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Instructional support and implementation structure during elementary teachers' science education simulation use

Amanda L. Gonczi[a], Jennifer L. Chiu[a], Jennifer L. Maeng[a] and Randy L. Bell[b]

[a]Curriculum, Instruction, and Special Education, University of Virginia, Charlottesville, VA, USA;
[b]Oregon State University, Corvallis, OR, USA

ABSTRACT

This investigation sought to identify patterns in elementary science teachers' computer simulation use, particularly implementation structures and instructional supports commonly employed by teachers. Data included video-recorded science lessons of 96 elementary teachers who used computer simulations in one or more science lessons. Results indicated teachers used a one-to-one student-to-computer ratio most often either during class-wide individual computer use or during a rotating station structure. Worksheets, general support, and peer collaboration were the most common forms of instructional support. The least common instructional support forms included lesson pacing, initial play, and a closure discussion. Students' simulation use was supported in the fewest ways during a rotating station structure. Results suggest that simulation professional development with elementary teachers needs to explicitly focus on implementation structures and instructional support to enhance participants' pedagogical knowledge and improve instructional simulation use. In addition, research is needed to provide theoretical explanations for the observed patterns that should subsequently be addressed in supporting teachers' instructional simulation use during professional development or in teacher preparation programs.

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Science education computer simulations (hereafter referred to as simulations) provide opportunities for students to build deep conceptual knowledge through rich interactions with virtual phenomena (Hilton & Honey, 2011). Simulations can help students visualize unobservable phenomena and enable students to directly manipulate objects from molecular to astronomic scales. Simulations can foster conceptual understanding by providing dynamic, more authentic visualizations than possible using static visualizations or materials (Ryoo & Linn, 2012). In addition, simulations can also overcome traditional lab implementation barriers including materials cost, safety concerns, and time limitations (Hofstein & Lunetta, 2004). As such, a body of research demonstrates the positive effects of using simulations in science instruction

CONTACT Amanda L. Gonczi alg3cb@virginia.edu University of Virginia, 405 Emmet Street, P. O. Box 400273, Charlottesville, VA 22904, USA

(e.g. Hilton & Honey, 2011; Rutten, van Joolingen, & van der Veen, 2012; Smetana & Bell, 2011).

Although simulations can benefit science learners, research documents difficulties students may have with simulation-based instruction (e.g. Yeo, Loss, Zadnik, Harrison, & Treagust, 2004). Students with various levels of prior knowledge may have trouble understanding or evaluating the visual representations within simulations (e.g. Ronen & Eliahu, 2000; Wecker, Kohnle, & Fischer, 2007), resulting in superficial understanding (e.g. Lowe, 1999; 2004). Students may have difficulty appropriately controlling or manipulating interactive simulations (e.g. de Jong & van Joolingen, 1998), or monitoring their understanding of dynamic visualizations (e.g. Azevedo, Guthrie, & Seibert, 2004).

Appropriate instructional support can help address these difficulties and positively affect student learning in science. For example, teachers who give informative instructional support tailored to students' needs positively affected learning outcomes with visualization-based instruction around thermodynamics (Chang & Linn, 2013). Gerard, Spitulnik, and Linn (2010) found that teachers who used an evidence-based approach to refine their pedagogical strategies around visualization-based instruction related to improved student learning outcomes.

Despite the importance of instructional support, current research often focuses on curricular, representation, or technology design and relatively little research investigates how teachers interact with students to promote learning with simulations (e.g. de Jong & van Joolingen, 1998; Moreno, 2004; Rutten et al., 2012). Furthermore, research demonstrates that teachers can successfully use simulations in whole group (Smetana & Bell, 2014), small groups (Ryoo & Linn, 2012), and individual settings (Baird & Koballa, 1988), yet very little is known about how science teachers, in general, and elementary teachers, in particular, implement simulations despite repeated calls for research that would illuminate these patterns (Higgins & Spitulnik, 2008; Lawless & Pellegrino, 2007).

This exploratory, mixed methods study begins to address the call for simulation research focused on teachers' implementation practices. This study followed elementary school teachers after a professional development (PD) program to investigate how teachers implemented and provided support during simulation-based science instruction. In particular, this study answered the following research questions:

(1) How do elementary science teachers implement simulation-based instruction following PD?
(2) How do elementary teachers provide instructional support to students during simulation-based lessons?
(3) What relationships, if any, are there between how teachers implement and support simulations in elementary science classes?

Background

Simulations and science learning

A simulation is an interactive, simplified virtual model of scientific phenomena designed and used to foster students' content understanding, and develop scientific practices and/or nature of science understanding (Hilton & Honey, 2011). Simulations can help students develop a rich conceptual understanding by offering students concrete visualizations of phenomena typically too small, large, or abstract to directly manipulate (e.g. Roth, Woszczyna, & Smith, 1996; Stieff & Wilensky, 2003). Simulations offer opportunities for students to make predictions (e.g. Kim & Pedersen, 2011), design investigations, collect and analyze data, as well as support the development of explanations or arguments (e.g. Chang & Linn, 2013; Mäeots, Pedaste, & Sarapuu, 2008; Saab, van Joolingen, & van Hout-Wolters, 2005; Sadler, Romine, Stuart, & Merle-Johnson, 2013). In elementary science classrooms, research demonstrates the benefit of simulation-based instruction to promote system-based thinking (e.g. Evagorou, Korfiatis, Nicolaou, & Constantinou, 2009) and conceptual understanding (Jaakkola & Nurmi, 2008; Jaakkola, Nurmi, & Veermans, 2011; Sun, Lin, & Yu, 2008).

Although various meta-analyses find simulation-based instruction beneficial for science learning (e.g. Höffler & Leutner, 2007; Rutten et al., 2012), research also documents difficulties students face during simulation-based instruction (e.g. Lowe, 1999; 2004). For example, familiarity with everyday digital technologies can encourage cursory, superficial engagement with simulations (e.g. Wecker et al., 2007). Students may struggle to make sense of visually overwhelming simulations (e.g. Yang, Andre, Greenbowe, & Tibell, 2003). Simulations that incorporate rich animations of phenomena may actually short-circuit important mental visualization processes for learners (Hegarty, Kriz, & Cate, 2003). Although simulations provide the ability for students to interact with visualized phenomena, without appropriate self-monitoring processes, students may fail to interact productively with simulations (Azevedo et al., 2004; Lee, Nicoll, & Brooks, 2004).

