Title (15 words)
Digital resources to support science instruction: Research, Development and Practice

Abstract (200 words)
Increasingly, science teachers integrate digital resources into their teaching "toolbox," alongside more familiar activities such as laboratory investigations, demonstrations and observations. Digital resources refer to web- or computer-based animations, simulations, games, and videos. While these resources sometimes replicate a non-digital experience, more often they offer a way to illustrate or visualize or a scientific concept beyond what non-digital tools can provide. But how might these resources help students learn? How should they be integrated into instruction? In this session, panelists will share their research and content development experiences as well as the theoretical underpinnings of their work to discuss implications of using digital resources in science instruction. Presenters will share varying perspectives on these issues through discussion of their research and development projects. The symposium presiders will facilitate audience comments within the framework of the guiding questions and the discussant will lend a constructive, critical view to the participants' ideas and suggest future directions for research. Symposium attendees will gain an understanding of the issues and contribute to the discussion about setting a research agenda for digital resource use in science education.

Confirmed Participants
Catherine Milne and Ruth Schwartz, NYU (Molecules & Minds)
Mimi Recker, Utah State University (The National Science Digital Library and the Instructional Architect)
Al Byers, National Science Teachers Association (NSTA Learning Center)
Chad Dorsey and Frieda Reichsman, The Concord Consortium (Geniverse)
Lauren Goldenberg and Alice Anderson, Education Development Center, Inc. and Ted Sicker, WGBH Interactive (Teachers' Domain/PBS LearningMedia: Advancing Biology through Online Professional Development Research Study)
Marian Pasquale and Alice Anderson, Education Development Center, Inc. (Possible Worlds)

Discussant: Eric Wiebe, NC State University
Presiders: Alice Anderson and Lauren Goldenberg, Education Development Center, Inc.

INTRODUCTION

A number of terms such as *digital media resources*, *multimedia tools*, *open educational resources* and *digital learning objects* describe a category of instructional tools that represent scientific phenomena. These terms refer to web- or computer-based animations, simulations, games, and videos that support curricula rather than replace it. Although they are increasingly used in science classrooms at all grade levels, science educators have few frameworks for selecting resources and assessing content quality, and little guidance on how to implement them into classrooms.

There is a small but growing body of research that addresses the use of what we call in this proposal *supplemental digital resources* for science instruction. In this session, panelists will share their research and development experiences as well as the theoretical underpinnings of their work to discuss implications of using digital resources in science instruction. The session will be organized around the following questions:

- What are the cognitive theories for how digital resources might support science learning?
- What models exist for how digital resources can be used in the classroom? What theories of implementation or instructional routines are promising?

Each participant will address the guiding questions from the perspective of their research and development projects (see the Symposium Participant section below). Contributions from the audience will be encouraged and integrated into the discussion. Alice Anderson and Lauren Goldenberg, the symposium conveners, will facilitate the session. Our discussant will be Eric Weibe, from the STEM Education Program and the Friday Institute at North Carolina State University. Dr. Weibe is involved in a number of research projects that examine how 2-D and 3-D graphics and interactive learning tools can communicate information effectively to a variety of learners. His expertise in this field will enable him to lend a constructive, critical summary of shared lines of inquiry and common findings and suggest future directions for research.

This proposal first presents some background and a review of the literature related to digital resources and their implementation in science classrooms. Symposium participants then share a brief overview of their work in this area. The proposal concludes with a discussion of this session's contribution to NARST and science teaching and learning.

BACKGROUND & LITERATURE REVIEW

A core activity of scientific inquiry in the science classroom revolves around students' reasoning about scientific phenomena. Until recently, phenomena needed to be staged as physical lab activities or bound in relatively limited ways in static text and graphics. Accessible new technology tools open up many possibilities of working with phenomena in virtual spaces with a wide range of rich media tools. In addition, these technology platforms provide numerous scaffolds supporting recording and modeling around these phenomena (and underlying concepts) of interest. However, teachers have been provided very little guidance as to how to deploy these tools and what instructional moves between physical and virtual, between teacher and technology led experiences, and between individual and group technology-mediated work make sense for any particular topic or student. The guiding questions that address these issues are explained below.

