How Teachers Use *Instructional Improvisation* to Organize Science Discourse and Learning in a Mixed Reality Environment

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Abstract: In this paper we describe our model of *instructional improvisation*, which blends rules of theatrical improv with a constructivist teaching approach to suggest practical moves teachers can make during classroom lessons to support students' science inquiry. We describe instructional improvisation through an analysis of interaction in the STEP (Science through Technology Enhanced Play) environment, a mixed reality simulation in which young children (ages 6-8) learn about complex science concepts. We present a case study analysis (n=26) and demonstrate how teacher moves aligned with our model of instructional improvisation support joint ownership of science knowledge and students having agency within science learning. After demonstrating the effects of these moves, we end with a discussion of how teachers might intentionally use instructional improvisation to support productive interactions in inquiry-based science classrooms.

Introduction

Good teachers develop plans to help students learn course content, yet constructivist theory requires they also recognize the value of students' prior knowledge and encourage students to be active participants in their own learning (Sanchez & Valcárcel, 1999). Thus, when students' interests and previous experiences lead to unexpected moments in the classroom, teachers must deviate from their scripted plans. While it is true that students can actively construct knowledge from any experience, including lectures and videos, it is hard to predict in advance just how instruction will interact with a child's exisiting knowledge. Seemingly clear statements can be assimilated into a child's existing understandings in unpredictable ways that distort the intended meaning to fit with what they already understand. Researchers have used improvisation as a metaphor to describe how teachers strike a balance between creating structures and being responsive to students during moments of instruction (Erickson, 1982; Sawyer, 2011).

Improvisation of this form is not simple nor is it entirely spontaneous. Audiences of theatrical improv and popular television shows such as *Whose Line Is It Anyway?* can be led to believe that improvisation is something that just happens between actors without much prior planning or thought (Yanow, 2001), however, theatre professionals describe improvisation as an overarching framework with specific rules that guide interaction (Fey, 2011; Halpern, Close & Johnson 1994; Sawyer, 2004). Prior work on improvisation and teaching has used existing rules of theatrical improvisation as a framework for identifying aspects of effective teaching and curriculum planning (Borko & Livingston, 1989; Brown & Edelson, 2003) or as a set of theatrical activities for teachers to engage with and apply to their practice (Lobman & Lundquist, 2007). However, the rules of improv do not neatly map onto the types of interactions that lead to student learning because teachers in classrooms have different goals than actors in improv theatre. Sawyer (2004) draws from improv to suggest practical ways for constructivist-minded teachers to integrate improv within their teaching. We aim for a more precise articulation of this translation and propose a hybrid model—*instructional improvisation*—of teaching as improv that aims to explicitly blend the rules of theatrical improv with research on constructivist teaching within science classrooms to suggest moves teachers can make to support students' science inquiry. Our model can help teachers remain flexible by offering guidance in how to respond to student contributions throughout a lesson and engage the ensemble with emergent concepts. We describe the model of instructional improvisation through a case study of one classroom (n=26) in our context: the Science through Technology Enhanced Play (STEP) learning environment (Danish et al., 2015; Enyedy, Danish, & DeLiema, 2015), a mixed reality simulation used to teach children about science concepts.

Rules of improvisational theatre in an education context

The rules of theatrical improvisation are established, yet fluid. For our model we developed and adapted a composite of six rules drawing from advice of improv experts (Fey, 2011; Halpern, Close & Johnson 1994; Sawyer, 2004). The rules of our model of instructional improvisation include: 1. Always agree; 2. Yes, and…; 3. Make statements or ask questions that elicit statements; 4. No mistakes, only opportunities; 5. The needs of the

ensemble are greater than the individual; and the rule towards which all the others aim, 6. Tell a cohesive instructional story. Below we describe the rules in theatre, focusing on how actors make and receive *offers*—dialogue or contributions that advance the narrative scene (Halpern, Close & Johnson 1994)—and translate the rules to make the model useful for teachers.

Always agree

The *always agree* rule is usually introduced as the first rule of theatrical improv because it frames how actors should interact and support one another when developing a scene. To illustrate, if your partner says, "I can't believe we're stuck in this dungeon," you should accept the premise that you are in a dungeon together whether you want to or not. If you instead say, "What are you talking about? We're not in a dungeon, we're on a boat," you have undermined the contribution, making it difficult for your partner to know what to say or do next.