Studies demonstrate that providing guidance to students during simulation-based instruction can benefit learning outcomes. Providing visual cues to guide students' attention to important information can positively affect learning (e.g. De Koning, Tabbers, Rikers, & Paas, 2011). Similarly, asking students to reconstruct key frames or features of simulations can be particularly beneficial (e.g. Paas, Van Gerven, & Wouters, 2007). For example, Kombartzky, Ploetzner, Schlag, and Metz (2010) helped students learn about honeybee communication through visualizations by asking students to identify and draw important aspects of the visualization, and then label and highlight important regions of their drawings. Successful science teaching with simulations is more than simply putting simulations in front of students (e.g. de Jong & van Joolingen, 1998). Science teachers need to be actively involved in and interact with students during simulation use to help them achieve desired learning outcomes.

This study builds upon current perspectives of teacher expertise (e.g. Koehler & Mishra, 2009; Russ, Sherin, & Sherin, 2011; Shulman, 1986) to explore how teachers support students' simulation use in classroom contexts. The following sections highlight various kinds of instructional resources that teachers may apply to teaching science with simulations: instructional support and implementation structures.

Instructional support

Teachers may support students to use simulations effectively by drawing upon existing resources and knowledge to promote productive learning habits, build student confidence, and foster students' conceptual understanding and inquiry skill development. Although all support measures may not be necessary in all lessons, teachers need to be aware of common student challenges during simulation use and means of overcoming them (Kim, Hannafin, & Bryan, 2007; Smetana & Bell, 2011).

Modeling simulation use. Research suggests that modeling interaction with simulations can help students become familiarized with and make sense of simulations (Adams et al., 2008; Klahr, Triona, & Williams, 2007) and focus on science-related learning objectives (de Jong & van Joolingen, 1998). In a study that included 89 students using a simulation for the first time, researchers found that unless explicitly pointed out, students rarely discovered functionality such as 'pause' buttons that were essential to successful simulation use (Adams et al., 2008). At best, without an introduction, students may waste instructional time trying to identify and find pertinent interactive elements. At worst, students may get frustrated, lose interest, and develop a negative attitude toward simulations (e.g. Marshall & Young, 2006). Teachers can also model data collection and analysis to promote desirable scientific practices.

Structure simulation use. Teachers may provide guidance to help students focus on instructional goals or engage in inquiry-based instruction (Quintana et al., 2004). Without a means to structure and guide simulation-based investigations, students may explore the virtual environment unproductively (de Jong & van Joolingen, 1998). Teachers may help students use simulations more purposefully by providing structure in various ways. First, teachers can simply provide clear instructional goals to help students manipulate and explore relevant variables (Podolefsky, Perkins, & Adams, 2010). A second means to providing structure can be through the choice of the simulation. Many simulations have embedded curricular support that prompt students to make relevant choices, record data, and come to data-based conclusions (Gerard et al., 2010; Quintana et al., 2004). Finally, guiding worksheets can structure student simulation use, leading to greater learning outcomes (Njoo & de Jong, 1993; Rivers & Vockell, 1987). These curricular supports can guide and structure students' scientific inquiry processes to foster relevant skill development (Klahr et al., 2007; Njoo & de Jong, 1993; Rivers & Vockell, 1987). Supporting curricula can also provide scaffolding to help students identify data patterns that may not be obvious or that students do not have fully honed skills to discern on their own (Edelson, Gordon, & Pea, 1999).

Promoting collaboration. Teachers may also provide support by promoting collaborative learning with simulations. Collaboration between students can lead to greater confidence during simulation use and the likelihood that students will engage in the associated educational challenge (Baird & Koballa, 1988). Students can ask each other for help and exchange ideas that lead to more successful simulation use (Saab et al., 2005). Simulations used in collaborative environments can facilitate argumentation, critical data analysis, evidence-based conclusion generation, and other social scientific inquiry aspects (van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005). Furthermore, collaborative simulation use allows students to exchange ideas, leading to greater learning gains (Donnelly, Linn, & Ludvigsen, 2014).

Promoting reflection. Promoting reflection during simulation-based instruction is critical for student understanding (Hennessy et al., 2007; Ryoo & Linn, 2012; Windschitl, 2000). Teachers can promote reflection and sense-making of concepts learned in simulations by interacting individually with students (e.g. Adams, 2010; Dega, Kriek, & Mogese, 2013). Probing questions and teacher-initiated interactions can be invaluable during student simulation use. Adams (2010) found that without reminders, half of students forget the instructional goal. Thus, teachers can ask questions to help focus student attention on learning objectives. Teachers also can initiate interactions to help students examine dynamic visualizations more critically or help discern patterns in data (Dega et al., 2013). Teachers can also lead reflective discussions following simulation use to provide students opportunities to articulate and review their findings, and reach consensus on data interpretations (e.g. Hennessy et al., 2007).

Technology-related support. Teachers can provide support to students during simulation use by answering student questions and troubleshooting technology-related issues. Although this instructional support type may only reflect the technical knowledge of teachers, its potential ramifications should not be overlooked. For example, in one study with secondary physics students, of the 99 students who used a circuit builder simulation to understand related concepts, the lowest scores were observed in a group of students whose computer repeatedly froze during simulation use and the instructor did not resolve the technical problem (Finkelstein et al., 2005). Clearly, technical difficulties can be more than just a nuisance; they have implications for student learning when not adequately and quickly addressed.

In summary, teachers may bring a variety of instructional supports to learning with simulations. Supporting students during simulation use potentially entails modeling simulation use, helping students engage optimally with the simulation, and guiding students to reflect on and discuss findings (de Jong & van Joolingen, 1998). As the amount and type of instructional support provided to students may influence learning outcomes with simulations (Marshall & Young, 2006; Njoo & de Jong, 1993), it is important to capture exactly how teachers are supporting students.

Implementation structures

In addition to instructional support, science teachers can choose various ways to implement simulations in their classes. Research demonstrates that teachers have students use simulations independently (Hsu, 2008), in small groups (Saab et al., 2005) or during whole group instruction (Williamson & Abraham, 1995). Each structure affords unique benefits and poses additional instructional considerations.

Individual simulation use. Teachers may elect to have students work on their own computer during simulation use. One noteworthy benefit of an individualized structure is the potential for instructional pacing and differentiation (Hilton & Honey, 2011). Science teachers can implement simulations using a one-to-one student-to-computer ratio so that students can work at their own pace, revisit previous simulation components or repeat trials as many times as necessary, and conduct investigations that reflect personal ability and interest. Hsu (2008) compared student learning in teacher-guided whole group use of simulations to students using simulations individually. Results demonstrated that student understanding was greater for students working individually (Hsu, 2008). Specifically, more students working independently developed accurate explanations for the change in seasons compared with students in the teacher-guided whole group instruction (Hsu, 2008).