What are the cognitive theories for how digital resources might support science learning?
Current thinking about good science teaching suggests that teachers should engage students in active learning with real science, contextualize information, and include visualizations and models to support students' understanding of complex concepts (Bransford, Brown, & Cocking, 1999; National Research Council, 1996). These instructional approaches are built on the research-based premise that having students articulate scientific explanations of natural phenomena is a powerful focus of science learning (Duschl & Osbourne, 2002; Kuhn & Reiser, 2005; Sandoval & Reiser, 2004; Schwartz & Crawford, 2006). Within this approach lies opportunities for teachers to integrate digital resources as effective supports for learning.

Digital resources offer a variety of cognitive affordances for science learners. Using a combination of text and pictures together can enhance comprehension and retention (Mayer, 2001; Paivio, 1990; Schnotz & Bannert, 2003). Dynamic depictions such as animations and videos can help students visualize concepts that are difficult to understand, such as differentiating heat from temperature (Linn, 1995) or phenomena that cannot otherwise be directly observed, such as particles of a substance or behavior of molecules (Ardac & Akaygun, 2004). Interactive tools can support active learning by giving students the opportunity to discern patterns through their own investigation (National Research Council, 1996), enabling them students to get feedback and constantly refine their understanding of phenomena (Bransford, Brown & Cocking, 1999). In the classroom, where learning objects are encountered in a social and discursive environment, digital resources can help teachers and students slow down and focus on the intermediate cognitive processes of observing, predicting and explaining that are central to science inquiry and understanding (Polman & Pea, 2007; Reiser, 2004).

In many scientific subjects that require students to conceptualize a system or process, the most valuable digital resources make accessible a simplified model of the target system or phenomenon, one that students can manipulate in order to observe, predict, and explain key causal variables or relationships. A focus on the modeling of specific phenomena is in keeping with the move to ground the teaching of inquiry science in models and explanatory processes (Minstrell & Kraus, 2005; Stewart, Cartier & Passmore, 2005; Windschitl, Thompson & Braaten, 2008). Research teams at NYU, Concord Consortium and Education Development Center, Inc., are currently investigating issues of digital resource design through iterative-design research informed by cognitive theories of learning (see Symposium Participants below).

What models exist for how digital resources can be used in the classroom? What theories of implementation or instructional routines are promising?
Despite the rich potential of learning objects and teachers' enthusiasm for them, there is little research to suggest that teachers are using the affordances of learning objects effectively with students. Indeed, a host of applied research and evaluation projects have found that teachers generally lack a framework for evaluating effective use of digital resources (Recker, 2006). When using digital resources, teachers often teach in traditional ways that emphasize illustration and lecture rather than student thinking and processing. One reason may be that digital resources are not contextualized with concrete images or models of practice.

The evaluations of two key projects that have examined instructional practices around digital resources in K-12 schools suggest that teachers need help recognizing the affordances of digital resources for effective science teaching, and acting on that understanding. First, an evaluation of a multi-country European Schoolnet initiative on digital resources found that teachers need the knowledge and skill not only to identify appropriate digital resources, but also to "identify the cognitive opportunities and limitations of [digital resources], and plan and organize activities to take [advantage of] their affordances and address their limitations" (McCormick, Scrimshaw, Li, & Clifford, 2004, p. 107). Moreover, the evaluation recommends that teachers need to support student understanding through questioning and scaffolding. Second, an evaluation of a digital library of digital resources used in Australia and New Zealand makes the case that "[digital resources] have value when they can be embedded in teachers' constructed teaching and learning sequences" – not as individual activities simply assigned to students (Freebody & Muspratt, 2007, p. 17).

Other literature tends to agree that integrating explicit instruction helps overcome issues of cognitive load when students are dealing with digital resources; in other words, learners need assistance of some sort in how to process and what to attend to in animations, simulations or videos (Mayer, Hegarty, Mayer, & Campbell, 2005; Bentrancourt & Chassot, 2008). However, this recommendation does not suggest that direct instruction is always the best practice; rather that it may be an important part of student learning that is best facilitated by a teacher.

Research suggests, then, that in order for teachers to best capitalize on the affordances of digital resources they may need more explicit models of effective instructional practices that appropriately bridge instructional techniques such as inquiry and explicit instruction to use with digital resources. One promising approach is what is known as instructional routines, or "simple patterns or structures, used over and over again, that support and scaffold specific thinking moves or actions" (Ritchhart, Palmer, Church, & Tishman, 2006, p. 1). Instructional routines have only a few steps, are instrumental in nature, get used over and over, can be adapted to various contexts, and promote student learning across problems and content areas (for a discussion about how this might apply to technology use in classrooms see De Barger, et al., 2010 and Roschelle, Kolodner & Gray, 2002). The potential for the instructional sequences described above are currently being examined by evaluating the use of notable digital resource libraries including PBS Teachers' Domain, the National Science Digital Library, and the National Association of Science Teachers' Learning Center, as described in the next section.

