Analysis of VISTA Teachers' Computer Simulation Use

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Abstract

This study sought to understand the instructional context within which 52 elementary (grades 4-6) and 11 secondary (grades 7-12) treatment teachers used simulations to support science instruction during their participation in a large-scale professional development program (PD). In addition, differences in the extent of simulation use between the treatment and 47 control participants were analyzed. Data collected included classroom observations, semi-structured interviews, surveys, ExploreLearning™ login reports, and classroom observation reports. Results of data analysis indicated that computer simulation professional development may have increased elementary treatment participant computer simulation use. However, this was not true for secondary participants. Program participants used simulations most often to teach traditional content related to earth, life, and physical science topics. The least common use was to support inquiry instruction within a problem-based learning context. This was inconsistent with the professional development goals, which promoted learning science content and using inquiry skills within the context of real world problems. Participants provided varying amounts of instructional support prior to and during student simulation use. In lessons where instructional support was minimal or absent students did not seem able to use simulations to engage with science content or skills as well as students in classes with more instructional support. These findings suggest that professional development may need to model simulations within an inquiry context and provide explicit instruction for supporting students. In addition, elementary and secondary teachers may not change classroom practices to the same extent following computer simulation professional development. This may be a result of unique elementary and secondary teacher characteristics or the availability of computer simulations for different age groups.

Introduction

Effective, reform-based science instruction includes several goals to facilitate the development of students that can think and behave like scientists (National Research Council [NRC], 2000). Reform-based science instruction should (1) promote students' conceptual understanding and use of science concepts (NRC, 2012), (2) include opportunities to develop science inquiry and process skills by providing occasions to practice science inquiry (NRC, 2012), (3) include explicit nature of science (NOS) instruction (Bell, Blair, Crawford, & Lederman, 2003; Khishfe & Abd-El-Khalick, 2002; Lederman, 2007), and (4) provide opportunities to use technology to support science content and reform-based pedagogy (International Society for Technology and Education [ISTE], 2002). The pressure for teachers to incorporate technology to support inquiry and other reform-based science instruction has substantially increased during the last decade (ISTE, 2002; NRC, 1996; NRC, 2000). As a result, there is an emphasis on providing teachers professional development to facilitate this goal (President's Council of Advisors on Science and Technology, 2010).

Computer simulations are one form of educational technology that can help teachers provide effective reform-based science instruction (NRC, 2011; Bell & Smetana, 2008; Kubicek, 2005). While a growing body of research indicates the potential value of simulations in science instruction, research suggests a variety of variables may impact their effectiveness, including teacher practices during lessons incorporating computer simulations (Bell, Gess-Newsome, & Luft, 2008; Kim, Hannafin & Bryan, 2007; Njoo & de Jong, 1993). As a result, there is a need to understand specific teaching strategies that increase teachers' effective use of simulations (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011) and to identify professional development elements that encourage simulation use to support reform-based science instruction (Gerard, Varma, Corliss, & Linn, 2011).

Computer Simulations in Science Instruction

Computer simulations are dynamic, computer generated models of real world processes and phenomena (Smetana & Bell, 2011). Potential advantages of using computer simulations to support science instruction include: addressing students' alternative conceptions (Bell & Trundle, 2008), increasing students' content understanding (Huppert, Lomask, & Lazarowitz, 2002; Raghavan, Sartoris & Glaser, 1998) and opportunities to practice process skills (Lee, 1999), improving students' attitudes toward science (Kiboss, Ndirangu, & Wekesa, 2004), providing ongoing feedback (Ronen & Eliahu, 2000), and a more time efficient learning environment (Klahr, Triona & Williams, 2007). When used appropriately, computer simulations support learner-centered, and inquiry-based pedagogy (Smetana & Bell, 2011).

Results of several meta-analyses and literature reviews have demonstrated the promise of computer simulations in supporting science instruction within varied content areas (Lee, 1999; Liao, 2007; Smetana & Bell, 2011). Simulations may increase student success in physics (Ronen & Eliahu 2002; Zacharias & Anderson, 2003), biology (Huppert, Lomask & Lazarowitz, 2002; Kiboss, Ndirangu, & Wekesa, 2004), chemistry (Plass et al., 2012; Winberg & Berg, 2007), and engineering design projects (Klahr, Triona & Williams, 2007; Triona & Klahr, 2003).

Computer simulations appear also to be valuable in preparing pre-service science teachers to use instructional technology in ways that support and reform-based practices (Bell, Maeng, & Binns 2013). Simulations can improve pre-service teachers' science conceptual understanding (Bell & Trundle, 2008; Trundle & Bell, 2010), and mastery of science practices such as theory development (Marshall & Young 2006). The value of using simulations with pre-service teachers is substantial since teachers' content understanding and adeptness at engaging in scientific practices will ultimately affect the instruction that occurs in classrooms.

Most simulation research considers the benefits when they are used in conjunction with other instructional methods, including hands-on labs and lecture (Gokhale, 1996; Huppert, Lomask & Lazarowitz, 2002; Marshall & Young, 2006; Plass et al., 2012). As a result, Smetana & Bell (2011) recommend simulations be used only in conjunction with other instructional techniques. In their synthesis of the research, Smetana and Bell (2011) conclude simulations are most beneficial when used prior to hands-on labs. However, the affordances of computer simulations may make them more or equally effective than traditional instruction under other circumstances as well (Klahr, Triona, & Williams, 2007; Liao, 2007; Triona & Klahr, 2003). For example, simulations allow more trials to be completed in the same amount as time as a hands-on lab (Klahr, Triona, & Williams, 2007). As a result, more data can be collected that can promote conceptual change (Ronen & Eliahu, 2000) and foster scientific skill development (Kubicek, 2005). In addition, simulations allow students to visualize processes that are otherwise impossible (Plass et al., 2012). Finally, simulations allow data to be collected on processes that might be unsafe or impractical in the classroom (Lee, 1999). It is unclear from the research how simulations should be incorporated into science instruction to achieve maximum student outcomes. It is possible that the varied characteristics of science content, learning objectives, and simulations explored in the aforementioned studies make drawing a single conclusion difficult.

Computer simulation research increasingly indicates their value in science instruction. However, student characteristics, software design, and instructional support practices may need to be taken into consideration for the benefits to be fully realized (Huppert, Lomask, & Lazarowitz, 2002; Rivers & Vockell, 1987; Winberg & Berg, 2007). Huppert, Lomask, & Lazarowitz (2002) found that students with varying reasoning abilities differentially benefitted from computer simulations. In another study, Winberg and Berg (2007) observed that students with low prior knowledge that completed a simulation pre-lab asked fewer theoretical and reflective questions during a chemistry lab than control counterparts that did not complete the simulation pre-lab, but had higher prior knowledge. The authors conjectured there may be a threshold of necessary prior knowledge for students to benefit from some simulations.

There is a broad range of available science computer simulations. Simulations vary in the amount of embedded instructional support, screen interface characteristics, and opportunities for inquiry learning. These simulation characteristics may facilitate or hinder student use. Ideal simulations permit student engagement in a wide range of scientific practices, including prediction generation and data analysis, foster reflection and real world application, and have a simple and easy to use screen interface (Bell & Smetana, 2008). Complex screen interfaces can overwhelm students and prohibit engagement with targeted science content (Sweller, van Merrienboer & Paas, 1998).

The role of the teacher and instructional strategies used to support students during simulation use have repeatedly been implicated as covariates in science computer simulation research (Marshall & Young, 2006; Rivers & Vockell, 1987; Ronen & Eliahu, 2000; Smetana & Bell, 2011). Rivers & Vockell (1987) studied students' problem solving skills after using simulations with or without instructional support. The treatment group given written directions and prompts outperformed the control group. In another study, written directions were given to pre-service teachers during a physics computer simulation used to explore properties of collision, momentum, and energy conservation (Marshall & Young, 2007). Based upon participants' failure to follow given written directions, the authors concluded that instructional support needed to include more elements to facilitate effective simulation use. Overall, findings suggest that instructional support may enhance the benefits of computer simulations for science instruction. In addition to the student support measures teachers use, teachers can help students learn with simulations by only incorporating simulations with ideal design characteristics.

Situated Learning Theory and Computer Simulation Use. One approach to support and improve teachers' implementation of computer simulations during science instruction is professional development. One goal of teacher professional development is to achieve long-term changes in teachers' classroom practices. Reforms documents call for technology to be integrated into teachers' classroom practices to a greater extent to support effective science instruction (ISTE, 2002; NRC, 2012). This requires teachers' professional development programs to be designed and implemented in ways that foster sustained changes in classroom practice. It is widely recognized that professional development that is content specific (Capps, Crawford, Constas, 2012; Cohen & Hill, 1998; Kennedy, 1998; Supovitz & Turner, 2000), provides opportunities for collaboration (Garet et al., 2001), is consistent with other learning activities (Garet et al., 2001), and considers coherency (Garet et al., 2001; Supovitz & Turner, 2000) is most effective. Furthermore, research suggests when teachers actively participate in designing lesson plans and curricula that integrate new instructional strategies and have opportunities for reflection on that instruction, changes in classroom practices are more extensive (Gerard, Varma, Corliss & Linn, 2011). Therefore, instructional technology professional development aimed at increasing teachers' use of instructional technology to support reforms-based instruction should include these elements.