In an education context this does not mean the teacher should agree with every student idea even if it is inaccurate, but it does mean that student contributions should be positioned as legitimate within the collective story the class is trying to tell. If in the case of discussing how bees pollinate a student suggests that bees try to pollinate when they collect nectar, a teacher could "agree" by responding, "That's interesting. You notice that bees pollinate and collect nectar at the same time." While the teacher is not agreeing with inaccurate information (bees *incidentally* pollinate flowers, they do not *try* to pollinate), she does not evaluate the student's offer either. Instead, she effectively "agrees" by positioning the student's everyday sensemaking as a legitimate resource (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2000) in service of moving the instructional story forward. If she had responded, "I don't think that's quite right" or "Are you sure?" she would be undermining the idea, making it difficult for the student to know how to best respond. Because improv is a co-construction of ideas and events, it is important for actors (and in classrooms, teachers and students) to support one another as the scene (lesson) unfolds.

Yes, and…

The next rule of improv is intimately connected to *always agree*. In addition to agreeing with a partner's contributions, an actor should also add something, or *yes, and…* her partner, to move the scene in a forward trajectory. If you only agree that you are in a dungeon but do not add detail—about your relationship with your partner, the plot, or what the dungeon looks/smells like—then you are essentially leaving all of the responsibility on your fellow dungeon dweller to figure out what comes next. A *yes, and…* move could sound something like, "Yes, thank goodness I brought this spoon to dig us out of here." In this case, the actor's offer adds to the narrative the partners are co-constructing as it pushes the scene forward.

In the classroom example above, if the teacher agrees but does not add detail or elaborate further then she would be leaving all of the responsibility on the student to figure out what comes next in their collective inquiry. A *yes, and…* move could sound something like, "After the bee is pollinating and collecting nectar, I notice that she goes back to the hive. What happens when she gets there?" By using a *yes, and…* move here the teacher prompts students to add to the story by describing the bees' subsequent actions. The *yes, and…* move advances the instructional narrative by linking student contributions to the teacher's broader learning goals.

Make statements or ask questions that elicit statements

A third rule of theatrical improv is to *make statements*, meaning that statements usually trump questions because when you ask questions you put pressure on your partner to come up with answers. If in the example above the responding actor asks about the spoon, "How are we going to dig with that thing?" he would be relying on his scene partner to come up with a quick, clever response. Instead, he could say, "Great work. And I have this shovel." This statement moves the scene forward as the two actors begin to formulate their escape plan.

The *make statements* rule translates to the classroom a bit differently because it is *necessary* that the teacher and students ask questions. The main thrust of this rule in our model is that the statements the teacher makes should add to the story and her questions should elicit statements from students that advance the narrative. Regardless of whether the turn at talk is a statement or question, it is important that offers push the lesson forward.

No mistakes, only opportunities

This next improv rule reinforces the first rule of agreement. It requires that as long as the general rules of improv are upheld, there are *no mistakes*, *only opportunities* for new discoveries. Because there are no wrong directions, all participants can help the scene evolve. In the classroom, this means that even if students veer down a path to explore a conceptually inaccurate idea, the teacher should allow their interactions to organically unfold because she knows that she can eventually pivot towards the target science content. In fact, she created structures and plans

before implementing the lesson for exactly this reason. The *no mistakes, only opportunities* rule plays out similarly in both the theatre and classroom because it is all about saying *yes* to whatever curveballs are thrown your way.

The needs of the ensemble are greater than the individual

It is important that actors refrain from "stealing" an improv scene in order to have their ideas and jokes heard. Actors should be good listeners and focus on what they can contribute to the narrative rather than writing the script in their heads. Improv is not really about individuals; a successful improv scene is evidenced through the form of the actors' *collective* storytelling. This rule of putting the *needs of the ensemble over the individual* is relevant in the classroom because teachers deal with conflicting demands from individual students and must decide which ideas to pursue while simultaneously honoring all student contributions and connecting ideas to core disciplinary concepts.