SYMPOSIUM PARTICIPANTS AND THEIR RESEARCH
The projects described below represent participants' most relevant recent work in this field and will serve as a basis for panel discussion.

Marian Pasquale and Alice Anderson, Education Development Center, Inc.
Project: Possible Worlds
Possible Worlds is a National Research and Development Center on Instructional Technology project, funded by the U.S. Department of Education's Institute of Education Sciences. Through this five-year project we are developing and testing four games on a handheld gaming device (Nintendo DS) and related activities for middle grades classrooms. The suite of activities

supplement regular middle-grades life science curricula (including the topics of chemical change, genetics and electricity) and target common scientific misconceptions. A large part of the project is to conduct formative research on the games and activities while they are in development and later to field-test all of the materials in classrooms. Finally, one of the games and related materials will be used in a randomized control trial during the 2011-12 school year.

The project's theoretical framework is influenced by Bransford and Schwartz's (1999) theory of "Preparation for Future Learning," which suggests that activities (such as games) "set the stage" for learning with direct instruction by providing students with experiences from which they can draw to make sense of subsequent material. In *Possible Worlds*, the games are designed as analogs to abstract, scientific concepts, furnishing teachers and learners with experiences they can draw upon to frame and make sense of challenging concepts. While students play the games on their own, the teacher plays a key role in facilitating their experience and making an explicit connection to the curriculum.

For example, the game about chemical change gives students an opportunity to play with the ideas of atoms and molecules changing, from which the teacher can help students make connections to concepts such as photosynthesis and respiration. Our formative research with students revealed that the primary source of misconceptions among middle-school students relates to changes of state and the chemical reactions and changes involved in this process. Due to students' inability to picture the chemical process of photosynthesis, they clung to inaccurate, albeit reasonable, theories. To counter this misconception, the game provides learners with a way to visualize the scientifically accurate process by requiring them to construct glucose repeatedly, as well as break it apart. The teacher then uses the game activities as an analogy to the science and push students to make these connections explicit.

Lauren Goldenberg and Alice Anderson, Education Development Center, Inc.; Ted Sicker, WGBH Interactive
Projects: Advancing Biology Education through Online Professional Development: Research Study** and **Teachers' Domain/PBS LearningMedia
In our applied research study, we are investigating the impact of an online professional development course on high school biology teachers and their students. The main goal of the study is to examine the impact of the course on teachers' content and pedagogical knowledge and on student knowledge of genetics and evolution topics; a secondary goal is to assess the quantity and quality of teachers' digital resource use in instruction. The professional development course was developed by public television station WGBH as part of *Teachers' Domain*, an online digital library that contains multimedia science resources from partnering museums, libraries, universities, and other public broadcasting stations across the country. Course participants explored challenging-to-teach concepts in genetics and evolution through online digital resources from *Teachers' Domain* and reflection on inquiry teaching strategies such as the "5 E's" learning cycle (Bybee et al., 2006).

Results demonstrate that the online professional development course influenced teachers' digital resource use as well as teachers' beliefs about their educational value (see Anderson & Strother, 2011). Following the course, teachers showed a significant increase in how they planned for and used digital media in the classroom, including streaming videos and web-based interactives.

Teachers also reported being more comfortable using digital media following the course. However, using qualitative data from case studies, researchers found that although teachers used digital resource more frequently than they had before the course, they were not incorporating the inquiry-based pedagogical practices that were also a focus of the course. Teachers consistently used streaming videos and online activities to illustrate or reinforce concepts but did not often use instructional strategies that engaged students in generating questions about, analyzing the data from, or evaluating the concepts encountered in the digital resources. (Results concerning teacher and student outcomes have been reported elsewhere – see Goldenberg & Strother, 2010; Strother & Goldenberg, 2011.)

In addition to discussing the implications of the professional development study, WGBH Interactive Executive Producer Ted Sicker and EDC researcher Lauren Goldenberg will discuss the evolution of the Teachers' Domain and PBS LearningMedia services and the role that research and evaluation has played in the development efforts. They will share findings from a variety of projects that investigated the use of Teachers' Domain digital resources and related professional development. In addition, Ted -- an active member of the NSDL development community since its inception over 10 years ago -- will share his experiences in creating and collaborating in the establishment of a national STEM digital library.