Pairs/small groups. During small group implementation, two or more students work collaboratively with a simulation. Much research investigates student outcomes during student-paired computer use (e.g. McElhaney & Linn, 2011; Ronen & Eliahu, 2000; Saab et al., 2005). Teachers are often encouraged to utilize small group computer use to help students develop socially mediated problem-solving and communication skills (Blumenfeld, Marx, Soloway, & Krajcik, 1996), as well as increase student attitudes (Matz, Rothman, Krajcik, & Banaszak-Holl, 2012) and confidence in science (Baird & Koballa, 1988).

Whole group instruction. During whole group instruction, the teacher typically displays a simulation in the front of the room on an interactive white board or projection screen. The teacher may solely manipulate the simulation or allow students to take turns using the simulation. Whole group instruction enables teachers to help students focus on crucial components of the simulation, help students discern relationships between variables, and reach common interpretations of collected data. During teacher-mediated discussions, students have opportunities to hear, reflect, and build upon their peers' ideas. Similarly, whole group instruction can provide opportunities for teachers to elicit student thinking more deeply, which can guide instructional moves to leverage existing ideas (Windschitl, 2002). Whole group instruction can also provide an avenue for the teacher to model thoughtful experimental design and critical engagement with the simulation use (Smetana & Bell, 2014).

Each implementation structure offers unique advantages. While whole group instruction allows teachers to model best simulation use practices, individual student use permits greater differentiation. In addition, students' prior knowledge and simulation experience may influence the relative effectiveness of different implementation structures. For example, implementation structures that include student collaboration and/or shared computer use may only benefit students when they are willing to ask for and/or give help from and to their peers (Blumenfeld et al., 1996). Little evidence exists that one structure is optimal and very few studies compare outcomes in different contexts (Hsu, 2008). More research is needed to clarify when each structure may be optimal and how instructional support may intersect with implementation structures to understand how teachers are choosing to implement and support learning with simulations.

Purpose

Although research has investigated the kinds of computer-based instructional support students need to take advantage of simulation-based instruction (e.g. Plass et al., 2012), relatively little research investigates how teachers actually provide instructional support for simulation-based instruction. Prior research utilized case studies to examine individual teacher's educational technology implementation practices (Guzey & Roehrig, 2009; Hennessy et al., 2007; Williams, 2008). These case studies have illuminated many challenges science teachers may face during simulation use, including classroom management and undesirable student–computer interactions (Guzey & Roehrig, 2009; Hennessy, Deaney, & Ruthven, 2006).

Elementary science teachers' practices establish student familiarity with simulations and may influence student attitudes toward the technology specifically, and science in general (Kiboss, Ndirangu, & Wekesa, 2004; Marshall & Young, 2006). Despite the importance of elementary teachers' simulation use, their actual practice is rarely described (e.g. Kim et al., 2007). This study seeks to capture how elementary teachers are currently implementing and providing support during simulation-based science instruction. By understanding how teachers structure and support students' learning with simulations, this paper aims to contribute to future lines of inquiry around developing teacher expertise, and in particular, how to support elementary teachers to develop expertise with simulation-based instruction.

Methods

Participants and context

Participants in this study included members of three cohorts (2011, 2012, and 2013) of elementary teachers who participated in a state-based PD program for science teachers. The PD project sought to improve elementary teachers' science instruction through a four-week summer institute, year-long coaching, and follow-up meetings. Participants attended summer institutes at the nearest of four participating universities. Participants were chosen based on videotaped simulation use during classroom observations documented on Quarterly Lesson Reports (QLRs) (Cohort 1: $N = 8$, Cohort 2: $N = 16$, and Cohort 3: $N = 18$). Participants taught at schools that reflected a range of demographics including those with as little as 3.4% of the students receiving free or reduced lunch to as high as 87.4% (Table 1).

During the summer PD, the PD introduced simulations as a tool to support inquiry-based teaching. The PD introduced participants to simulations during a three-hour module during the summer institute at each of the four implementation sites. The module aimed to (a) make participants aware of simulations as a science educational technology tool, (b) help participants become acquainted with simulations, and (c) provide participants time to use simulations and plan how they might incorporate them into their own science instruction.

The PD did not specifically address the affordances of different implementation structures or explicitly identify instructional support provisions. Instead, the PD sought to increase participants' pedagogical knowledge about simulations as it related to inquiry-based instruction and as an alternative to hands-on labs. The purpose of the study was to characterize elementary science teachers' simulation use in regard to implementation structure and instructional support following the PD. The findings of the study are not used to draw conclusions about the effectiveness of the PD, since the variables under investigation were not explicit considerations included in PD implementation.

Data sources and analytic methods

Lesson observations were the primary data source. An *a priori* and emergent coding scheme consistent with systematic data analysis was utilized (Miles & Huberman,

Table 1. Demographic and descriptive cohort data.

	Teacher data					School data					
	Gender		Years teaching			% Free/reduced lunch			% White		
	Male	Female	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Cohort 1, $n = 8$	3	5	3	24	11.8	4.7	87.4	48.6	1.0	90.0	42.7
Cohort 2, $n = 16$	2	14	0	29	11.3	3.4	83.3	43.5	.38	83.3	42.7
Cohort 3, $n = 18$	2	16	2	31	12.4	30.8	86.4	61.4	3.2	92.1	39.1

1984). Details regarding the codes are given in the Lesson Observation section below. The data sources and analysis methods reflect the theoretical stance that teachers' instructional practices reflect their pedagogical knowledge (Shulman, 1986). Furthermore, elementary teachers share common beliefs about science instruction that mediate actual practices (e.g. Ireland, Watters, Brownlee, & Lupton, 2012). Thus, elementary teachers likely have common instructional practices that justify grouping individual data together to identify group implementation patterns and pedagogical knowledge.

Pre-perception surveys. Participants ranked their confidence using simulations as well as frequency of use on two Likert-style questions. The purpose of these Likert questions was to justify aggregating data across cohorts and did not otherwise address the research questions. Research demonstrates that as teachers gain confidence using educational technology, including simulations, the type of instructional support provided to students and the quality of interactions initiated by teachers can change (Meskill, Mossop, DiAngelo, & Pasquale, 2002). Thus, it was important that each cohort have similar frequency and confidence of simulation use means to be able to aggregate data and draw subsequent conclusions. Three science education researchers established face and content validity for the survey questions.

Quarterly lesson reports (Appendix 1). Participants completed QLRs at four evenly spaced time intervals during the academic year. QLRs provided lesson descriptions for seven consecutive science lessons. These lesson descriptions provided details about a single observed lesson as well as three lessons prior to and three following the observed lesson. In addition to describing lesson goals and curricular activities, participants noted technology integration elements. QLRs were used as a screening tool to identify videotaped lessons with simulations.