To accomplish long-lasting changes in teachers' classroom practice situated learning theory supports the inclusion of academic content and an active, social learning environment during professional development programs. The situative perspective on learning perceives cognition as (a) contextual within a physical and social environment, (b) social in nature, and (c) distributed across the person, other persons, and tools (Lave & Wenger, 1991; Putnam & Borko, 2000). The context in which new activities take place becomes fundamental to what participants learn (Greeno, Collins, & Resnick, 1996). Situated learning theory suggests that if we want teachers to use computer simulations and other educational technology to teach science content and scientific practices, professional development should engage participants in relevant content and practices. The most extensive piece of research that takes into consideration situated learning and pre-service teachers' practices with educational technology was conducted by Bell, Maeng & Binns (2013). In this study, 26 pre-service teachers participated in a secondary science methods course where they were taught to use educational technology based on McLellan's (1996) model of situated learning theory. Findings indicated that modeling educational technology in the context of a science teacher preparation program facilitated teacher technology integration to support reforms-based instruction. In addition, collaboration and reflection led to greater integration of educational technology into science instruction during student teaching. This provides evidence that grounding educational technology experiences for pre-service teachers in situated learning theory affects classroom practice. The extent to which this may also be true during professional development of in-service teachers needs to be examined.

Purpose

Computer simulations are increasingly accessible and popular technology tools that may promote science content understanding, conceptual change, and scientific skill development amongst K-12 students (Smetana & Bell, 2011) and pre-service teachers (Bell & Trundle, 2008; Marhsall & Young 2006). Therefore, it is desirable for teachers to be exposed to and adept at incorporating computer simulations into science instruction. Recent investigations indicate that pre-service teachers may readily use educational technology such as computer simulations to support reform-based instruction (Bell, Maeng, & Binns, 2013; Maeng, Mulvey, Smetana, & Bell, 2013; Irving, 2009). However, other studies have identified challenges in achieving technology incorporation within in-service teachers' instructional practices (Norris, Soloway, & Sullivan, 2002; Russell & Bradley, 1997; Supovitz & Turner, 2000), especially to support desired reform-based science instruction (Schneider, Krajcik & Blumenfeld, 2005).

Additional research on in-service teachers' technology use following professional development is needed to explain these contradictory findings. Possible explanations include professional development elements and educational technology characteristics that either facilitate or hinder classroom incorporation. Therefore, to simplify the instructional technology variable, this study examined the extent participants incorporated a specific type of computer simulation, ExploreLearning™ Gizmos™, into their classroom instruction following professional development

Absent from the educational technology professional development literature is an examination of computer simulation use following targeted in-service science teacher professional development. Instead, pre-service teachers' computer simulation use is often considered in conjunction with other educational technology (Bell, Maeng & Binns, 2013; Guzey & Roehrig, 2009). Furthermore, only one study examined teachers' intentions to use computer simulations for Physics instruction following exposure in a pre-service science teachers' methods class (Zaccharias, 2003). From these studies, conclusions cannot be drawn about features of effective in-service science teacher professional development that are specific to computer simulations.

Given the potential benefits of computer simulations to support reform-based science instruction, it is important to determine the extent computer simulation professional development leads to changes in teachers' classroom practices. In this study, the computer simulations presented to teachers during the professional development program were ExploreLearning™ Gizmos™. ExploreLearning™ develops K-12 science simulations with many ideal features. Gizmos™ have a relatively simple screen interface, accompanying instructional materials, and allow students to engage in a wide range of scientific practices. As a result of these features, ExploreLearning™ Gizmos™ may be relatively easy for teachers to incorporate into reform-based science instruction.

It is also important to identify desirable professional development elements that support in-service teachers' sustained use of technology to support reform-based science instruction. Additionally, teachers' reported ease or challenges in using simulations may inform computer simulation software development.

Thus, the following research questions guided this investigation:

1. What was the extent of treatment participant ExploreLearning™ Gizmo™ use compared with control participant use? Did treatment participants use Gizmos™ to a greater extent than control participants?
2. How did participants use Gizmos™ in their classroom during science instruction? Was it within a reform-based learning context? What methods of instructional support did participants provide students?
3. How did participants experience the ExploreLearning™-related professional development? What did participants identify as strengths/challenges?

Methods

Context

VISTA Professional Development. The *Virginia Initiative for Science Teaching and Achievement* (VISTA) provided intensive professional development to elementary (grades 4-6) and secondary (grades 7–12) science teachers to promote effective science teaching and increase student achievement. The VISTA professional development incorporated a *Learn, Try, Implement* model piloted in two previous studies (Sterling & Frazier, 2010; Sterling, Matkins, Frazier & Logerwell, 2007). An example of how the *Learn, Try, Implement* model is incorporated into the VISTA PD is described in the Elementary Science Institute and Secondary Teacher Program sections below. Ultimately, the goal of VISTA PD was to improve the quality of science education in the state of Virginia. Teachers applied for participation in VISTA and were then randomly assigned to control and treatment conditions.

The VISTA professional development supported science teachers' inclusion of inquiry-based and explicit NOS instruction in the context of problem-based learning (PBL). Problem-based learning is an ideal mechanism for effective science instruction since students solve meaningful, real world problems by acting like scientists. VISTA defined the constructs PBL, NOS and inquiry as:

- <u>Problem-based learning</u>: Students solve a problem with multiple solutions, over time, like a scientist in a real-world context; both the problem and context must be meaningful to students;
- <u>Inquiry</u>: (1) Asking questions; (2) collecting and analyzing data; (3) using evidence to solve problems;
- <u>Nature of science instruction</u>: The values and assumptions inherent to the development of scientific knowledge. Key elements include: (1) scientific knowledge is empirical, reliable and tentative, and based on observation and inference, (2) scientific theories and laws are different kinds of scientific knowledge, (3) scientists use a variety of methods to develop scientific knowledge. (Mannarino, Logerwell, Reid, & Edmondson, 2012)

In addition to promoting the inclusion of NOS, PBL, and inquiry, VISTA encouraged use of technology in the classroom. In particular, VISTA encouraged technology use to support hypothesis and prediction generation, data collection, and data analysis that could be used to answer a research question or a larger problem. These scientific practices or scientific skills are fundamental to science instruction and learning (NRC, 2012).

Participants

Participants were all elementary and secondary VISTA participants. Teachers applied to VISTA and upon acceptance were randomly placed in control and treatment conditions. The treatment group included 52 elementary and 11 secondary teachers. The control group included 36 elementary and 11 secondary teachers. Elementary treatment teachers participated as teams of 2 to 5 teachers from a school and taught science to 4th, 5th or 6th grade students in the VISTA Elementary Science Institute (ESI). VISTA elementary participants had prior teaching experience that spanned zero to thirty-eight years and averaged 9.8 years. Secondary treatment teachers participated in the VISTA Secondary Teacher Program (STP). Teachers in the STP were uncertified, provisionally-licensed, or licensed first or second-year secondary science teachers who taught grades 7-12 science (i.e. life science, physical science, biology, earth science, chemistry, physics).

Elementary Science Institute (ESI). The VISTA ESI was a four-week summer institute complemented by follow-up academic year support. Teams of university science educators, scientists, and engineers, along with science classroom teachers and mathematics specialists, co-planned and co-facilitated the 4-week summer learning experiences. Elementary teachers spent week one of the ESI *learning* how to teach science through inquiry within a problem-based learning context. During weeks two and three participants alternated *practicing* teaching science to high-needs students in a summer camp using inquiry-based approaches in a problem-based learning context and participating in teaching modules. In one of these teaching modules, teachers were introduced to ExploreLearning™ Gizmos™ (www.ExploreLearning.com). ExploreLearning™ Gizmos™ are computer simulations specifically designed to facilitate students' understanding of abstract science content by allowing them to make observations, manipulate independent variables, measure dependent variables, and conduct experimental and correlational investigations. In addition, ExploreLearning™ provided online support to teachers in the form of student worksheets, lesson plans, state content standard information, and other resources, that may facilitate use of simulations during science instruction. Treatment teachers in the VISTA program received a two-year subscription to ExploreLearning™ that allowed them to access online science computer simulations and supplemental materials. In addition, VISTA professional development outlined how to use the ExploreLearning™ website and introduced participants to the types of Gizmos™ available.

During the Gizmos™ module, teachers were acquainted with the ExploreLearning™ website, available Gizmos™, and supporting resources such as student worksheets, vocabulary guides, and lesson plans. During week four of the ESI, participants reflected on their summer teaching experience and planned a new PBL unit to be *implemented* at their school during the upcoming academic year. The elementary teams planned the PBL together, which fostered collaboration, reflection, and the development of curriculum materials relevant to the teachers' context. Across the academic year, instructional coaches spent the equivalent of 21 hours with participants planning, co-teaching, and observing to provide feedback. Finally, participants implemented PBL and inquiry-based science in their classrooms and met with coaches to share and analyze samples of student work.