Catherine Milne and Ruth Schwartz, New York University
Project: Molecules & Minds
Over the past six years, Molecules and Minds, housed at NYU's CREATE Lab, has worked to develop, test, and implement a sequence of interactive multimedia simulations on kinetic molecular theory and the associated topics of diffusion, gas laws, and phase change. This work is supported by the U.S. Department of Education's Institute of Education Sciences.

Our approach emphasizes that students need to experience science as a process of inquiry and exploration, in which they organize information around concepts and principles rather than memorizing facts (Bransford et al., 1999; Glenn, 2000). The design of our simulations is predicated on principles of best practices in science teaching, including learning as an active process, the importance of contextualizing science by linking to students' everyday experiences, and using visualizations to support students' understanding of and ability to move between the multiple levels of representation central to understanding chemistry: the observable, the explanatory, and the symbolic. Our research is informed by theories of learning with multimedia, such as Mayer's Cognitive Theory of Multimedia Learning (2001), and takes into consideration the importance of students' prior knowledge and existing beliefs (Lijnse & Klaasen, 2004) as well as questions of guidance and scaffolding (Sweller, 2006; Wood, Bruner, & Ross, 1976).

Based on this framework, we developed the simulations over several years using a theoretically and empirically based process of iterative design. Our goal was to reach a broad range of learners, including individuals from racial, ethnic, and economic groups who have historically been poorly served in science classrooms. With high school teachers and students as research partners, we first tested the efficacy of the simulations in small-scale usability studies and revised the simulations accordingly. We then conducted a large-scale effectiveness study, integrating simulations into the curricula of chemistry classes in urban and rural public schools. Based on results of these studies, we continue to revise and update the simulations, and have just

conducted our first large-scale teacher workshop. Thirty-five New York City public school teachers were introduced to the simulations and the design and learning principles behind them. Participants were then assigned to work in small collaborative teams to develop a lesson sequence utilizing one of our simulations. Next term we will follow up with specific teachers, observing their integration of these lessons into their chemistry or biology curriculum. We are also developing an online teacher resource to make available to a broad audience the simulations, our supporting curricular materials, and teacher-developed materials.

Mimi Recker, Utah State University
Projects: The National Science Digital Library and the Instructional Architect
The National Science Digital Library (NSDL.org), a 10-year program funded by the National Science Foundation (McArthur & Zia, 2008) is a portal providing access to online learning resources targeted at STEM learners and teachers of all ages. Resources in NSDL support new visualizations and modeling tools and allow access to and manipulation of real-world datasets.

To further support teachers within this emerging environment, we developed a web-based authoring tool, called the Instructional Architect (IA.usu.edu), which enables teachers to create instructional activities for their students using online learning resources from the NSDL and the wider Web (Recker, 2006). Teachers can share these resulting activities, called IA projects, by making them available for just their students or publicly on the Web. These IA projects can then be viewed, copied, and adapted by other IA users, in ways that support innovative teacher peer production. Since 2005, over 6,300 teachers have registered with the IA, and more than 14,000 IA projects (using 62,000 online resources) have been created.

Professional Development Models for Classroom Implementation. In this work, we compared two technology-related teacher professional development (TTPD) designs in terms of their impacts on teacher and student learning. In one design (*tech-only)*, teachers solely learned technology skills to design student activities using online learning resources. In the other, teachers learned technology skills to design *inquiry-oriented* and specifically problem-based learning activities for their students using online resources (*tech+pbl*). In this way, our study compared the impact of a TTPD design focused on technology alone, with one integrating technology and pedagogy. The study involved 36 science and mathematics teachers and 1,247 students over a period of three months.

Quality in Peer-Produced Resources. In peer production environments, such as the IA, how does one identify quality online content in sustainable, cost-effective, and scalable ways? To address these questions, we built upon the Open Educational Resource Assessments (OPERA) model and rubric to evaluate "quality" in teacher-created IA projects (Leary et al., 2011). Acknowledging that quality is contextual, OPERA avoids a binary "thumbs-up/thumbs-down" assessment; instead it relies on characterizing quality as decomposable into six indicators, with can be applied individually or in combination (Bethard et al., 2009). The OPERA rubric was used by three secondary science teachers to rate 200 IA science projects, while the OPERA machine learning model also rated these projects. Not surprisingly, study results showed that these teachers sometimes agree and disagree about quality once decomposed into different indicators. Results also showed that this was a hard task for teachers, and that reliability results improve with multiple raters.

