped hone students' expectations for what presentations could look like. The drawback from those examples, however, was that they also limited the scope of what a presentation could be for some of the students. Looking toward my third *IJ* iteration, I will encourage originality and creativity when it comes to the presentations and what they can look like. I'd like to avoid a future regret whereby my students' representations of inquiry-based learning relies exclusively upon didactic, slide-show presentation.

Reflecting on the Second MQ and IJ Iterations

As I look back at second iterations of both *MQ* and *IJ,* I see that the difference between the two learning experiences is best explained through the distinction between games and puzzles. *MQ* was a puzzle, though certainly a puzzle with an improvisational enactment. *IJ,* on the other hand, was more like a game. How do I understand this difference?

MQ was, undoubtedly, teaching as improvisation. What would Creepor say to my students, and how would he act? As is evidenced in Edith, Anna, and Erin's data tables, our class wiki was used in a variety of authoring capacities, some of which were unpredictable. Podcasting was, literally and figuratively, unscripted. From the engaging lab structure, to the autonomy of self-guided learning, my students were improvising in their learning, just as I, too, was improvising in my teaching. Nevertheless, my students had no interest in playing *MQ* again. There was no replay value, absolutely zilch. As they would with a completed crossword, my students had no inherent desire to play a second time. And, as with all puzzles, the answers were predetermined. Each level had one right answer. Creepor's riddles were revealed when my students answered a problem with an answer I already knew. While there was some room to navigate a different pathway toward the answer—again, some room for improvisation—the end was determined in advance. Once they understood that air took up space, they were done with it. There was no need to repeat it. Some of them expressed an interest in doing the next unit, energy transfer, in a style similar to *MQ,* but no one wanted to go through *MQ* again.

My students' responses to *IJ,* on the other hand, reveal a more inherently engaged commitment to play, questioning, and—most important—inquiry-based learning. Upon completing *IJ,* many students asked to play again; they wanted to select new topics (such as black holes—a tremendously popular idea among my students), new groups, and new presentation opportunities. Not only did *IJ* have greater replay value, my students were also eager to explore new questions in new ways. And, most important, I had not preselected the questions; thus, there were no predetermined answers. I believe my students found *IJ* so engaging because, in some ways, they knew we both didn't know the answer. I could support their inquiry, but we'd be journeying on a pathway toward an unknown outcome. Could I have predicted that my students would not only communicate with actual scientists, but that they also would incorporate expert testimony into their final presentations? Through multiple iterations, *IJ* transformed our shared learning from an improvisational puzzle to a new method of inquiry-based learning. In the process, gameful learning became a means of students' defining, pursuing, and valuing their own learning objectives and experiences. This was a style of learning that kept the best parts of *MQ*, but that gave the students the room to set their own learning objectives.

Ultimately, by adopting a gameful design attitude in my teaching, I revisited an initial desire to dramatically change the experience of *doing* science class. Now, I was better able to support my students' deep dives into scientific inquiry. I gave myself space to create on the fly, improvise reflectively, and yield to the creativity of my students as codesigners. Together, our learning produced the types of positive results that I hadn't achieved through traditional methods. My students left our classroom demonstrating an ability to engage and explore the world (and beyond!) with a level of autonomy and mastery that they did not have only a few months earlier. Part of that growth was due to my facilitation of a space where students could explore and practice like scientists, with authentic tools, and pursuing genuine curiosities. Nevertheless, our growth was mostly fueled by my students and their desire to play.

ADVICE FOR TEACHERS LOOKING TO CRAFT GAMEFUL LEARNING EXPERIENCES

With this complete narrative in mind, educators interested in starting gameful learning activities may want to consider these four ideas as they begin crafting experiences for their students. First, play games. It may sound simple, but play some games. While playing board games, video games, and card games, I've been inspired to either play those games with my students or adapt them for my classroom. I've found that the more games I play, the more I'm inspired to bring games into my classroom.

Second, start small. Rather than jump in with a gameful (or "gamification") unit, look to start with a small lesson, or even an attention-getting activity at the beginning of a lesson. Give yourself, and your students, a chance to enjoy a gameful experience in the classroom that has a beginning, middle, and end, without the pressure of sustaining it for a marking period or semester. I think this is especially true if teachers are attempting these experiences without a colleague with whom to share, reflect, and critique.