Secondary Teacher Program (STP). Support for treatment participants in the VISTA STP included a basic science methods course (three graduate credits), an advanced science methods course (three graduate credits), in-class coaching, and web-based resources across two years. During the first year of the STP, emphasis was placed on *learning* NOS and inquiry, planning and *trying* lessons that incorporated these constructs into teaching, and receiving feedback from peers and implementers before further *implementation* of NOS and inquiry lessons. In-class coaches were retired science teachers who helped the new teachers plan, teach, and problem-solve. This support provided teachers a collaborative mentor that helped them in their individualized contexts. These coaches worked with teachers in their classroom the equivalent of 90 hours during the first year and 21 hours during the second year of a teacher's participation in the STP. At the time of this report, the secondary treatment participants had only completed the first year of the professional development intervention.

Secondary and elementary treatment participants also attended the Virginia Association of Science Teachers (VAST) annual conference to learn about science teaching and learning, and to meet for professional development team follow-up sessions. Professional development at the annual conference allowed all participants to share ideas, lesson plans, and receive support from their peers and mentors. This follow-up professional development included instruction for the secondary participants on how to incorporate ExploreLearning™ Gizmos™ into science instruction. This professional development mirrored the elementary professional development during the ESI. Elementary and secondary control participants did not attend VAST, receive ExploreLearning™ accounts or participate in Gizmo™ professional development. However, it is possible that control teachers had ExploreLearning™ accounts through their school district.

Data Collection

Data consisted of observations of computer simulation components of the VISTA professional development, weekly ExploreLearning™ login reports, ExploreLearning™ Use Surveys, follow-up interviews with a subset of teachers who employed simulations in their science instruction, observations of participants' classroom science instruction, and VISTA observation reports. A panel of experts evaluated the ExploreLearning™ Use Survey and interview protocol to ensure internal validity. The variety of data sources helped increase the internal validity of the findings through triangulation. A description of data sources is below.

Professional Development Observations. ExploreLearning™-related VISTA professional development observations captured the implementation and experiences of the teachers during ExploreLearning™-

related VISTA professional development. The ExploreLearning™ professional development lasted two hours during both the ESI and STP. During these observations, evidence of effective professional development elements was of particular interest. These professional development elements included content specificity, participant relevancy, simulation modeling within desired reform-based practices, and opportunities for lesson planning. In addition, participant engagement with peers, implementers, and the ExploreLearning™ website were recorded. ExploreLearning™-related VISTA professional development observations served as a valuable source of data when compared with classroom observations and teacher interview responses about their professional development experience. For example, the implementers used specific instructional strategies during the professional development. These modeled strategies may transfer into the teachers own classroom practices to a greater extent than others.

ExploreLearning™ (EL) weekly login reports. These reports, obtained through ExploreLearning™, provided the dates each week VISTA control and treatment participants logged into their ExploreLearning™ account. These were analyzed to determine teachers' frequency of account use and to determine which teachers should receive the ExploreLearning™ Use Survey, described below. From weekly ExploreLearning™ login reports, 53 participants (47 elementary and 7 secondary) were identified as ExploreLearning™ website users and were asked to complete the ExploreLearning™ Use Survey.

ExploreLearning™ Use Surveys. The 53 ExploreLearning™ website users identified from login reports were asked to complete the ExploreLearning™ Use Survey. Seventeen of the 53 participants (32%) completed the survey. This survey intended to capture more detailed information regarding participants' frequency of Gizmo™ use, methods of instructional incorporation of Gizmos™ into instruction, and satisfaction with ExploreLearning™ resources and professional development (Appendix A).

Interviews. Of those teachers who responded to the ExploreLearning™ Use survey, one elementary and one secondary teacher agreed to be interviewed. These semi-structured follow-up interviews lasted approximately an hour and sought to explicate how the teachers implemented and experienced ExploreLearning™ resources and professional development (Appendix B). These interviews were audiotaped and transcribed for analysis.

Classroom Observations. Each treatment and control participant's academic year science instruction was observed and videotaped during four three-week windows evenly spaced throughout the year. Of those observations (n=440), seven videos (six elementary and one secondary) captured the instructional incorporation of a Gizmo™. Patterns of instructional practices with Gizmos™ were characterized in the seven videos.

VISTA Observation Reports. For each of the four recorded classroom observations, observation reports documented the context of the observed science lesson, including lesson objectives, instructional use of technology, and teachers' inclusion of inquiry, problem-based learning, and nature of science instruction. Additionally, lesson topics and activities were recorded for the three science classes prior to and following the observed class to provide context. As a result, complete observation reports documented a total of 7 consecutive science lessons for each science teacher. All four observation reports for each treatment and control teacher were analyzed for evidence of Gizmo™ use during the lesson. The number of observation reports collected during each target period differed as a result of reasons including teacher illness or exclusion of science instruction during the target time period. A total of 336 elementary (208 treatment, 126 control) and 82 secondary (41 treatment, 41 control) observation reports were analyzed for instructional use of Gizmos™.

Data Analysis

Data from weekly login reports, VISTA observation forms and each participant's ExploreLearning™ Use Survey were analyzed using descriptive statistics. Weekly login reports and VISTA observation reports were analyzed to establish the number of elementary and secondary treatment and control teachers using Gizmos™ during science instruction. The ExploreLearning™ Use Surveys were analyzed to triangulate findings from classroom observations and patterns of ExploreLearning™ website use.

Analytic induction, as described by Bogdan and Biklen (1992) and Erickson (1986), was used to analyze the open-ended survey responses (ExploreLearning™ Use Surveys), observations, and follow-up interviews. All video observations including Gizmos™ were watched, initial field notes recorded and inferences added. The field notes and inferences were then used to compose a descriptive write-up for each video observation. These individual write-ups were then read and re-read to identify initial categories that described science lessons incorporating Gizmos™. Survey responses and interview transcripts were read for confirming or disconfirming evidence of categories and for further category refinement. For example, an initial category of "instructional purpose" was established and later refined to reflect alignment/nonalignment with VISTA professional development when it emerged participants used Gizmos™ for reform-based and traditional instruction. Patterns were identified in the data set with the goal of characterizing the experiences of participants and students with regard to Gizmo™ use. These well-supported patterns of use, which represent a synthesis of the entire data set, are presented in the results section as: frequency of use, classroom implementation, alignment with VISTA goals, and ExploreLearning™ resources and professional development. Supporting evidence for these patterns of implementation is presented in the form of quotations, observation notes, and vignettes.

The relationships between data sources, analysis, and research question are described in Table 1.

Table 1
Overview of Research Questions, Data Sources and Methods of Analysis

	Data Sources					
Research Questions	PD observations	EL Use Surveys	Teacher Interviews	Classroom Observations	Observation reports	Data Analysis
To what extent did participants in a professional development program use ExploreLearning™ Gizmos™ during science instruction?					X	Descriptive statistics
How did participants use simulations in their classroom during science instruction?		X	X	X		Descriptive statistics and analytic induction
How did participants experience computer simulation professional development? What did they identify as strengths/challenges?	X		X			Analytic induction

Results

VISTA participants differed in their use and experience of Gizmos™ during classroom instruction. These differences included variations in extent of simulation use, frequency of Gizmo™ use, methods of classroom implementation, provision of student instructional support, and experiences during

ExploreLearning™-related professional development. The following sections describe evidence for each of these categories and assertions.

Extent of Simulation Use

Weekly ExploreLearning™ login reports indicated that 47 of the 52 elementary treatment participants (90.4%) and 7 of the 11 secondary treatment participants (63.6%) used their ExploreLearning™ accounts following Gizmo™ professional development. In comparison, only one of the 36 elementary control participants (2.8%) and 1 of the 11 secondary control participants (9.1%) logged into a personal ExploreLearning™ account during the acadmic year. This indicates ExploreLearning™ professional development might have positively influenced participants to use the ExploreLearning™ website. However, conclusions regarding the number of teachers using Gizmos™ during science instruction cannot be drawn from this data since teachers may have logged into their ExploreLearning™ accounts to view available Gizmos™, look at recommendations or any of a number of non-instructional reasons.

VISTA observation reports documented ExploreLearning™ Gizmo™ use by 37 elementary treatment teachers (71.2%). Analysis of these forms demonstrated 2 elementary control teachers (5.6%) used ExploreLearning™ Gizmos™ during science instruction (Table 2). The large difference in the percent of elementary and control teachers using Gizmos™ during science instruction suggests that Gizmo™ professional development may have provided an instructional tool to elementary treatment teachers incorporated into science instruction.

The observed difference in Gizmo™ use between elementary treatment and control teachers was not apparent for secondary participants (Table 2). Three of the 11 secondary treatment participants used Gizmos™ for science instruction (27.2%). Of the 11 secondary control participants, 2 used Gizmos™ during instruction. Therefore, the difference in percent of treatment and control teachers using Gizmos™ was small. This indicates Gizmo™ professional development did not influence changes in secondary teacher's classroom practices to the same extent as elementary teachers.

Table 2
Use of Gizmos™ (VISTA Observation Reports)

	Number of teachers used Gizmos™ (%)
Elementary treatment (n=52)	37 (71.2%)
Elementary control (n=36)	2 (5.6%)
Secondary treatment (n=11)	3 (27.2%)
Secondary control (n=11)	2 (18.8%)

Frequency of ExploreLearning™ Gizmo™ Use

Of the 47 elementary and 7 secondary treatment participants who received the ExploreLearning™ Use Survey, 17 teachers (32%) responded; 13 elementary teachers and 4 secondary teachers. Half of respondents indicated they used Gizmos™ on a monthly basis (Table 3). ExploreLearning™ account login data supported this self-report data, revealing that 21 of the 50 participants (42%) logged into their accounts on a monthly or bi-monthly basis. There were no obvious differences in the frequency of Gizmo™ use between elementary and secondary treatment participants.