Lesson observations. Participants were video-recorded teaching a science lesson at four evenly spaced intervals during the academic year following their participation in the summer institute. Video-recorded lessons that included simulations were identified from QLRs and included a total of 50 lessons (year 1, $N = 10$; year 2, $N = 16$; year 3, $N = 24$) taught by the 42 participants. Video-recorded lessons were watched twice during data analysis. During the first viewing, field notes described simulation implementation structure, instructional support provisions, and interactions between students, participants, and simulations. Field notes were then used to create a descriptive write-up that included inferences about interactions and participant instructional actions. One of our goals in the study was to characterize and distinguish implementation structures (research question one). Because student talk with each other and the teacher may be more likely in certain structures, characterizing the nature of these interactions was important in understanding how they actually served to be instructionally supportive and to provide exemplar lesson descriptions for each structure. Examples of inferences drawn included lack of engagement when students were not looking at their computer screens, increased comprehension from discourse, or frustration from student talk and body language.

Video-recorded lessons were watched a second time and binomially coded for elements of instructional support and implementation structure. Initial instructional support codes were derived from the literature, reflect those external to the software, and included (a) modeling simulation use (e.g. Adams et al., 2008; Klahr et al., 2007), (b) instructional goals (e.g. Podolefsky et al., 2010), (c) probing questions (e.g. Dega et al., 2013), (d) closure discussion (e.g. Hennessy et al., 2007), (e) technical support (e.g. Finkelstein et al., 2005), (f) student collaboration (e.g. Donnelly, Linn, & Ludvigsen, 2014), and (g) worksheets (e.g. de Jong & van Joolingen, 1998). There were two additional emergent instructional support codes: initial play and lesson pacing. In lessons with an initial play period, students were explicitly told to either play with or explore the simulation prior to being given any instructional goals. Lesson pacing was evident in lessons where the teacher controlled student work on the simulation by either withholding worksheet elements or by giving periodic verbal instructions.

Implementation structure initially included three codes: whole group, individual, and small group. Rotating stations emerged as an additional implementation structure and was added to the coding scheme.

A science education research assistant coded 15% of the lessons following the development of the nine instructional support and four implementation structure codes. The lessons dually coded were purposefully selected to represent at least one lesson in each implementation structure. After independent coding, video analysis differences were discussed and resolved. Differences in initial codes stemmed from different interpretations of instructional support codes. Thus, during the inter-rater agreement discussions, code descriptions were refined to provide greater clarity. Inter-rater reliability was established at 92%.

A final stage in data analysis resulted in grouping the lesson write-ups based upon implementation structure (whole group, individual, small group, and rotating stations) to find commonalities within each structure. This final stage was added since the authors are unaware of previous research documenting simulation use within rotating stations and, therefore, it was necessary to characterize and distinguish this structure. In addition, documenting the presence/absence of instructional support measures would not necessarily allow us to draw conclusions regarding the value of the support within each context. By analyzing the write-ups, we were able to identify how certain supports may contribute to student learning with simulations, and therefore how its absence may limit learning. This study went beyond looking simply at teacher expertise in general, but also sought to determine how the context of simulation use may uniquely influence the apparent application of teacher pedagogical knowledge.

Data analysis

Data were collected concurrently and initially analyzed sequentially based upon the research questions (Hesse-Biber, 2010). Data from all three cohorts were combined for analysis on the basis that participants reported having a similar frequency of simulation use and confidence using simulations at the start of the PD (Table 2). Instructional

Table 2. Participant simulation use (initial self-reported frequency and confidence).

	Frequency mean (SD)	Confidence mean (SD)
Cohort 1 ($n = 8$)	2.8 (1.3)	2.6 (1.1)
Cohort 2 ($n = 16$)	2.7 (1.0)	2.9 (1.3)
Cohort 3 ($n = 18$)	2.9 (1.3)	2.8 (1.3)

Note: 1 = never/not very confident; 5 very frequently/very confident.

support codes and implementation structures were quantized to help identify patterns and establish the first two assertions (Hesse-Biber, 2010; Miles & Huberman, 1984). Since there were less than twenty lessons in each of the implementation structures and variables were dichotomously coded, relationships between quantized data were identified using point biserial correlation coefficients and Chi-square analysis (Corder & Foreman, 2009; Thorne & Giesen, 2002). Implementation structure was the predictor variable and instructional support types were the outcome variables. Because there was no *a priori* reason to expect participants would not utilize each instructional support type with equal frequency, expected values for Chi-square analyses were set at .50. Trends in participants' instructional simulation implementation are provided as assertions and supported by lesson coding patterns, lesson notes, and statistical analyses, when applicable.

Results

Interpretation of the data resulted in three assertions. In the sections that follow, each of these assertions is elaborated upon, with supporting evidence.

> Assertion 1: Participants implemented simulations most often in class-wide individualized or rotating station implementation structures. Whole group instruction was least common.

Of the 50 observed lessons, simulations were incorporated within science instruction within one of the four obvious structures: (a) rotating stations (17 lessons, 34%), (b) class-wide individual computer use (13 lessons, 26%), (c) small group computer use (11 lessons, 22%), and (d) whole group instruction (9 lessons, 18%). Seven participants were observed implementing simulations within more than one lesson. Three of these seven participants implemented simulations only within a rotating station structure. The other four participants utilized different implementation structures within different lessons.

Rotating stations

During a rotating station implementation structure, students used simulations either individually or in small groups. Unlike lessons coded as class-wide individual or small group implementation structures, student simulation use during a rotating station lesson was not class-wide. Instead, a subset of students used the simulation, while other students engaged in other activities located at other stations. Students spent a designated amount of time at each of the learning stations. During lessons with rotating stations, individual simulation use was observed in seven of the 17 lessons (41%), and shared computer use in the remaining ten (59%). In lessons with rotating stations, all stations typically addressed similar science content with different activities. For example, in Daisy's lesson (Appendix 2), all the stations had the common theme of energy and electricity use in their lives within the rotating station structure.

In other lesson observations, the rotating stations had weakly related or completely unrelated targeted learning outcomes. For example, in one lesson, some students completed a spelling quiz, while others used an ocean floor-related simulation. The spelling words did not reflect the simulation content or any other obvious science content addressed in the current unit (Parker, 2nd Observation). This indicates that teachers did not always implement simulations to support a common learning goal within a rotating station structure.

Class-wide individual simulation use

During class-wide individual simulation use, all students simultaneously interacted with a simulation either in the classroom or in a computer lab on their own computer. Although each student had access to a computer, a class-wide individual structure was not necessarily marked by the absence of student talk or collaboration. In some observed lessons, teachers explicitly told students collaboration was acceptable or did not object when students did talk. For example, as students in Chrissy's class individually used a food chain simulation, they made exclamations including 'Nothing's growing. It's just dying,' and 'Oh my gosh! Look at the bar chart' (Observation 1). In these lessons, collaboration between students resembled collaboration in the small group structure. Students were allowed to ask peers for help and share findings. However, in other lessons with class-wide individual computer use, participants prohibited student talk.