Tell a cohesive instructional story

We end with the most central rule of improv for our model of instructional improvisation, which is to *tell a cohesive instructional story*. In both theatrical improv and improv as used in our education context, the ultimate aim is for participants to tell a story through dialogue that develops relationships between characters and drives the narrative towards a set of co-constructed goals. While not evidenced through isolated moves, the story that the teacher and students tell together is a collective co-construction of knowledge and understanding over the course of a lesson, instructional unit, or other bounded learning experience. Stories make content more memorable (Berk & Trieber, 2009), which is valuable both in the theatre and the classroom. This final rule is one on which all the others depend because all improv moves are made in service of telling a cohesive and compelling story.

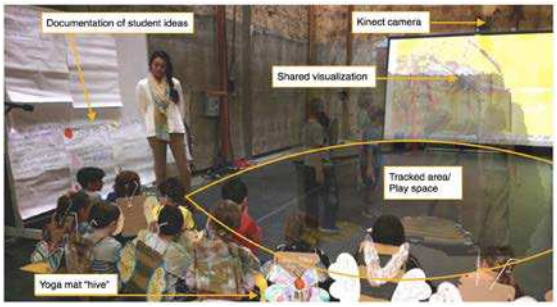

Figure 1. The STEP mixed reality environment.

Describing the STEP environment

The Science through Technology Enhanced Play (STEP) environment (see Figure 1) is a mixed reality simulation built to support the collective inquiry of teachers and students in science (Danish et al., 2015; Enyedy, Danish, & DeLiema, 2015). The mixed reality helps participants build conceptual understandings as they link movement in the real world of the play space to what happens visually within the simulated system (Danish et al., 2015; Lindgren, Tscholl, Wang, & Johnson, 2016). In STEP, students participate by stepping into the space and "becoming" bees that retrieve nectar and pollinate flowers on the projected screen. As students move, their motion is tracked by Xbox Kinect cameras using the OpenPTrack software (Munaro, Horn, Illum, Burke, & Rusu, 2014) to feed their location and motion into a computer simulation. We encouraged teachers to be playful in their pedagogical approach but did not explicitly suggest they engage in what we came to understand as instructional improvisation. Our model emerged from observing teachers during STEP lessons given our guiding suggestions to support play-based inquiry.

Methods

We designed lessons to teach first and second-grade students about key science concepts, including the differences between nectar and pollen, how bees communicate within the hive to forage for nectar, and the complex process of pollination. While young students might know that bees live in a hive and have something to do with honey, nectar, and pollen, they usually do not know much about how bee communication via a "waggle dance" allows bees to efficiently gather nectar, which in turn supports the larger ecosystem by leading to pollination of the flowers they visit. To illustrate how our model can elucidate teachers' interactional practices and support play as a form of inquiry, we present a case study analysis of when students first learned about the role of the "waggle dance." As we watched the teacher allow students to be productively playful, our model of instructional

improvisation emerged as we found ways to name interesting moments in interaction that seemed to support students' agency in inquiry.

Participants

The STEP project was developed as part of a collaboration across two universities and affiliated elementary schools. The present analysis focuses on the implementation of the bees unit at one school, which involved children from three mixed-age classrooms (n=76; 42 first-graders and 34 second-graders). The three teachers each had more than six years teaching experience and two years working with the STEP system. When we first introduced them to STEP, we emphasized the value of pretend play and allowing students to discover content with minimal guidance. We focused on Ms. Jones' classroom (n=26) for our initial theory-build because we felt she was particularly successful at balancing students' agency with the curricular goals in a manner that felt truly "playful" for all.

Data sources and analysis approach

Our goals were to understand how teachers supported the playful, conceptually rich narrative we witnessed and to identify specifically what teachers did to support that narrative. Understanding the teacher's moves as improvisation emerged during initial video analysis; we then used this frame to analyze the rest of the video data and found similar moves throughout. To determine whether students in the classroom had learned the content, we used pre/post interviews that consisted of ten questions about the target science. Two coders analyzed responses (interrater agreement=97.5%). We developed our model by focusing on Ms. Jones' class (12 hours). We made logs that indicated where we felt like the teacher was using improvisation, developed conjectures around these points, and adjusted conjectures as we reviewed additional video (Erickson, 2006). We chose two lessons to pursue with the goal of showing how teacher moves encouraged student agency and supported engagement with content.