Table 3.
Frequency of Gizmo™ Use

	Several times/wk	Once/wk	Twice/ Month	Monthly	Once/Yr	Never
# of teachers (%)	0 (0%)	2 (11.8%)	5 (29.4%)	9 (52.9%)	1 (5.9%)	0 (0%)

Note: Percentages are based upon the number of survey respondents.

VISTA observation reports and ExploreLearning™ login data indicated that elementary treatment participants included Gizmos™ in instruction most often during fall 2011 while secondary treatment participants more frequently included them in instruction during December 2011 and January 2012 (Table 4). This trend suggests treatment participants used Gizmos™ most frequently after being initially exposed in professional development; however, the level of use did not appear to be sustained toward the end of the year, especially for elementary treatment teachers. Analysis of control VISTA observation reports indicated more consistent Gizmo™ use by elementary control teachers compared with elementary treatment teachers. For secondary teachers, there was a decline in documented use by both control and treatment participants during the last observation window (Table 4).

Table 4
Treatment and Control Elementary and Secondary Participant Gizmo™ Use (VISTA Observation Reports)

Observation Window	Number (Percent) Indicating Simulation Use			
	Elementary		Secondary	
	Control	Treatment	Control	Treatment
1 (Oct 12-Nov 2, 2011)	2 (5.7%)	9 (19.2%)	0 (0%)	0 (0%)
2 (Nov 28-Dec 19, 2011)	2 (5.9%)	10 (20%)	2 (18%)	1 (9.1%)
3 (Jan 25-Feb 15, 2012)	1 (4%)	2 (5.3%)	2 (18.1%)	2 (22.2%)
4 (Mar 14-Apr 4, 2012)	1 (3.1%)	3 (7.7%)	0 (0%)	1 (9.1%)
Total	6 (4.8%)	24 (13.8%)	7 (17.1%)	4 (9.8%)

Overall, treatment participants reported using Gizmos™ on a monthly or bi-monthly basis. VISTA observation reports indicated that more treatment teachers used ExploreLearning™ Gizmos™ for science instruction than control teachers. The influence of Gizmo™ professional development may have been greater for elementary treatment teachers than secondary treatment teachers. A much larger percent of elementary treatment teachers (71.2%) used Gizmos™ during science instruction compared with 5.6% elementary control participants. This pattern was not as obvious for secondary teachers. Of the treatment secondary teachers, 27.2% of them used Gizmos™ during science instruction compared with 18.8% of control secondary participants. These trends indicate that receiving Gizmo™ professional development and having access to Explore Learning™ Gizmos™ greatly increased the percent of elementary teachers that incorporated Gizmos™ into instruction, but had a much smaller influence on secondary teachers.

Classroom Implementation

This section describes the variety of science content participants addressed through Gizmos™, the format of instruction (small group, individual, whole class) participants employed when using Gizmos™ in their science instruction, and participants' instructional purposes for Gizmo™ use (content knowledge, exploration/discovery, skill development).

Content Addressed Through Gizmos™. Analysis of VISTA observation forms and ExploreLearning™ Use Survey responses indicated elementary and secondary VISTA treatment participants utilized Gizmos™ to teach a wide variety of science topics (Table 5). Elementary participants used simulations to teach about food chains, forces, states of matter, ecosystems, plant morphology, atoms and temperature, circuits, seasons, Pangaea, sound, rocks, earthquakes, inertia, and energy. Secondary participants used simulations to teach students about ocean currents, homeostasis, osmosis, water pollution, water quality, solar system, seasons, minerals, pH, inclined planes, and the rock cycle.

Based upon references to state standards on their observation forms, VISTA participants aligned their science instruction with the *Virginia's Standards of Learning* (SOLs). The used simulations are reflective of SOL topics, especially for elementary teachers. Virginia SOLs for students in grades 4-6 emphasize energy, matter, the solar system, plants, adaptations, weather, and basic chemistry. In grades 7-12 the standards focus on life, Earth, or physical science content.

Table 5

Science and Math Concepts Taught with Simulations (number responding in parentheses, when n>1)

Subject area	Concepts taught using Gizmos™
Math/Measuring	area and perimeter, volume, place value, weight and mass, graphing skills, triple beam balance
Earth Science	rock cycle, hurricanes (3), solar system, seasons (2), eclipses, coastal winds (2), water pollution, humidity, Pangaea, earthquakes, moon phases, tides, weather maps, water cycle, relative humidity, minerals, conduction/convection
Chemistry	ionic bonds, covalent bonds, stoichiometry, limiting reactants,
Physics	electricity (3), circuits (3), energy conversions, energy (2), friction, motion, potential energy, household energy
Life Science	Food chains/food webs (3), half-life, natural selection (3), disease spread (2), adaptations, plant growth (3), greenhouse effect, pond ecosystems, evolution, hearing, ecosystems (2), forest ecosystems (2), cell division, osmosis/diffusion, cell structure, inheritance, photosynthesis, soil, biomes

Instructional Format and Gizmo™ Use. Observational data indicated that participants used Gizmos™ in a variety of group composition contexts (e.g. centers, pairs, one on one, whole groups). Based on ExploreLearning™ Use Survey responses (Table 5) and observational data, elementary and secondary participants often used Gizmos™ within a cooperative learning context such as small group or pair instructional settings. For example, Colby used a sound Gizmo™ within a context of learning centers where students spent 6 minutes at a center to answer a question and then moved on. While students were at the simulation center they talked to each other about what they were observing (Observation 3).

Table 6

Instructional Format of Gizmo™ Implementation

	Percent of the Time				
Instructional format	0-20%	20-40%	40-60%	60-80%	80-100%
Whole class	7	4	2	1	1
Small group/pairs	4	6	5	1	1
Individual	5	1	4	1	1

Note: Table values indicate number of teachers

Students also worked collaboratively to learn about water pollutants in Norma's class. The students worked at individual computers but were paired with a student of unequal skill to provide a peer tutoring opportunity. Even though students were working at separate computers Norma instructed them to work at the same pace. This setting allowed students to discuss their predictions and answers about the effects of excess pollutants on aquatic organisms. For example, one boy in the class raised his hand to ask a question of the teacher. Then he talked to the student next to him and put his hand down when his peer answered his question. At another point, a student asked her partner about a certain chemical. They leaned toward each other and discussed the material. These examples provide evidence that simulations can be used successfully to support students' collaboration while learning science content (Observation 3).

Participant teachers also used whole-class instruction during some science lessons that incorporated Gizmos™. Although participants commonly used whole group instruction to introduce students to a Gizmo™, there was also evidence that participants employed whole class instruction to conclude instructional activities that incorporated Gizmos™. For example, Norma explained in her interview that she displayed Gizmos™ on the board the day after students used them to discuss what they should have learned in their peer tutoring pairs (Interview).

Matt reported using Gizmos™ for small group instruction in centers as well as one-on-one tutoring. Matt also reported having the students use Gizmos™ "on their own or with a partner" (Interview). The wide range of group composition across teachers indicates different Gizmos™ may lend themselves to a range of instructional uses or are flexible educational tools that allow for variety in student grouping.

Instructional Support. Based on classroom observations, the amount of instructional support provided by the teacher prior to and during Gizmos™ use varied which influenced students' experiences with simulation. The three most common ways participants provided support were: (1) whole group instruction prior to group or individual use, (2) teacher circulating and answering students' questions or guiding students to make observations and inferences, and (3) using worksheets to provide instruction and focus investigations.

The following vignette demonstrates how Bert used whole class instruction to focus elementary students' attention on proper Gizmo™ use.

> *After displaying a temperature Gizmo™ on the screen in front of the class, the teacher tells the students that they are going to use the microview tool within the simulation, which is then shown on the projector screen. As the teacher turns the microview onto a cooling beaker of water, the class is asked, "What changed at zero degrees?" Students observe the change and respond that, "the molecules are moving slower." The teacher tells the class, "Please don't try this right now because you will miss out on the purpose of the whole experiment." The teacher points out different aspects of the screen interface including how to use the microview, the location of the thermometer, and how to manipulate the temperature before releasing students to work on the Gizmo™ individually and answer questions on a worksheet (Bert, Observation 1)*

The above vignette demonstrates how modeling simulation use may facilitate independent student work to achieve instructional goals. The participant took the time to show the class how to use the simulation tools and focused student attention on specific content important to the lesson. By focusing student attention on molecular movement the participant guided them to make the sorts of observations and inferences important for them to complete the activity and worksheet on their own. The ExploreLearning™ worksheet served as an additional form of support by guiding students through a series of questions and focusing their attention on relevant content and simulation elements.

In observed instances where the teacher did not provide substantive support to students in the form of directions or structured guidance during Gizmo™ use, students experienced difficulties navigating simulations and accomplishing instructional goals. The following vignette demonstrates some of the difficulties students experienced when a teacher did not provide instructional support.