Small group simulation use

Small group simulation use was marked by two or more students sharing a computer. Although students in these lessons could have shared the responsibility of manipulating the simulation, unless specifically instructed, only one student actually used the simulation. Other than computer sharing, another obvious feature of the small group structure was continuous student talk. For example, in MaryBeth's classroom (Appendix 2), students were observed helping each other during shared computer use and articulated what they were observing to their peers. In the classroom observation, before writing down an answer on the worksheet about molecular movement, one student took the opportunity to express to her partner how she was interpreting the visualization. This communication may have helped the students develop an understanding about the simulation and depicted science concepts.

Whole group instruction

Whole group simulation instruction was marked by student interaction with a simulation via a projection screen or an interactive whiteboard located at the front of the room. In many instances, students took turns either independently, or in groups, interacting with the simulation to answer teacher questions. For example, Gabe asked a student to come to the interactive whiteboard and recreate a series circuit he and his partner had designed. After the student was done, Gabe exclaimed, 'Harrison you have the one right answer!' The students in the class quickly and simultaneously yelled, 'Wrong!' Following this outcry, Gabe asked a student, 'Taylor, are you disagreeing with me?' Taylor walked up to the interactive whiteboard and built another correct circuit model (3rd Observation). Throughout this lesson, students regularly volunteered to interact with the simulation on the interactive whiteboard. This student-centered whole-class instruction provided students the opportunity to disagree with each other and the teacher, provide evidence for assertions, and observe multiple ways of achieving functional circuit designs. Gabe used whole-class instruction to foster class dialogue and collaboration, and provide opportunities for students to share and revise their content understanding.

> Assertion 2: Teachers supported students during lessons with simulations in nine different ways. The most common support forms included technical support, peer collaboration, and worksheets. Least common were an initial play period, lesson pacing, and closure discussion.

Teachers were observed providing at least one form of instructional support to students in all lessons that involved simulations. Some instructional support types were much more common than others. In the 50 observed lessons, participants provided technical support in 40 of the 50 lessons (80%). Student collaboration was either intended or allowed in 34 lessons (68%). Worksheets and an explicit instructional goal were also common forms of instructional support visible in more than half of the observed lessons (66% and 62%, respectively) (Table 3). Chi-square analysis demonstrated that worksheet use, student collaboration, and technical support were provided most often. Conversely, initial play (6%), lesson pacing (36%), and a closure discussion (36%) were implemented significantly less often than other instructional support types.

Technical support

This instructional support type occurred when participants made sure students could access and use simulations. Technical support varied from lesson to lesson depending upon students' familiarity with simulations and unforeseen issues. In some lessons, technical support was as minor as the participant walking around the class and asking students 'Are you in yet?' to make sure they had accessed the simulation (Felix, Observation 1). In other lessons, the participant spent a large portion of the lesson providing technical support. For example, Gabe spent 21 of 45 instructional minutes going from one laptop to another updating computer software. He told the class, 'If you've got a blue bar there's an add on we need to do.' This prompted more than half the students in the class to raise their hands and wait for Gabe to make the necessary software changes (Observation 3).

Student collaboration

Student collaboration was the second most common instructional support form and was observed in 68% of lessons. Participants often allowed or directed students to collaborate

Table 3. Frequency of instructional support types ($n = 50$).

Instructional support type	Number of lessons (%)	Chi-square	Sig. (two-tailed)
Technical support	40 (80%)	18.00	0.000*
Student collaboration	34 (68%)	6.48	0.011*
Worksheet	33 (66%)	9.68	0.002*
Instructional goal	31 (62%)	2.88	0.090
Model simulation use	25 (50%)	0.000	1.000
Probing questions	22 (44%)	0.720	0.396
Lesson pacing	18 (36%)	3.920	0.048*
Closure	18 (36%)	3.920	0.048*
Initial play	3 (6%)	38.720	0.000*

*$p < .05$.

about their simulation-related observations and potential difficulties, even during whole group simulation use. For example, as Kyle led his students through various circuit designs, he periodically asked the class a question and then instructed them to 'share up with your shoulder partner' to discuss the question before providing an answer or demonstrating a possible solution on the interactive whiteboard (3rd observation). Collaboration and communication between students in all implementation structures resembled student talk described in the small group section above. Students rarely disputed each others' observations or analysis. Instead, students took the opportunity to explicate their findings and express enthusiasm or surprise.

Worksheets

Of the 50 observed lessons, teachers provided curricular support in 36 lessons in the form of worksheets. In 35 of the 36 lessons with worksheets (97%), participants used pre-made curriculum materials provided on the simulation website. This indicates teachers used worksheets as instructional support when they were readily available, but were not likely to create their own if not provided with the simulation. Some observations revealed that participants encouraged students to think more creatively or rely on classmates when worksheets were not available. For example, in one lesson, a participant utilized a simulation where students could fill glasses of varying sizes with different amounts of water to create unique sounds when they were virtually tapped with a spoon. After a whole group introduction, students worked in pairs to recreate familiar songs of their choosing. During simulation use, students depended on each other's sound observations to ascertain whether they had filled the glasses with the correct amount of water (Kilby, 3rd Observation).

Instructional goals

An instructional goal was provided in 31 of the 50 observed lessons (62%). Often the teacher stated the goal(s), displayed them somewhere in the room, and/or included them on worksheets. The instructional goal ranged in specificity and complexity. For example, Lonnie vaguely directed students to 'learn about each of the planets orbits' while using a solar system simulation (4th Observation). In comparison, Chloe instructed students to use a simulation to determine 'if salt raises or lowers the freezing point of water and by how much' (3rd Observation). Instructional goals directed students' investigations and attention during simulation use.

Modeling simulation use

A teacher-led introduction to the simulation prior to instructional use was evident in 25 lessons (50%). The depth of modeling varied for each introduction. For example, Chrissy provided a very in-depth introduction of a forest ecosystem simulation by introducing relevant simulation elements, providing students with an overall learning objective, and modeling desirable simulation use by collecting and analyzing data (Appendix 2). Ultimately, Chrissy provided an introduction that familiarized students with the simulation and desired use to promote deep student engagement during individual use. In other lessons, participants only pointed out relevant simulation elements without modeling use to the same extent as exemplified in Chrissy's lesson.