Findings

Episode 1. Using improv to introduce science content and support student participation

Our analysis of pre/post gains showed there was a significant increase in content learning across classes from pre-test (M=3.8, SD=2.02) to post-test interviews (M=9.18, SD=3.03); (MD=5.38; $t(75)= -15.47$, $p < .05$), yet the primary focus of our findings is on the model of instructional improvisation in classroom interaction. In the first lesson, Ms. Jones' objective was for students to understand that bees have the goal of collecting nectar and as they do, they incidentally get pollen on their hind legs, which they bring with them to other flowers. The technology indicated the bees were collecting nectar when they hovered over flowers and a number of hearts rose from the center of the flower (1 heart=okay nectar, 2 hearts=yummy nectar, and 3 hearts=outrageously yummy nectar). As they foraged, the pollen animation was simultaneously activated, meaning that golden sparkles emanated from the flower as the bees collected the nectar. Although students playing bees were not purposefully trying to pollinate, it was impossible to collect nectar without also getting pollen on their legs. The scene below (see Table 1) is from the end of the lesson in which five students played in the STEP space as others participated from the yoga mat hive.

Table 1: Episode 1

Turn	Speaker	Talk	Action
1	Ms. Jones	Adam got some. Dylan's going …	*Dylan walks back to hive*
2	David	You have to fill it and then bring it back to the hive	
3	Ms. Jones	What are you filling it with?	
4	Many students	Nectar!	
5	Ms. Jones	The honey?	
6	Jesse	No	
7	Ms. Jones	No honey?	
8	Jesse	Oh, maybe that's the pollination you did! The-	*Leans in from yoga mat*
9	Zed	Oh, pollen!	*Points to screen from yoga mat*
10	Jade	Oh, I thought of something. If you like go into there and fill up a lot of nectar	*Points to screen from yoga mat*
11	Jesse	When the little dots are coming out of you, that means you're pollinating	*Gestures towards the screen from mat*
12	Ms. Jones	Oooh	

13	Zed	Oh, I get it!	*Stands up to enter the space*
14	Ms. Jones	Sit down, sit down. Use your words, use your words	*Gestures for Zed to sit down*
15	Zed	I get this! I get this! So-	*Sits down*
16	Ms. Jones	What do you get? What do you get?	*Crouches down towards Zed*
17	Zed	Um, the, when, if you, if hearts come out that means your, your, your pocket fills up with nectar and then you bring it from the–out and then and then a heart comes up and that means you fill the, the bees are filling the hive with nectar	*Gestures towards the screen*
18	Ms. Jones	Oooh there was some good observations that you just had right there	
19	Multiple	[Overlapping talk]	

This episode begins in line 1 when Ms. Jones *agrees* with student actions by *making statements* about what students do with their bodies—collect nectar in the simulation. When she narrates, "Adam got some. Dylan's going…" she is noting that a key aspect of their behavior is tied to the nectar they collected. By labeling the students' actions in this way, Ms. Jones focuses students' attention on how the story is one of collecting nectar and delivering it to the hive, thus tying students' actions to the building narrative aligned with curricular objectives. Ms. Jones' labeling is an important first step that supports her next moves.

In turns 5 and 7 Ms. Jones asks students *questions that elicit statements*—"What are you filling it with?" and "The honey?" Student responses are in the form of three distinct contributions connected to lesson objectives. In turn 8 Jesse predicts that what they see is pollen, not nectar, and Zed verbalizes agreement. In turn 10 Jade connects the location on the flower to nectar collection, and in turn 11 Jesse calls attention to what the animation is communicating—"when the little dots come out of you, that means you're pollinating." As students discuss what they know about pollen and nectar, the most important instructional effect of Ms. Jones' moves is that students build on their prior knowledge and are ultimately able to make distinctions between honey, nectar, and pollen on their own. Of course this episode is just a snapshot of much longer, more involved conversations and debates students had during the first several lessons of the unit. However, Zed's understanding of the difference is finally made evident in turns 15-17 when he excitedly declares that he "gets it" and provides an explanation that correlates the hearts he sees on the screen with nectar, an understanding that aligns with the "correct science." In turn 19 other students talk over one another in agreement. Through this short exchange, Ms. Jones' intentional moves allow students to have the floor to author the class story and participate in the shared ownership of science knowledge.