> *Students in this class were exploring what happens to water molecules when they are cooled and heated. The students were given the instructions to share computers with a classmate and use the simulation. No other verbal or written instructions were given. One student gets out of his seat and looks at his neighbor's computer screen for guidance. A male student tells his partner, "I'm confused. You think we should turn it into ice?" Another student says, "What do we do?" With only 5 minutes remaining in the class, no students have written anything down. The teacher never stops circulating between groups and helps students get logged in and onto the simulation website. A student sighs, "This is never going to work." One female student walks over to a male classmate who says, "I think you have to do that first." She goes back to her computer to follow his instructions but then returns to his desk. When she gets there the teacher says, "One more minute left." The student slumps her shoulders and turns around to return to her own computer. (Kilby, Observation 2)*

In this instance, students were unclear about instructions which affected their ability to use the simulation for learning. The teacher spent the majority of the time helping students log onto the ExploreLearning™ website rather than helping them engage with the curriculum. This shows how important it is for teachers to make sure students are familiar with the technology and can access it ahead of time. The heat Gizmo™ used during Kilby's observation is the same as in the previous vignette and demonstrates how different students' experiences with simulations can be when they are not introduced to the screen interface and are not given clear learning objectives. During Kilby's observation the students were interested in the simulation, but without explicit directions, they did not know what to do with it. This confusion and frustration is exemplified by the student who slumped her shoulders and by the comments, "What do we do?" and "This is never going to work." While some students responded to these situations in a positive manner by developing their own questions others were never able to completely engage with the simulation and the potential of the simulation was not fully realized in the class.

Like Bert, many VISTA participants felt whole-class and individualized support was needed to facilitate students' successful use of Gizmos™. For example, Norma explained the need for student support and direction in using the simulations:

> …my general kids and the special ed kids just have the hardest time following the directions even though it tells you very plain, 'Click this,' 'Reset this,' 'Check this…' I'm just walking around asking questions, looking at what they're doing…and I'll ask them, 'Why is it this way?'…Some of them I'll try to get further in and others try to back up and steer them the right way." (Norma, Interview).

Without guidance, students had difficulty focusing on specific instructions or identifying on their own which instructions to follow. Norma identifies that students have a wide variety of questions and need different levels of help during simulation use. The actions of the teacher during class were critical as she interacted with individual students to help them use the Gizmo™ and think analytically about collected data.

In many instances teachers used worksheets to provide instructions and prompts for data analysis or reflection. These worksheets often helped students focus on the content, use the simulation efficiently, and accomplish instructional goals. Classroom observations, VISTA observation forms and interview data indicated Norma, Bert, and Colby used ExploreLearning™ worksheets and teacher guides to support science instruction with Gizmos™. In these cases, the worksheets were ExploreLearning™ products that participants printed from the website. For example Riley noted,

> …I took the packet that's online. It's Word™ so you can go in and take things out, change them around…I tried to limit it to…just one sheet and had maybe three or four things that they [students] were to focus on to accomplish (Interview).

Both interviewed participants mentioned the value of the ExploreLearning™ worksheets. This provides evidence for the importance of the ExploreLearning™ worksheets as an instructional tool to target specific instructional objectives and facilitate students' successful use of the Gizmos™.

Although worksheets generally seemed to facilitate student use of simulations, the experience of one teacher demonstrates how difficult it can be to support students during simulation use using commercially produced curriculum materials. In Norma's third observation, she used a water pollution Gizmo™ and accompanying ExploreLearning™ student worksheets. At the start of class, Norma defined the terms "consequence" and "excess" prior to students using the water pollution Gizmo™. Even though these words were defined to the whole class, many students asked what these words meant while they were working. Students asked vocabulary-related questions on multiple occasions during the class. These vocabulary-related difficulties resulted in some students' inability to answer worksheet questions or successfully achieve the teachers' instructional goals for the lesson. While this lesson included many elements of instructional support, including whole-class simulation modeling, individualized questioning by the teacher, and worksheet use to guide students, the teacher did not seem to realize the extent of the obstacles created by the vocabulary on the worksheet. This example reflects the challenges teachers face when using teaching materials that do not reflect students' prior knowledge.

In summary, effective verbal and written instructions, simulation modeling, and whole-class and individual support helped students use simulations successfully. Without these supports in place, students sometimes expressed frustration and had difficulty engaging with learning goals.

Instructional Purpose of Simulation Use. When asked to rate the frequency of Gizmo™ use for different instructional purposes participants reported using Gizmos™ to accomplish varied instructional goals. However, data indicated Gizmos™ were not consistently used for any single purpose (Table 7). The average rating was highest for content/concept-focused instruction (M=3.14, SD=1.2) and lowest for problem-based learning instruction (M = 2.53, SD=1.3).

Table 7
Instructional Purpose of Gizmo™ Use (n = 17)

Type of instruction	Likert Rating Mean (SD)
Content/concepts	3.14 (1.10)
Inquiry-based	2.81 (1.05)
Nature of science	2.71 (1.07)
Skill-focused	2.57 (1.34)
Problem-based	2.53 (1.13)

Note: Percentages in table are based upon the number of survey respondents. Likert rating: 1 (never), 5 (very frequently)

Interview and observational data also indicated that participants used Gizmos™ to accomplish varied instructional goals including supporting students' science content acquisition and skill development.

Content understanding. Several participants used Gizmos™ to facilitate students' science content understanding. For example, Bert provided students with learning objectives before the students used a s Gizmo™. The content goals included helping "students be able to describe and compare the molecular properties of solids, liquids, and gases" and to be able to "show how heat affects molecular motion" (Observation 1). During this lesson, students were asked questions while they used the simulation that were consistent with these stated objectives. For example, Bert asked one student, "What do you notice is different about the water at zero and one hundred degrees? What is happening to the speed of the molecules?" This participant effectively used the simulation and questioning to guide students to acquire specific science content.

Similarly, Kilby used a Gizmo™in an observed lesson to demonstrate to the class how changing the temperature affected water molecule movement. As Kilby manipulated the simulation on the projector in front of the whole class, questioning focused students on the target content. For example, Kilby asked, “How many atoms are in each of those molecules? And what kind of atoms are they? What happens when we chill it? What happens to the molecules?” The similarities between Bert and Kilby’s observations indicate using simulations can provide teachers the opportunity to interact either with individual students or with the whole class and questioning strategies can help the students build content understanding.

Skill development. Gizmos™ were used to promote student engagement with scientific inquiry skills during some science lessons. Matt used a Pangaea Gizmo™ to help students practice the skills of making observations and inferences. Matt noted, “They can click on it and see where fossils match and then they can look another place. I think it’s on the rocks that match” (Interview). Matt described that as a result of using the simulation, students would conclude that in places where rocks and fossils match the continents were once joined. This required the skills of making observations, inferences, and conclusions.

Norma also used Gizmos™ for scientific skill acquisition during at least two lessons. In one lesson, the instructional objective was for students “to understand pollution comes from a variety of different sources” (VISTA Observation Form 3). In addition to learning the content, Norma instructed students to make predictions about the effects of a pollutant and then write down the correct answer next to it. At one point Norma noticed that one student did not do this and used the opportunity to remind the class of the instructions. This indicated it was important to Norma for students to take the time to use their prior knowledge to make predictions. Norma also explained an instance where a graphing Gizmo™ was particularly valuable to her 6th graders:

> …the graphing one because my students- if it’s not a pie chart they have no clue. So to be able to go in and build the graph... To be able to make the data and then build the graph and interpret what that says… That was a huge one (Interview).

In this excerpt Norma mentioned three separate skills the students worked on while using a Gizmo™: data collection, data analysis and data representation in the form of graphs. This data indicates that Gizmos™ can be used to help students develop a wide variety of skills including data collection, data analysis, data representation and prediction.

Alignment with VISTA Goals

Many treatment participants used simulations within a PBL unit, an inquiry lesson or to explicitly teach NOS tenets. These instructional purposes were consistent with overall VISTA professional development goals. However, there were instances of participant Gizmo™ use that was inconsistent with VISTA professional development. For example, Gizmos™ were used within lessons that provided implicit, or incorrect NOS instruction and unstructured exploration/discovery (Table 8).

Table 8
Representative Examples of Instructional Practices with Gizmos™

Instructional Practices	**Example**
Aligned with VISTA professional development	
Problem-based Learning (Bert, Observation 1)	Before starting a lesson the teacher reminded the class of the overarching problem by asking, “Why do you think the pipes burst in Minnesota in the winter?” The teacher then used a simulation to show students how water molecules change at different temperatures.

Inquiry (Bert, Observation 1)	The teacher asked the class, "So when it froze what happened to the water inside?" A student answered, "it expanded and pushed out." The teacher said, "We are going to test that hypothesis."
Explicit Nature of Science (Norma, Observation 3)	The teacher emphasized the collaborative and social nature of science when she told the students they will be working in pairs because "scientists tend to talk to each other."
Not aligned with VISTA professional development	
Unstructured Exploration (Kilby, Observation 2)	Students are instructed, "I want you to take turns moving the magnifying glass and looking." Students are not given any further guidance about what to look for.
Incorrect NOS instruction (Colby, Observation 3)	After a lesson using a simulation, the teacher asked students for nature of science tenets that had been practiced or observed. A student told the teacher that science is unbiased and the teacher nodded and said that is correct.