Probing questions

Teacher-generated questions regarding student interpretation of data and visualizations were observed in less than half the lessons (44%). Probing questions were initiated by the teacher and served to foster critical and scientific thinking. For example, Dierdre stood behind one student's computer and looked down at his worksheet as he used a density simulation. Dierdre asked, 'Why do you think it rises faster in sea water than in corn syrup?' After the student responded Dierdre prompted, 'What is less dense?' (Observation 1). In this exchange with the student, Dierdre encouraged the student to try to develop explanations for the collected data as well as use precise scientific language. Sometimes, participants prompted students to engage more critically with the simulation and data following a student-generated question. In Gertrude's second observation, students shared computers while using a wave simulation. During the lesson, several students struggled and asked for help. Two students yelled at Gertrude from across the room, 'We don't get this question.' Gertrude walked over to the students and asked questions to direct their attention to relevant parts of the simulation: 'You see the dividers. What is the pressure between the dividers? What does it show you here?' Dierdre and Gertrude provide examples of how they and other participants utilized probing questions to help students construct understanding from the simulations.

Lesson pacing

Pacing was observed in 18 (36%) of the observed lessons. Instructional pacing was apparent when the participant withheld parts of the worksheet, instructed students to stop working at certain junctures and wait for directions, or directed student attention throughout the lesson during whole group instruction. Gabe directed students to only follow certain directions on the worksheet that accompanied a circuit builder simulation. When Gabe sensed a student went further ahead than instructed, he said, 'You're moving ahead. You need to stay with me so you can participate in our discussions' (Observation 3).

Closure discussion

A closure discussion that helped students reflect upon simulation use was one of the least observed forms of instructional support (36%). A closure discussion may have also allowed student thinking to be more visible. For example, Parker was able to ascertain student confusion after using an Ocean Mapping simulation (Appendix 2). If Parker had not taken the opportunity to lead a whole-class discussion, at least one student would have left the room not understanding the visualization and science content the simulation intended to teach. In other lessons with analogous lesson closures, the teacher participants often became aware of science content that students did not fully understand during simulation use and were able to address misunderstandings.

Initial play

An initial 'play' period was rarely observed (6%). In the three lessons characterized by initial play, the teacher explicitly indicated the purpose of play was for students to familiarize themselves with the simulation. For example, after directing students to the appropriate simulation website, Collette told her students, 'You're just going to play around a little bit with it today.' A student asked, 'I can play with it?' and Collette responded, 'You're playing around with it so that tomorrow you are not playing around with it you are using it .... Pay close attention on when you click certain things what happens' (Observation 1). Although Collette termed it 'play,' she also indicated there was a purpose; students should familiarize themselves with simulation elements so that on the following day students could direct their attention to specific instructional goals.

> Assertion 3: The types of instructional support varied by implementation structure. Students were most supported in a class-wide individualized structure and least supported in rotating centers.

When instructional support was examined within the different implementation structures, a notable difference in the amount and types of instructional support provided in each structure existed. Correlation coefficients were computed between the total instructional support measures observed in lessons in each implementation structure. There was a negative correlation ($a < .05$) between the total amount of instructional support in a rotating station structure, $r(48) = -.303$, $p = .033$. Conversely, a statistically significant positive correlation existed between total instructional support types and a class-wide individualized structure, $r(48) = .337$, $p = .017$.

The limited observed instructional support within rotating stations may reflect practical considerations of this structure. In lessons with rotating stations, there was often a station involving student manipulation of physical materials that demanded the participant's attention and resulted in a different pattern of interaction and support than in other simulation implementation structures. For example, in a lesson on solar systems, Joanne's students completed four activities for 10 minutes each. Students alternated looking through books on the solar system, completing a moon phase card sort, measuring the distance from the sun to different points on the Earth using a model, and using a moon phase simulation (3rd Observation). Joanne spent the majority of her time at the measurement station and only visited the simulation station twice during the 40-minute class. Unfortunately, a closure discussion, which might have compensated for the absence of other instructional support forms, was only observed in five of the 16 (35.3%) rotating station lessons (Table 4).

Further correlation coefficients demonstrated relationships between the likelihood of certain instructional support types being given within each implementation structure. Because of the large number of tests, a more conservative alpha value was set at $a < .01$. A rotating structure was negatively correlated with modeling simulation use, $r(48) = -.464$, $p = .001$, and pacing, $r(48) = -.450$, $p = .001$. The only significant correlation in a small group structure was an increased occurrence of student collaboration, $r(48) = .364$, $p = .009$. This positive correlation was expected, given the fact that in this structure students shared computers in completing a common task. Lesson pacing was significantly correlated with whole group instruction, $r(48) = .000$, $p = .000$. This correlation is also not unexpected since the teacher is directing student work during whole group instruction. There were no significant correlations between instructional support type and a class-wide individual implementation structure.

Table 4. Correlations among implementation structure and instructional support types ($N = 50$).

	Instructional support type								
	Pacing	Model use	Collab.	Tech. support	Probing questions	Closure	Play	Worksheet	Goal
Whole group (9)									
n (%)	9 (100%)	6 (66.7%)	3 (33.3%)	5 (55.6%)	5 (55.6%)	0 (0%)	1 (11.1%)	4 (44.4%)	3 (33.3%)
r_{pbis}	.625	.156	−.348	−.286	.214	−.351	.101	−.172	−.277
Sig. (two-tailed)	**.000***	.279	.013	.044	.136	.012	.486	.233	.052
Sm. group (11)									
n (%)	3 (30%)	8 (72.7%)	11 (100%)	10 (90.0%)	3 (27.3%)	5 (45.5%)	1 (9.1%)	8 (72.7%)	5 (45.5%)
r_{pbis}	−.097	.241	.364	.145	−.179	.105	.069	.009	−.181
Sig. (two-tailed)	.505	.091	**.009***	.316	.214	.470	.633	.953	.208
Individual (13)									
n (%)	5 (38.5%)	8 (61.5%)	7 (53.8%)	13 (100%)	8 (61.5%)	7 (53.8%)	1 (7.7%)	12 (92.3%)	11 (84.6%)
r_{pbis}	.03	.137	−.180	.296	.209	.220	.042	.268	.276
Sig. (two-tailed)	.834	.344	.211	.037	.144	.124	.771	.060	.052
Rotating stations (17)									
n (%)	1 (5.9%)	3 (17.6%)	13 (76.5%)	12 (70.6%)	5 (29.4%)	6 (35.3%)	0 (0%)	11 (64.7%)	12 (70.6%)
r_{pbis}	−.450	−.464	.130	−.169	−.211	−.011	−.181	−.117	.127
Sig. (two-tailed)	**.001***	**.001***	.367	.241	.141	.942	.208	.420	.339

*$a < .01$

Discussion

This study sought to fill a void in the research literature (Kim et al., 2007; Rutten et al., 2012) and describe patterns in elementary science teachers' simulation use with regard to instructional support types and implementation structure. Collectively, the participants evidenced a breadth of knowledge and expertise in simulation use. However, the limited utilization of whole group instruction, consistent absence of certain types of instructional support, and the correlation between rotating stations and less support suggest that variables other than general teacher expertise influence patterns in simulation use. These patterns reveal room for improvement in teachers' instructional simulation use. The following sections explore the implications of the findings, provide possible theoretical explanations for the observed patterns, and highlight the need for research seeking theoretical explanations.