Third, find support. I was incredibly lucky to begin working on a gameful classroom with the support of my research partner, Amanda Pratt. Her help, along with that of my teaching partner Winona Tinholt, gave me a lot of direction and feedback. Your most important supporters, aside from students, will be your fellow educators with whom you interact daily. Share your experiences with them, and see if you can find someone you work with who would be interested in trying it as well. Having that type of support down the hall is going to be your biggest touchstone and encouragement to experiment.

Finally, revise and edit along the way. If I had waited to launch *Matter Quest* or *Intergalactic Jury* until I thought they were perfect I would never have launched them. I'm comfortable using my classroom as a lab for new experimentation and inquiry about my own teaching, and I'm not afraid to make changes if a better path becomes clear. This attitude, along with being open to input and suggestions from my students, allows me to make the revisions needed to improve the games we play.

CODA: A REFLECTION BY REMI **KALIR**

I met Tim in 2011 when he was my graduate student in the University of Michigan-Flint's Global Program. The program attracted many teachers, like Tim, who were as interested in educational technologies and app development as they were in international partnerships and prosocial design thinking.[9] The collaborative trajectory he and I have crafted in the past few years extends from the early stages of classroom practitioner inquiry, when Tim first piloted game-based approaches to learning across subject areas,[10] to our examination of identity, ignorance, and "lusory attitudes" (see Suits)[11] in approaches to gameful learning,[12] to our ongoing involvement in the national Playful Learning movement. Much of what informs our partnership is evident in the narrative presented in this chapter: a pedagogical commitment to curiosity-driven learning, a desire to tinker (whether with media or our habits of mind), and a willingness to identify the qualities of our ignorance so as to more fully explore and engage our work as educators.

Reading about *Matter Quest* and *Intergalactic Jury,* I am reminded that Tim and his students are unique (this is, after all, a book about "pioneers"!). Yet this distinctiveness notwithstanding, Tim's case studies are buoyed by unresolved questions pertinent to many other educators, across grade levels and disciplines. Tim, his students, *MQ* and *IJ,* and this narrative are *pioneering* because they surface questions that demand the concerted attention of classroom teachers, policymakers, and parents alike. In what ways—and to what degree—are teachers encouraged to design their own stance toward inquiry *in* and *of* learning?[13] How do teachers play, and why is this consequential for their students' learning? The intellectualism of teachers' play—whether as a reflection of inquiry or as an indicator of professional learning—is well represented across the philosophies and pedagogies of Dewey,[14] Paley,[15] Greene,[16] and Montessori.[17] Unfortunately, it often appears as though these possibilities for playful pedagogy are lost on teachers and administrators who search for and buy some highest-rated video game. Shouldn't they create and play their own? And how is gameful learning an educational technology, and why does this matter? *MQ* and *IJ* provoke questions such as these, questions that suggest more critical reflection about the qualities of inquiry *in* inquiry-based learning and *as* relevant to teachers' ongoing professional learning.

From a student's perspective, it is important that children and youth ask and pursue their own questions during scientific inquiry—to question as a means of developing "higher quality ignorance" (as Firestein puts it),[18] rather than didactically consuming predetermined knowledge. Indeed, such an approach to inquiry aligns well with trends in K-12 science education.[19] From a teacher's perspective, a reflexive questioning of "inquiry-based learning"—as a pedagogical practice, as an oft-celebrated model—is also necessary in a political environment that delimits the improvisations of teaching and learning in favor of the audits and standardizations of schooling. In this respect, whatever the