There were several instances in which participants used simulations to support problem-based learning, inquiry, or explicit NOS instruction in ways that were consistent with the VISTA professional development. At least two participants used simulations within a problem-based learning unit to reinforce the concepts in the larger problem. For example, Matt described his problem-based unit and simulation use as follows:

> … had to do with ecosystems and part of the idea was that in an ecosystem when one thing changes it affects something else. We have school gardens that the kids had to, were told that the county was going to put in a new parking lot right where our garden was...That was the problem and then part of the answer to that problem was kind of, how could we sell them [the county] on keeping the garden there? So part of that was to understand the ecosystem that was outside of their door and what the parts were. So…the Gizmo™ was getting at ideas, that all things are interrelated and that you touch or affect one thing and it can affect others. So I used a Gizmo™ that's actually a high school Gizmo™. Something about aliens. The aliens… you can change their light, their water and all kinds of things and it affects their population…the Gizmo™ was getting at ideas, that all things are interrelated and that you touch or affect one thing and it can affect others (Interview).

Several participants demonstrated use of a simulation aligned with the VISTA definition of inquiry. For example, Norma described how her students used a simulation to answer a research question and investigate the relationship between environmental variables and plant growth. During Norma's interview, she provided some examples of student questions: "Well, what can I change? Okay, on paper I can say I am going to measure the growth of the pea pod but what really happens to it? Does water affect it?" (Interview). These questions demonstrate Norma's intent to facilitate students' answering a research question through data collection and analysis, which is congruent with the VISTA definition of inquiry learning.

In at least one instance, a VISTA participant teacher used a simulation to support explicit NOS instruction. Students in this lesson used a Gizmo™to find written information about different pollutants.

In this lesson, the participant paired students up because "scientists tend to talk to each other…" The participant explicitly pointed out the collaborative and social nature of science to the students (Norma, Observation 3). This and other observations, in addition to interview excerpts, support the conclusion that some of the VISTA treatment teachers used Gizmos™ to support reform-based practices promoted by VISTA professional development.

While Gizmo™ use often reflected reform-based teaching practices treatment participants learned in VISTA, there were also examples of use that did not align with the goals of the VISTA professional development. For example, two of the participant teachers repeatedly used the words "discovery" and "exploration" in their interviews or classroom observations to describe simulation use. In both situations, students were told to explore the variables within a simulation; however, there was no underlying research question or stated objective to the simulation use. Therefore, these examples could not be included as examples of inquiry instruction and do not reflect constructs learned in VISTA professional development.

Several participants made an effort to include NOS instruction in instructional use of Gizmos™. The following vignette demonstrates how use of a Gizmo™ in the context of centers was intended to remind students about several aspects of the nature of science. However, students did not demonstrate a true understanding of them and the teacher misrepresents one tenet.

> *After students finish going through centers, one of which is the a sound simulation, Colby asks the students, "Tell me how you were able to see the nature of science, or understand the nature of science in your lab today." One student raises his hand and says, "One main thing is that we were able to prove, with the experiments that we have done…" The teacher rephrases the student's statement by saying, "The nature of science demands evidence" but did not actually correct the student's use of the word "prove." Another student says, "It was social because we were all talking." A student mentions that they developed questions from what they did. Colby elaborates and says, "It is durable but things can change – like the world isn't really flat, right?" Another student raises his hand and says, "It's definitely not biased." Colby says "Ahh" and nods her head up and down while she smiles. She prompts the student further to elaborate by asking "Why?" The student responds, "There's no obvious opinion - it's all fact." The participant responds by saying "very good." (Colby, Observation 3)*

From students' quick and confident responses, it is apparent they were very familiar with nature of science tenets and had been asked for them before. However, even though the students could verbally provide some of the tenets, several of their answers were problematic and require further elaboration/qualification. For example, one student talked about "proving" ideas, which could indicate an inappropriate absolute view of scientific knowledge. Another student claimed science is not biased, also indicating this student views science as absolute and unchangeable. In the first discussed tenet the participant tried to rephrase the student's comment, but did not correct him. In the second, the teacher agreed with the student. These teacher responses may lead to incorrect student views about the nature of science.

Several participants also used Gizmos™ to implicitly, rather than explicitly, teach some of the nature of science tenets. For example, after using a Gizmo™ on temperature, Bert told the students, "Maybe we can make a law based upon what we saw in our experiments." The class was then asked, "The higher the temperature in the water what happens to the molecules?" Some students said, "They go faster." The participant followed up with another question, "And when it boils what happens?" Students answered, "It evaporates into a form of gas" (Bert, Observation 1). While the participant demonstrated knowledge that laws illustrate relationships between two variables, the participant did not explicitly point out to students that laws and theories serve different purposes in science. This was an instance in which a participant missed an obvious opportunity to clarify an important nature of science tenet.

Simulation Professional Development

ExploreLearning™ professional development observations suggested teachers became familiar with the ExploreLearning™ website and features that would facilitate instructional use of Gizmos™. The majority of information participants needed to become familiar with ExploreLearning™ website features was provided in a QuickStart Guide. During the ExploreLearning™ professional development, participants learned how to use the ExploreLearning™ website, examples of Gizmos™, and associated worksheets. The following vignette describes the Gizmo™-related professional development that occurred for secondary treatment participants and is reflective of the professional development content for elementary participants as well.

> *Lisa, an employee of ExploreLearning™ who provides Gizmo™-related professional development, instructed VISTA participants how to use website features that would facilitate classroom use of Gizmos™. For example, she explained and walked teachers through the process of creating classroom tabs and managing Gizmos™ for different classes. Lisa explained Gizmos™ can be used to teach science concepts before students use hands on materials, can help students internalize learning after doing a lab by encouraging reflection, or as a warm-up before science content is addressed in a lecture. To help participants get familiar with Gizmos™ they were instructed to "play around." Not all teachers had their own computer and had to share with peers. Many of the participants engaged with the ExploreLearning™ website by changing variables within a Gizmo™ or trying to set up classroom tabs. A few participants looked at their email and were not on the ExploreLearning™ website. After ten minutes, Lisa asked for everyone's attention and demonstrated the process of taking a screen shot of a Gizmo™. Lisa explained how to import a screen shot into a Word™ document and how to export collected data into Excel. Lisa encouraged the participant teachers to utilize the screen shot feature to help create exams or to embed images in PowerPoint™ presentations. Finally, Lisa opened one of the student worksheets that accompanied a Gizmo™ and pointed out how teachers can modify the Word™ documents provided on the website. (Observation).*

It was clear that VISTA participants became acquainted with many ExploreLearning™ website features. However, the Gizmo™-related professional development did not mention the importance of providing instructional support during student Gizmo™ use, provide teachers the opportunity to plan a lesson with a Gizmo™ or model how to use a Gizmo™ within an inquiry, NOS, or PBL lesson. Although the teachers were given the opportunity to "play around" and might have looked at content-relevant Gizmos™, this was not explicitly addressed and not all teachers were engaged. Furthermore, a Gizmo™ was not modeled within desired reform-based instruction. Therefore, the professional development did not incorporate effective practices that might lead to the most teachers using simulations to support reform-based teaching. The computer simulations were not grounded in relevant content or meaningful context. The ExploreLearning™ professional development primarily helped teachers understand technical aspects of the website rather than situating the experience in a meaningful and collaborative environment that would facilitate instructional simulation use within reform-based teaching practices.

VISTA treatment participants overall indicated satisfaction with Gizmo™-related professional development. Fifteen of the 17 survey respondents indicated the Gizmo™-related professional development was effective or very effective. While the majority of survey respondents were satisfied with the Gizmo™-related professional development, one participant made recommendations for professional development that may encourage more frequent and sustained use of simulation. The participant indicated more simulations would have been used in instruction if professional development opportunities provided planning time:

> I think it's just an element of time. I mean we had a chance to kind of look at it and think about it some last summer and I was used to the curriculum and what we were teaching, but we were also

> like teaching. So, you know I tried to incorporate it some. I wish I could incorporate it more … So I think the disadvantages… it's just having the time as a teacher to be able to integrate it well into our curriculum… So if there was an opportunity where all the teachers actually did some kind of exemplary lesson… (Matt, Interview).

The above quote exemplified the planning constraints teachers often face and the desire to have more time to plan how to integrate new instructional tools into lessons. The teacher intuitively identified a desirable professional development element that was absent in his experience. Matt indicates if relevant lesson planning time had been incorporated into the Gizmo™ professional development he may have incorporated them into his own instruction to a greater extent.

The same participant recommended modeling simulation use in a structured format to encourage use:

> …one thing that would be good… I think it really helps when you work with teachers if you model things. …. My advice to have some sort of a structured experienced for the teachers … (Matt, Interview).

Overall, the VISTA professional development model included opportunities to learn, try, and implement new pedagogy such as inquiry teaching; however, this was not extended to the Gizmo™-related professional development. Contextualizing the simulations within an inquiry or PBL context might have helped teachers understand the relevancy of the simulations and encourage transfer to their classroom instruction. In addition, the professional development did not situate the simulations within relevant content. As a result, participants may not have used simulations as often as they otherwise would and may not have known how to use the technology to support reform-based teaching practices learned in VISTA. However, the examples of participant Gizmo™ use to support reform-based science instruction indicates that some teachers were able to use Gizmos™ in their context for reform-based teaching and that improvements in future professional development models may further facilitate desirable instructional Gizmo™ use.