Implementation structure

Despite the instructional benefits of whole group simulation use (Smetana & Bell, 2014), the participants in this study only utilized it in 18% of the observed lessons. Instead, participants most often employed a one-to-one student-to-computer ratio or small group computer use by implementing simulations within a class-wide individualized or rotating station structure.

The finding that participants did not utilize a whole group structure more often in light of the structure's instructional and practical benefits may have several explanations, including limited pedagogical and/or technological knowledge (Koehler & Mishra, 2009; Shulman, 1986), teacher beliefs, and school context.

The dominant use of one implementation structure by several participants indicated some teachers may not be aware of or take advantage of each structure's benefits. Schneider and Plasman (2011) suggested teachers may implement curricular options in certain structures to compensate for their own limited pedagogical knowledge. It is also possible that teachers lacked adequate comfort with the technology to successfully lead whole group instruction that requires the use and manipulation of a simulation using additional technology, such as an interactive whiteboard. PD and teacher preparation programs may need to not only explicitly identify the benefits of different implementation structures, but also strengthen elementary teachers' pedagogical and technological knowledge by providing opportunities for practice and reflection (Gerard, Bower, & Linn, 2008; Neiss, 2008) using simulations in each implementation structure.

Individual beliefs and school context may also contribute to teachers' decisions regarding the structure to implement simulations (Hennessy, Deaney, & Ruthven, 2005). Teacher beliefs regarding educational technology have been implicated in influencing how simulations are used (Dawson & Heinecke, 2004; Ertmer, 2005) and might also influence the structure for implementation if teachers believe that students learn optimally when engaging with computers in certain ratios. In fact, Hennessy et al. (2005) found teachers were often unsure how students might uniquely benefit from whole group technology-mediated instruction. Furthermore, with the increasing number of computers in schools, there may be pressure for teachers to utilize the technology by having students work independently on their computers, and the benefits of other structures, especially whole group instruction, may be overlooked (U.S. Department of Education (DOE), 2015).

This study suggests that elementary teachers may regularly implement simulations within rotating stations, perhaps more often than any other structure. Stations may solve classroom management issues by offering a change in activities. Stations can also help teachers include simulations when faced with limited computer resources, as teachers only need a few computers (e.g. Jones, 2007). Although the student-to-computer ratio in schools is continuing to decline, there are still schools with limited computer availability (DOE, 2015). Perhaps these practical considerations shaped participants' implementation patterns. While a handful of studies have compared the effectiveness of simulation use during whole group, small group, or individual structures, there is no research to our knowledge about their use in rotating stations. Based upon the finding that elementary teachers may most often embed simulations within a rotating station structure, future research should broaden the contexts in which student outcomes with simulations are usually investigated.

Instructional support

This study brought to attention additional support forms not previously described during instructional simulation use: initial play and lesson pacing. An initial play period was rarely observed; but when it was, the participant clearly indicated the purpose was for students to familiarize themselves with the simulation so that productive use could follow. Lesson pacing was utilized in all whole group implementation lessons and in a small number of lessons with other structures. By focusing student attention on certain tasks and restricting movement ahead by withholding instructions or worksheet elements, participants tried to focus student attention. Since pacing was an integral component of whole group instruction, it is possible whole group instruction was the secondary purpose of pacing. Whole group instruction may have been an avenue to more easily pace student work.

Participants implemented technical support, worksheets, and collaboration most often to support student simulation use. Teachers most often utilized pre-made student worksheets, suggesting teachers will use instructional/educative materials that accompany simulations. However, some of the most creative use of simulations occurred in lessons without worksheets; for example, when students used a simulation to create familiar songs. Thus, worksheets may not always be necessary or desirable during simulation use. Instead, worksheets may offer teachers a means to initially scaffold the final goal of independent and creative simulation use. One would expect that as students gain familiarity with simulations, worksheet support may not be as necessary. In the present study, there was no evidence that the elementary participants faded this form of support. This may be a result of student needs, or reflect limited teacher consideration of scaffolding support.

A closure discussion was infrequently observed (10% of lessons). A closure discussion offers a teacher important opportunities to lead discourse and foster student reflection, understanding, and idea integration (Linn & Eylon, 2011). Our study demonstrated how closure discussions can provide teachers opportunities to elicit naive student conceptions that were difficult to ascertain in a rotating station structure. Simulation PD should consider making participants aware of a closure discussion as an important form of instructional support, especially when the teacher cannot promote student reflection during actual simulation use.

Although each type of instructional support likely provided some value in certain instances, the results of the present study indicate that instructional support provisions often reflect the implementation structure, and not necessarily the application of teacher knowledge or expertise. For example, modeling simulation use would be expected in any implementation structure where students would use the simulation independently. However, modeling was rarely observed in lessons where students used simulations within a rotating structure. This may indicate that teachers did not recognize the need to model simulation use prior to student use or there may have been other obstacles such as time limitations.

Several lessons with rotating stations followed a model where teachers remained at one station. When simulations were not the primary station, teachers had limited or no interaction with the students, and therefore instructional support was minimal. Although students could seek help from peers also working at the simulation station, students may not be comfortable asking for help from peers (Blumenfeld et al., 1996). Since the participant generally stayed at another station with hands-on materials during rotating station lessons, the participant may have purposefully chosen simulations he/she thought students could use independently. Or perhaps, participants implemented simulations within rotating stations following simulation use in a different implementation structure that included more support. Due to the limited number of teachers observed using simulations in more than one lesson, the extent participants scaffolded instructional support or progressed through certain implementation structures is unknown. However, the instructional practices during rotating stations in particular suggest a need for greater teacher awareness of potential student difficulties during simulation use and how instructional support can be provided in all implementation structures.

Implications/future research

The study results have implications for simulation developers, PD designers, and researchers. Participants almost always utilized the accompanying resources with simulations, such as worksheets, when they were available. In addition, participants used simulations that had accompanying curriculum materials, especially student worksheets, more often than other simulations. Together, these findings suggest that providing supporting curriculum resources may be integral in promoting simulation use among elementary teachers (Davis & Krajcik, 2005).