Al Byers, National Science Teachers Association (NSTA)
Project: NSTA Learning Center
The NSTA Learning Center provides digital resources and professional development supports to science teachers across the country, with an aim of increasing teacher's science content knowledge and science teaching abilities. The challenge for the center and other digital resource libraries is to provide scalable, sustainable, and customizable infrastructure for the needs and learning preferences of the individual teacher. NSTA is working with states and districts across the country to develop a transformative model of blended professional development leveraging self-directed diagnostic tools (Byers, Koba, Sherman, Scheppke, & Bolus, 2011), on-demand inquiry-based digital resources called SciPacks, and related Science Objects and SciGuides to address this need (Sherman, Byers, & Rapp, 2008).

Formally launched in 2008, the Learning Center has over 80,000 active teachers spending hours each week completing self-directed experiences across a range of digital resources and documenting their growth pre- and post-assessments. Multiple third-party evaluations have documented significant gains in teacher learning, self-efficacy, and preparedness to teach looking at elementary through high school grade levels and multiple science content areas. The most recent evaluation using a random assignment delayed pretest/posttest treatment and control design also demonstrates impact in student learning for those teachers completing SciPacks through the Learning Center (see: http://learningcenter.nsta.org/impact). I will discuss our template for the SciPack/SciGuide digital resource, which incorporates a coherent suite of interactive components (i.e., simulations, personal feedback, hands-on activities, interactive reference, and pedagogical implications) coupled within an online learning environment.

Chad Dorsey and Frieda Reichsman, The Concord Consortium
Project: Geniverse
Geniverse is a National Science Foundation funded project creating a collaborative, game-like environment for student learning of genetics and bioinformatics. *Geniverse* builds on a longstanding strand of work at the Concord Consortium involving technology-enhanced curriculum activities and assessments grounded in a theory of model-based learning (Buckley, 1992, 2000; Gobert and Buckley, 2000) and guided by model-based scaffolding (Buckley, 2000; Buckley et al., 2004; Gobert and Buckley, 2000).

Learning activities within the curriculum are designed to foster the development of students' mental models of the structures involved in transmission genetics and their role in supporting the inheritance of traits from one generation to the next. Student investigation involves students in model-based inquiry via a set of scaffolded activities within a game-like environment. In the game, students breed individuals of a model dragon species, manipulate genes at the chromosome level, examine and modify DNA sequences and related proteins, and view and manipulate meiotic models involved in fertilization. Scientific argumentation and explanation are additional key foundations in this project (Duschl & Osbourne, 2002; Kuhn & Reiser, 2005; NRC, 1996; Sandoval & Reiser, 2004; Schwartz & Crawford, 2006). As students proceed through the curriculum, scaffolds for scientific explanation (Kuhn & Reiser, 2004; McNeill, Lizotte, Krajcik, & Marx, 2006; McNeill & Krajcik, 2006, 2008a) aid them in articulating scientific explanations of the phenomena they encounter. Students share, debate, and revise these

scientific explanations as they come to consensus regarding the phenomena they encounter.

One particular focus of this project and related research involves the mode of delivery and support for activities within the curriculum. The *Geniverse* project makes use of a cross-cutting narrative thread and a gaming environment, elements currently under study for their potential to increase student content learning and motivation, among other factors (Dede, Ketelhut, and Ruess, 2002; Ketelhut, Dede, Clarke, and Nelson, 2006; Neulight et al., 2007; Tuzan, 2004, Barnett et al., 2004; Clark et al., 2009; Jenkins, Squire, and Tan, 2004; Moreno and Mayer, 2004). Upcoming research with *Geniverse* will investigate the effects of these factors on student affect and motivation, potentially extending the project to involve social aspects of gaming and a play environment, and researching their effects.

CONTRIBUTION TO NARST & GENERAL INTEREST
This symposium brings together research and development projects that are contributing to a new endeavor: creating supplemental digital resources for science teaching and learning and investigating the impact of their use in classrooms. Although digital resources have been available in one form or another for decades, their ubiquity and relatively low barriers to access make their use and implementation in science classrooms easier than in the past. This ease brings with it new questions that will interest NARST members and will also contribute to building knowledge about the effective creation, selection and use of supplemental digital resources for teaching and learning science.

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