9. Holden, J. (2013). Playful possibilities for assessment: Fluffy ducks and the queen's gambit. The Scholarship of Teaching, 6(1), 4-8.
10. Saunders, T. (2013). The games we play: Leveraging gameful learning. HaYidion, 28-30.
11. Suits, B. (1978/2005). The Grasshopper: Games, life and utopia. Ontario, Canada: Broadview Press.
12. Holden, J., Kupperman, J., Dorfman, A., Saunders, T., Pratt, A., & MacKay, P. (2014). Gameful learning as a way of being. International Journal of Learning Technology, 9(2), 181-201.
13. Cochran-Smith, M., & Lytle, S. (2009). Inquiry as stance: Practitioner research for the next generation. New York, NY: Teachers College Press.
14. Dewey, J. (1902/2013). The school and society and the child and the curriculum. Chicago, IL: University of Chicago Press.
15. Paley, V. G. (1992/2009). You can't say you can't play. Cambridge, MA: Harvard University Press.
16. Greene, M. (1988). The dialectic of freedom. New York, NY: Teachers College Press.
17. Montessori, M. (1964). The Montessori method. New York, NY: Schocken Books.
18. Firestein, S. (2012). Ignorance: How it drives science. New York, NY: Oxford University Press.
19. National Research Council. (2011). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: National Academies Press.

challenges or successes of *MQ* and *IJ,* Tim's approach to gameful learning is necessary if classroom teachers are to transform their "curriculum-as-planned" into the "curriculum-as-lived."[20] *MQ* and *IJ* show that inquiry-based learning is not a blindly adopted teaching method; the generative creativities of students must be matched by equally compelling experimentation on the part of their teachers.

Tim shows us how to transform the planning, implementation, and iteration of inquiry in an inquiry-based science classroom. Gameful learning describes the possibilities of this transformation, whether by remixing prepackaged curricula as improvisational puzzles, or by embracing the novel methods of research and presentation invented in the moment by his students. As Sawyer suggests, creative teaching occurs when "the rigid division between teacher and student is somewhat relaxed, creating an environment where teacher and students jointly construct the improvisational flow of the classroom" (p. 15).[21] From Tim's planned role-play as Creepor, to his students' precocious and interest-driven emails to leading scientists, this gameful approach to inquiry challenges bounded presumptions about the *where*, *how*, and *why* of inquiry in the science classroom.

In addition to broadening notions of inquiry, gameful learning also questions the device-centric technodeterminism of many pedagogical reform efforts. Consider, briefly, the notion that gameful learning is *an* education technology—in and of itself. The pioneer video-games researcher—and former classroom teacher—Kurt Squire has argued that educational technology is, by definition, a "creative" endeavor.[22] Squire suggests that teachers such as Tim and his fourth-grade students exemplify an approach that embraces the "desire to go out and *create* the future of learning rather than to simply study it" (original emphasis, p. 227). In other words, educational technology is not only about devices, using those devices, and then studying students' use (and such use, of course, might not reflect their learning!). Rather, gameful learning is one creative approach to iteratively envisioning and enacting a future of learning that coordinates many different practices, tools, expressions, setbacks, and curiosities. In this type of educational environment, students do learn relevant skills, dispositions, and disciplinary content; the evidence of such accomplishment is sprinkled throughout Tim's story.

Of course, Tim's classroom does feature "educational technology" in the guise of devices, such as laptops, voice recorders, and digital video. Access to such resources cannot be discounted. As important, however, is the fact that gameful learning afforded particular teaching and learning practices, or participatory norms. Iteratively enacting *MQ* and *IJ* meant that Tim's teaching became experimental, collaborative (whether with his principal or his students), and open-ended. For Tim's students, their participation in *MQ* and *IJ* changed their learning behaviors, too; they critically assessed learning experiences (recall that they didn't want to play another *MQ*-style "improvisational puzzle" again), they asked new types of questions (and to real astrophysicists, nonetheless!), and they pursued their own interests about complex disciplinary topics. Together, the educational technology of gameful learning usefully constrained shared practices so both Tim and his students could recurrently accomplish various scientific, pedagogical, and interest-driven inquiries.

20. eghetto, R. A., & Kaufman, J. C. (2011). Teaching for creativity with disciplined improvisation. In R. K. Sawyer (Ed.), Structure and improvisation in creative teaching (pp. 94-109). Cambridge, England: Cambridge University Press.

21. Sawyer, R. K. (Ed.). (2011). Structure and improvisation in creative teaching. Cambridge, England: Cambridge University Press.

22. Squire, K. (2011). Video games and learning: Teaching and participatory culture in the digital age. New York, NY: Teachers College Press.

Tim's story is a counternarrative to the fetishism of innovative product, a hopeful rejoinder that teachers can create their own educational technologies that powerfully and provocatively redesign the *doing* and *knowing* of inquiry-based learning.