This study did not address *why* participants made the instructional choices observed in the lessons. The observed simulation use patterns in the present study indicate that pedagogical knowledge application may be somewhat context specific, in particular dependent on the implementation structure. It is possible the purpose of simulation use is characteristically different for teachers in each implementation structure and this structure guides instructional support practices. It is also possible the structure either facilitates or hinders teacher noticing of student behaviors and interactions that might signify instructional support needs (Russ & Luna, 2013). Future research should consider how school context, teacher knowledge, and beliefs shape teachers' instructional choices with simulations.

The study included elementary teachers with varying levels of teaching experience across the state from a number of different school districts. While the diversity may afford a certain degree of generalizability, we are hesitant to generalize about elementary teachers nationally. School computer use policies, education standards, and teachers' prior simulation use may shape implementation patterns (Dawson & Heinecke, 2004; Meskill et al., 2002). However, the documented patterns should encourage science education faculty and PD programs to consider more broadly how to improve elementary science teachers' simulation use. In particular, teachers may need help recognizing the need for and providing instructional support in each implementation structure. For example, if teachers frequently implement simulations within a rotating station structure, PD implementers should explicitly help teachers identify how they can support struggling students amid a classroom with diverse activities occurring simultaneously.

There were several limitations to the study. Although 50 classroom observations constituted the data set, the actual number of observations in each implementation structure was 17 or less. Thus, analyses and conclusions about each implementation structure are based on relatively few observations. Another limitation of the study is the 'snapshot' nature of recorded lessons. For example, closure discussions were seldom observed during observed lessons with simulations. It is possible teachers held closure discussions during the following, unrecorded class. Finally, this study did not investigate changes in participants' instructional simulation use and aggregated data throughout the school year. Elementary teachers may in fact scaffold certain instructional supports and/or change implementation structures as students have more opportunities to use simulations. Future investigations should be designed to mitigate these limitations and explore if and how elementary teachers scaffold simulation use in regard to instructional supports and implementation structures.

Conclusion

The emergent patterns in this study provide new insight into how elementary teachers implement and support students' simulation use. Elementary classrooms are the first opportunity many students have with educational technologies, including simulations. Elementary school students should learn to use simulations in scientific ways, develop positive and accurate attitudes about simulations, and understand they are just one tool to help unearth patterns and develop understanding. If elementary teachers utilize simulations most often in rotating structures, where they may find it difficult to support student use, it is unlikely students will obtain the maximum benefit. Science education faculty and PD implementers should help teachers develop instructional practices so that support provided reflects student needs and is not a function of the implementation structure.

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Appendix 1. Quarterly lesson reports

Section I. Background Information

Observer:	Observation # (bold one): 1 2 3 4
Teacher Name:	School:
Grade Level/Content Area:	
Date:	Start Time: End Time:
Total number of students in class:	

Section II. Contextual Background
Ask teacher before observing:

A. Objective(s) for lesson:
B. How does the lesson fit in the current context of instruction? (e.g. connection to previous and other lessons; What topics/activities/lessons occurred in the three science lessons prior to this lesson? What topics/activities/lessons will be covered in the three science lessons following this lesson?) All blanks should be completed and answers should be based on the teacher's interpretation of the lesson, not the coach's.
= yes, the lesson includes these criteria, N = no, the lesson does not include these criteria, DK = participant indicates they either do not know what the criteria mean or whether the lesson meets the criteria

	Days preceding				Days following		
	Day 1	Day 2	Day 3	Today	Day 1	Day 2	Day 3
Topic(s)							
Activities							
Problem-based learning?							
Nature of science?							
Inquiry?							
Technology?							

Note: If you indicated 'yes' for PBL, NOS, Inquiry, and Tech, briefly describe below what made it (why you think it is) a PBL/NOS/Inq/Tech lesson.

C. Classroom setting. Describe anything about the classroom layout that would constrain the teaching of science.
D. Other relevant details about the time, day, students, or teacher that you think are important? (i.e.: teacher bad day, day before spring break, pep rally previous hour, etc.)

Section III. Description of events over time (indicate time when the activity changes). (You may complete this section or include the notes you took on this lesson.) Make sure that you describe the activity.

Appendix 2. Example classroom observations

Daisy, 2nd Observation

Students work for approximately 10 minutes at each of three stations. At the first station, students work in pairs and explore the Household Energy Usage Gizmo®. At another station students use balloons, rub them on various items, and try to adhere the balloons to vertical surfaces. The last station is a card sort with different household items that students are supposed to inductively group based on similarities. As students complete the tasks at each station, they record what they learned from the activity. After all students have rotated through all three stations, Daisy asks the class to talk with tablemates and try to identify a word that describes the commonality in all stations.

MaryBeth, 3rd Observation

MaryBeth starts the lesson by explaining to students what Gizmos® are and showing students how to use the Freezing Point of Salt Water Gizmo®. After the introduction, students work in pairs, determine how salt affects the freezing point of water, and complete the guiding worksheet. At first, some students read the worksheet directions to their partner. Sophia tries to explain to her partner what she is observing in the simulation and says, 'I think that like … the molecules … are moving all around.' Sophia moves her hands as she speaks. Another student indicates to her partner the simulation is not depicting what she expected, 'It's still not freezing. Somehow they got a little faster.'

Chrissy, 1st Observation

Chrissy starts the lesson by having students sit in front of the SmartBoard™. Chrissy tells them, 'You're going to have the opportunity to watch a food web change over time.' During the introduction, Chrissy shows students' relevant Gizmo® elements such as the 'reset' button and demonstrates how to manipulate variables relevant to the instructional goal. After pointing out the simulation's dependent and independent variables, Chrissy tells the students, 'Let's go ahead and do one of these simulations.' The students guide the teacher in setting ecosystem parameters such as a diseased hawk and healthy snake population. As the Gizmo® plays, Chrissy tells the students to 'Look at how the numbers are changing.' The students yell out explanations for what they observe such as ' … because the grass is diseased' or 'They're eating it.' After students finish making observations, Chrissy shows students how to access and interpret the data table and bar graph. The students look at the graph to answer questions, such as 'What trend do you see in the hawks? What trend do you see in the rabbits?' Following this introduction, students use the simulation to investigate their own research questions.

Parker, 2nd Observation

Within a rotating station structure, students use a Gizmo® to answer the question, 'How do we explore the ocean floor?' During the entire lesson, the participant stayed at a spelling quiz station and read words to students. During the culminating class discussion, Parker asks students what they learned at the Gizmo® station about how scientists explore the ocean floor. A student summarizes his observation, 'They had a boat and an anchor that was going down, down or something.' Parker shakes her head from side to side indicating the observation is inaccurate. She asks the class, 'What was going down off that boat in your Gizmo®?' Another student answers 'Sonar.' Parker agrees, 'Yes. So that's definitely one way to explore the ocean floor.'