Discussion

Extent of Simulation Use

The results of this study indicated 37 elementary treatment teachers (71.2%) and 2 elementary control teachers (5.6%) used ExploreLearning™ Gizmos™ during science instruction. Only 3 of the 11 secondary treatment participants used Gizmos™ for science instruction (27.2%). Of the 11 secondary control participants, 2 used Gizmos™ during instruction. Following Gizmo™ PD, participants included these simulations into science instruction to teach life, physical and earth science lessons. The Gizmo™ professional development led to initial changes in teacher classroom practices; however, elementary treatment teacher simulation use declined as the academic year progressed. Teachers used computer simulations within a variety of student groupings and provided different types and amounts of instructional support.

Fewer secondary and elementary treatment participants used ExploreLearning™ Gizmos™ than expected. Furthermore, the decline in elementary use during the academic year was unexpected. ExploreLearning™ Gizmos™ are designed with an easy to use screen interface and supporting instructional materials that promote inquiry learning (www.explorelearning.com). We thought these features would lead to a greater number of teachers using the ExploreLearning™ Gizmos™ than was documented. In addition, the ExploreLearning website provides state testing standard correlates for each Gizmo™. Therefore, teachers can potentially use Gizmos™ to support inquiry learning and state testing mandates that are often viewed as opposing goals. Many other types of simulations are more complicated and do not have accompanying instructional materials. Given the lower than expected treatment teacher Gizmo™ use, the potential for instructional incorporation of more complicated computer simulations may be unlikely. The extent and patterns of treatment teacher's Gizmo™ use has potential implications for computer simulation design and /or computer simulation professional development. Subsequent research will examine contextual factors that also may contribute to instructional ExploreLearning™ Gizmos™ use.

The apparent difference of the influence of the Gizmo™-related professional development on the number of elementary and secondary teachers using simulations is an interesting finding. The pattern may indicate secondary teachers have greater exposure to computer simulations in their schools or there are more content and age relevant simulations available to secondary teachers. For example, PhETs (http://phet.colorado.edu/en/simulations/category/new) are a popular free simulation that generally address secondary science content. This possible explanation needs to be explored to provide useful computer simulation professional development to elementary and secondary teachers in the future. There are several other possible explanations for the disparity in elementary and secondary treatment Gizmo™ use including VISTA professional development and participant characteristics. These are elaborated on in the following paragraphs.

VISTA elementary teachers participate in the professional development as school teams of 2-5 individuals. These teams may foster a professional learning community and technology use (Gerard, Varma, Corliss, & Linn, 2011). VISTA secondary teachers do not participate as school teams. Although VISTA encourages a broader professional learning community via blogging and Sharepoint™, this broader community may not be able to address the immediate and local struggles teachers have when trying to incorporate simulations into instruction. For example, Gerard, Varma, Corliss, & Linn (2011) found that in the first year following technology professional development teachers often experience difficulties using the technology and without help, fail to use it. Elementary teachers may have been able to rely on school team members to troubleshoot technology issues and permit simulation incorporation into science lessons.

A second difference between the elementary and secondary treatment conditions is the timing of the ExploreLearning™ professional development. The professional development came prior to the start of the academic year for elementary participants, but did not occur not until the third month of the academic school year for secondary participants. The earlier timing during the ESI may have facilitated greater opportunities for elementary teachers to individually and collaboratively plan how to use simulations for content relevant lessons that supported reform–based science lessons. During the ESI, elementary teachers learned how to use computer simulations prior to implementing their PBL during camp in the second and third weeks of the Institute. This permitted some of the elementary teams to create and incorporate content-relevant, reform-based simulation lessons into the camp. These planning and implementation opportunities were absent for the secondary teachers. This corroborates the findings of previous research that indicates technology professional development that provides time for lesson planning and opportunities for implementation results in effective and sustained technology integration (Pope, Jayroe, Franz, & Hamil, 2008; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). The current study extends the findings of these previous two studies by comparing two PD conditions that varied on these key characteristics.

Situated learning theory contends a collaborative and social learning environment greatly improves the ability of teachers to transfer new knowledge and skills to their classrooms (Lave & Wenger, 1991). Furthermore, a relevant context is also essential for transfer. Both of these conditions were met to a greater extent in the ESI than the STP. Elementary teachers participate in teams that can support each other in their schools and also had the opportunity to plan and implement content specific and relevant lessons during the ESI. The opportunity to plan and implement simulations during the camp, receive feedback from implementers, and plan a new PBL during the last week of the ESI that may have incorporated simulations essentially resulted in a Gizmo-related professional development experience that was longer in duration than what the STP participants received. These professional development elements have already been shown to help teachers adopt new classroom practices (Garet et al., 2001; Gerard et al., 2011; Supovitz & Turner, 2000) and may have increased the elementary teachers' comfort with simulations and ability to use them to a greater extent than the secondary VISTA participants.

Elementary and secondary VISTA participants vary greatly in their prior teaching experience. This variable may have influenced the extent of computer simulation use by secondary teachers. The average teaching experience of elementary participants was 9.8 years while all secondary participants were either 1st or 2nd year teachers. As a result, elementary teachers may have had more experience or comfort with the curriculum. Increased elementary teacher familiarity with the science curriculum may have made them more willing and able to integrate technology into science instruction. Furthermore, research indicates that teachers may face implementation barriers when first trying to implement reform-based pedagogy (Wee, Shepardson, Fast, & Harbor, 2007; VanHook, Huziak-Clark, Nurnberger-Haag, & Ballone-Duran, 2009; Wheeler, Bell, & Whitworth, 2013), or technology (Russell & Bradley, 1997) into the classroom. As a result of these combined challenges, it may be unrealistic to expect novice teachers to incorporate technology to support unfamiliar reform-based pedagogy immediately following professional development. This may have implications for the implementation of professional development with teachers that vary in experience. Perhaps professional development for novice teachers needs to have unique characteristic, such as increased modeling, time for content-specific lesson planning, and increased duration for it to result in classroom changes. Luft, Hewson & Ntemngw (2013) have identified the necessity for professional development research that examines teachers at different points in their career and the results of this study corroborate this need.

Frequency of simulation use indicated elementary teachers used ExploreLearning™ Gizmos™ less often toward the end of the academic year. This may reflect demands placed on teachers toward the end of the school year that prohibit simulation use or a failure of the PD to result in long-term changes. Studies that are longer in duration may support or refute this hypothesis and are needed to determine the extent teachers continue to use technology tools after professional development. In addition, research should consider factors that may affect instructional use of computer simulations at different points in the academic year.

Simulation Use and Reform-Based Teaching

The VISTA professional development encourages technology integration to support reform-based teaching. Computer simulations are viewed as an instructional tool that can facilitate implementation of PBL, NOS, and inquiry. ExploreLearning™ Gizmos™ are specifically designed to allow students to engage in inquiry by manipulating variables, collecting data, testing hypotheses, and making conclusions. The VISTA PD introduces participants to computer simulations after reform-based constructs to permit computer simulation use that supports reform-based pedagogy. Therefore, it was surprising that teachers did not primarily report using simulations for this purpose, but rather used simulations most often for direct instruction of science content and concepts. This contradicts the findings of Bell et al. (2013) who documented pre-service teachers' regular incorporation of instructional technology to support reform-based practices during student teaching.

The differences in the findings between the two studies may be explained by differences in the study participants and context. First, Bell and colleagues (2013) reported participants were pre-service teachers that did not have prior teaching experience. It may be easier for pre-service teachers to incorporate technology to support newly learned teaching practices than to accomplish teaching practice changes among in-service teachers. Furthermore, simulations were modeled in each of the content areas to support reform-based pedagogy. While the overall Learn, Try, Implement model of VISTA was implemented for inquiry, NOS and PBL, such integration was not observed during the computer simulation professional development. Elementary teachers may have chosen to plan and implement lessons with simulations during the ESI, but this was not required. An opportunity for secondary teachers to plan and try a lesson incorporating simulations was absent. Finally, in Bell et al., (2013), simulations were modeled within relevant content and reform-based practices that pre-service teachers could easily transfer into their student teaching classrooms. An authentic and relevant context is an integral component of a situated learning environment. The computer simulation professional development in this study did not situate or model simulations within a diverse range of content areas or in reform-based teaching strategies which may explain characteristics of use. Finally, it is possible that given more time, more teachers would have reported using simulations to support reform-based teaching strategies. Schnittka & Bell (2009) found that pre-service teachers increasingly used technology to support inquiry instruction as more time passed. This indicates that there may be a learning curve, and immediate teacher use of technology to support reform-based instruction may not occur, especially among novice teachers. This would be consistent with the technological pedagogical content framework that indicates teacher knowledge of content, pedagogy, and instructional technology are separate and interacting domains that take time to develop (Koehler & Mishra, 2009). It may take time for teachers to master new pedagogy before effectively implementing technology to support new teaching practices.