Episode 2. Improvisation to support joint construction of science learning

In the fourth lesson students investigated how the bees' "waggle dance" works to communicate nectar locations and then invented their own communication system in order to tell one another where to forage for the best nectar. A small group of students would fly into the mixed reality field as bees to find previously hidden flowers and collect nectar. The students would then fly back to the hive (the literal inside of the hive was projected on the screen) and dance for a partner bee to show them where to find a flower with nectar. Like bees, students invented ways to communicate three critical pieces of information about the flower—its distance from the hive, its direction, and the quality of the nectar. For bees, the distance is communicated by the length of the dance itself, direction is communicated in relation to the angle the flower is from the sun, and quality is communicated by the amount of times the bee repeats the dance and how rapidly the bee waggles (our students called it the bee's "booty shake"). Bees communicate this information to the hive at large when returning from a foraging trip. In the scene below (see Table 2), students in the hive just watched their partner bees' waggle dances and went to find the flowers. However, they were unable to locate them in the field because instead of translating the dance from inside the hive to out in the field, students went to the literal spot on the floor where their partner ended the dance (see Figure 2).

Table 2: Episode 2, scene 1

Turn	**Speaker**	**Talk**	**Action**
1	Student	Guys, not near the sun!	
2	Jesse	Go to the sun!	
3	Dylan	Go to the red flower, David!	*A predator flies across the screen*
4	Jesse	David!	
5	Zed	Ah, I died!	
…			

6	Zed	I died! Did you see that?	
7	Ms. Jones	What happened?	
8	Zed	The, the eagle came, and I died!	
9	Ms. Jones	Oh, lay down	*Gestures for Zed to get down on the floor*
10	Ms. Jones	Lay down	*Repeats gesture for Zed to get down on floor*
11	Zed	Oh	*Lays down on floor*
12	David	I can't find it	
13	Ms. Jones	Zed's dead	
14	Zed		*Begins to lift his head*
15	Ms. Jones	Stay there, stay there, don't get up	*Zed stays on ground*
16	Jesse	David, go to the sun!	
17	David	I tri- I am!	
18	Ms. Jones	So is there a flower-	
19	Zed		*Stands up*
20	Ms. Jones	Nope, sit down. You're dead, lay down.	*Playfully grabs Zed's hand, gestures for him to lay down, laughs*
21	Zed	No, look it, no look it. I'm still alive!	*Notices his avatar is alive, runs to left side of the screen, Ms. Jones laughs*
…			
22	Adam	There is no other flower, Jesse!	
23	Ms. Jones	Why is there no other flower, Adam? So why, why isn't there a flower up there?	
24	Jesse	There's no information that, from the last time we did it, that there was a flower up there	

Ms. Jones gives students the floor at the beginning as they offer suggestions and react to what is happening in the space. In turns 7 and 9 Ms. Jones uses a *yes, and…* move to agree with Zed's declaration of death and urges him to "lay down" to show that he is a dead bee. Zed plays along with his teacher, yet when he realizes that the technology stopped tracking him (the Kinect cameras lost his image when he was on the floor), he stands up in turn 21 and declares that he is "still alive!" While at first Ms. Jones plays with Zed and tries to get him to lay back down, she realizes that he actually *is being tracked* once he stands up and according to the technology, that means he *is still alive* as a bee. She positions Zed's return from the dead as *no mistakes, only opportunities*. Rather than erasing and replacing his idea, Ms. Jones allows Zed to resume his play from this new starting point. Instead of sticking to her plan, she laughs and turns her attention towards Adam and Jesse in lines 22-24 who are discussing ideas in line with the learning objectives, that the bees must translate the waggle dance from inside the hive to out in the field by starting their dances at the hive. As a result of this pivot, Ms. Jones skillfully puts the needs of the *ensemble over the individual* by getting back to the science content.

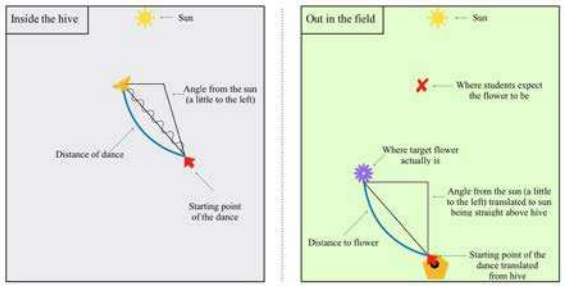

Figure 2. Map of how students initially translated their partner bees' dances.

Ms. Jones' turn to the ensemble is productive because it gets students talking together about how to translate the dance from the hive to the field. A few minutes into the discussion Ms. Jones realizes that in order to have a more focused conversation about the translation and continue to advance the narrative, she needs to direct students' attention to where bees start from when foraging. She centers their conversation below (see Table 3).

Table 3: Episode 2, scene 2

Turn	**Speaker**	**Talk**	**Action**
1	Ms. Jones	Where do the bees always start, though, when we go out into the field?	
2	Multiple	The hive!	

3	Ms. Jones	They always start at the hive. So this red dot, I have to move it to the hive, right? So I have to start at the, I have to move it this way.	
4	Researcher		*Hands teacher a large red arrow*
5	Ms. Jones	Oh, there's a red arrow!	*Researcher laughs*
6	Ms. Jones	So which way is my red arrow pointing?	
7	Student	That way	*Student points to the left*
8	Ms. Jones	So the red one?	
9	Zed	Look it, look it	*Moves to take the arrow from the teacher*
10	Zed	It's pointing the same way. See, look it!	*Runs to the screen with the arrow*
11	Zed	It's pointing the same way. Can you see that?	*Runs towards screen and holds arrow up to screen*
12	Researcher	Put it at the hive, and point it in the right direction	
13	Ms. Jones	Put it at the hive and point it in the right direction	

Ms. Jones *makes statements* in turns 1 and 3 to help *tell a cohesive story* and focus students on curricular objectives. Her improv moves, along with the physical red arrow prop, help Zed connect how the dance starting point translates from the hive to the field. In the turns following, the students finally come to a collective conclusion that because the bees start at the hive, to find the flower you have to start doing the dance at the hive rather than an arbitrary starting point. Although our case is from a mixed reality environment, teachers in all sorts of situations experience this tension between structure and responsiveness in pursuit of telling a story, and thus instructional improvisation can be a way for all teachers to effectively respond to diverse student contributions during science inquiry.

Discussion

Instructional improvisaton can help teachers think about balancing structures and responding to student needs. Furthermore, students can exercise agency and understand concepts even when the teacher acknowledges student contributions that fall outside of normative science. The rules—including *agreement* with contributions, *yes, and-ing* to elaborate on prior knowledge, *making statements* to advance learning, positioning *mistakes as opportunities* for learning, prioritizing the work of the *ensemble over individual*s, and *telling a cohesive story* about content—are flexible and allow for ambiguity. For example, although Ms. Jones takes up Zed's untimely death, the ensemble discusses and constructs a cohesive story about lesson objectives that does not include tangential lesson digressions.

Although our case study is from a mixed reality environment, we think that instructional improvisation can apply to other contexts as a way of organizing learning and discourse in science more generally. Although improv does not describe all of the moves that make a great conversation or lesson, as a lens on interaction it can help us understand the value of certain key moves. The effects of instructional improvisation include students having agency and joint ownership over science knowledge—students came to conclusions on their own as Ms. Jones used improv to support their inquiry. Additionally, we believe our model can support productive interactions that complement current reform recommendations. For example, Michaels and O'Connor's (2012) "talk moves" is a framework for productive science talk that details types of conversations students should be having with a focus on the academic purpose of the conversation and teacher moves that reinforce this purpose. Our model can further reinforce frames like "talk moves" by focusing the teacher on the nature of the joint inquiry and opening space for student agency in conversations. Instructional improvisation emphasizes the subjective experience of what the classroom conversation should *feel like*—a playful, spontaneous co-construction of science inquiry. Our model also complements ideas like Reiser's (2013) of building coherent storylines in science. Yet while storylines emphasize how conversations ought to be structured in ways that build coherence for students, instructional improvisation focuses on the qualitative experience of the collective interaction of students and teachers working together to write the story through a collaborative, coordinated effort. Future work might include explicitly supporting instructional improvisation in classrooms to observe how teachers take up and implement their interpretations of the model in different contexts.

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