Computer Simulation Instructional Support

While the data supporting the effectiveness of computer simulations is widespread (Lee, 1999; Raghavan, Sartoris & Glaser, 1998; Kiboss, Ndirangu, & Wekesa, 2004; Bell & Trundle, 2008), differences in student outcomes using simulations are regularly observed (Huppert, Lomask, & Lazarowitz, 2002; Marshall & Young 2006). Some of these student outcome differences may be accounted for by diverse student characteristics and instructional support employed by teachers (Smetana & Bell, 2011). Teachers in the present study provided varied types of instructional support to students. In instances where instructional support was not incorporated to support students' simulation use, students had difficulty focusing on and achieving instructional goals. These findings support previous researchers' assertions that teachers' instructional practices may be pivotal for students to succeed during science lessons with computer simulations (Kubicek, 2005; Marshall & Young, 2006; Pea, 2004)

Multiple authors have indicated a need to identify teacher practices that foster instructional technology use that permits student engagement with and understanding of the curriculum (de Jong & van Joolingen 1998; Kim, Hannafin & Bryan, 2007; NRC, 2011). Current research on computer simulation instructional support focuses on embedded, standard support measures (Hmelo & Day 1998; Moreno, 2004). Only a handful of published studies have examined the benefit of specific teacher-provided instructional technology support strategies (Njoo & de Jong, 1993; Rivers & Vockell, 1987). In the present study, teaching strategies that promoted student engagement with simulations and learning objectives included: whole class simulation modeling that introduced students to the simulation and screen interface ahead of time, providing clear instructional goals, written assignments, and questioning by the teacher to encourage data analysis and synthesis.

Njoo & de Jong (1993) found written assignments that structured data collection and analysis helped students engage in scientific skills such as conclusion generation. The current study found that worksheets were widely used to guide and support student computer simulation use. Although they were often helpful to students, at least one classroom observation highlighted the importance for written assignments to reflect student reading skills and prior knowledge. This indicates the need for teachers to preasses student knowledge and take it into consideration during assignment development and extends the findings of Njoo & de Jong (1993).

It was clear from classroom observations that different students had different needs and the teacher's role in providing individualized support was pivotal. This is consistent with the findings of Veenman and Elshout (1995) and Marshall and Young (2006). Veenman & Elshout (1995) found that large levels of support hindered the success of high-achieving students. Marshall and Young (2006) also found that prior knowledge was a key variable contributing to the effectiveness of simulations. This calls into question the effectiveness of embedding standard support measures into simulations and highlights the essential role of the teacher in pre-assessing student knowledge and providing appropriate individualized and whole-class support that is reflective of students' prior knowledge and skill sets.

Implications

Interpretation of the results of this study should be considered in light of the methodology employed. For example, survey data were self-report, which may have impacted the conclusions drawn about the context within which the simulations were used. Specifically, teachers indicated whether they used simulations for NOS, PBL, or inquiry instruction on the ExploreLearning™ Use Survey. To accurately respond to this question, participants must have a fully aligned understanding of these VISTA constructs. However, participants' views of these constructs were not assessed in the present study. In addition, while teachers reported using simulations to teach science concepts and content most often in a non-reform-based context, teachers may not have accurately considered when elements of inquiry or NOS were incorporated into lessons because of an incomplete understanding of the constructs. Future research should assess teachers understanding of these constructs. Additionally, these results need to be confirmed with larger sample sizes and consideration of elementary and secondary science teacher characteristics and contextual factors that may have contributed to these results. For example, elementary teachers may not have as much in-depth science content knowledge as secondary science teachers. As a result, elementary teachers may more readily use instructional tools, such as computer simulations, that provide students with accurate science content. Finally, elementary and treatment teacher computer simulation use patterns need to be compared in light of differences in the VISTA professional development program for these two groups of teachers.

The results of the present study results have implications for computer simulation professional development. Gess-Newsome (1999) asserts that in order for teachers to use reform-based practices they need to be immersed in the experience as part of professional development. If the goal of computer simulation professional development is to result in a change in classroom practice, teachers need to use simulations within an reform-based context during professional development. Instruction about simulations needs to be done within an authentic context consistent with situated learning theory that incorporates relevant content and provides participants with opportunities to plan instruction, practice, and receive feedback using the new tools (Lave and Wenger, 1991). This becomes even more important when computer simulations are the pedagogical tool under investigation since teachers often have anxiety about using technology (Norris, Soloway, & Sullivan, 2002). Furthermore, technology professional development may need to be sustained over a longer period of time to help participants overcome technology related challenges and to promote their use to support reform-based teaching, especially for novice teachers. Future research should compare elementary and secondary science teachers after receiving computer simulation professional development that provides more uniform opportunities for planning content and context relevant lessons aligned with effective components of PD.

There is a significant body of research on effective technology professional development (Capps et al., 2012; Luft et al., 2011; Supovitz & Turner, 2000). However, none of the previous studies examined computer simulation-related professional development for teachers at the elementary vs. secondary levels or for teachers at different points in their teaching careers. The difference in the extent of use between elementary and secondary teachers in this study indicates that there may be differences in these two teacher groups that contributed to the extent of simulation use by elementary and secondary treatment teachers. More research is needed to clarify these differences. Professional development may need to be tailored to meet the needs of different groups of teachers that vary by professional and teaching experience that might impact their readiness to learn and adopt new teaching strategies. Furthermore, previous research indicates it may take time for teachers to effectively incorporate technology into reform-based science instruction (Schnittka & Bell, 2009). Therefore, the duration of this study may not have extended long enough to capture changes in teachers' classroom practices. Future research needs to extend beyond one year to document teacher growth and changes.

Finally, classroom observations and interviews indicated that instructional practices before and during a lesson that incorporated simulations may influence students' ability to use simulations and engage with targeted science content. As Tamim et al. (2011, p. 17) indicated,

> "…it is arguable that it is aspects of the goals of instruction, pedagogy, teacher effectiveness, subject matter, age level, fidelity of technology implementation, and possibly other factors that may represent more powerful influences on effect sizes than the nature of the technology intervention."

Kim, Hannafin, and Bryan (2006) expressed the concern that despite a plethora of research showing the pivotal involvement of teachers during inquiry instruction "few have documented the teacher's role in implementing and supporting technology-enhanced tools in the classroom" (p. 1016). General guidelines to help pre-service teachers implementation of technology in science classrooms has been created (Flick & Bell, 2000; Maeng, Mulvey, Smetana, & Bell, 2013), but little has been done to document how teachers already use instructional technology, such as simulations. Such documentation may inform the development of an instructional technology use framework that will lead to better teacher practices (Kim, Hannafin & Bryan, 2006; NRC, 2011). The authors of the current study began to document some of the instructional practices that may affect students' successful use of computer simulations.

In summary, the current study is unique from previous investigations in its design and findings. These features permitted the emergence of possible different treatment effects that have not been previously identified and need further examination with larger sample sizes and control for additional variables. Results of this study indicate that in practice, teachers use computer simulations for different reasons and with different instructional strategies. Instructional strategies that facilitated technology use, reflected student skills and knowledge, and included individualized support promoted students' effective use of simulations. These strategies need to be further documented and clarified. Furthermore, the extent to which teachers integrate successful support strategies at different points in their teaching careers is an area of needed research (Koehler & Mishra, 2009). Incorporating effective teaching strategies in technology-enhanced reform-based lessons requires a complex set of skills that develop over time. The extent to which these skills mature needs to be documented and understood further. Research that addresses these needs can guide the development of effective professional development programs that support teachers and student achievement in science.

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Appendix A
Sample ExploreLearning™ Use Survey Questions

This survey is designed to learn more about your use of ExploreLearning™ Gizmos™. Your answers will be blinded.

Name:
School:
Date:

	Never	Seldom	Frequently	Very Frequently
1. What types of lessons do you use Gizmos for?				
A) Discovery learning				
B) Inquiry-based instruction				
C) Problem-based instruction				
D) Nature of science instruction				
E) Content/Concept-focused instruction				
F) Skill-focused instruction				

	Never	Seldom	Frequently	Very Frequently
2. Of the times you use Gizmos™ rate the frequency with which you use them in each of the following formats:				
A) whole class (teacher presents and manipulates Gizmo™ in front of entire class)				
B) small group/ pairs of students working together				
C) individual (students work individually)				

Appendix B
Sample Interview Protocol Questions

Tell me about your experiences using ExploreLearning™ Gizmos™ and other simulations

Describe how you incorporate a simulation into a lesson. *Probes: Do you have students use the simulation before introducing the subject matter or afterwards? Do you use handouts or other supplementary materials to guide them through the simulations? If so, where have these supplemental materials come from?*

Describe you role when students are using a simulation. *Probes: What sorts of comments might you make to students? How often do you visit a student using a simulation? Describe the amount of support/guidance you give individual students or the class? Describe any help they have needed using the screen interface. Do you use one computer/projector to give whole class instruction or do students work individually or in groups/pairs? Compare your role in a classroom when students are using a simulation with a hands on lab*.

How would you characterize the impact of the simulations with regards to helping student learning? Describe any evidence you had that the simulation was successful or not successful in helping students learn the intended content/skills. *Probes: Describe comments students made that indicated understanding or lack thereof? Describe instances when students asked classmates for help? How did assessments indicate understanding/or lack of understanding of content/skills?*

Describe any factors that would make you more likely to use more simulations in future lessons. *Probes: Describe any recommendations you have for further training? How would you like that training to occur (where, duration, content)? Would changes in access to computer technology change your use of simulations?*