Chapter Title: "Neomillennial" Learning Styles Propagated by Wireless Handheld Devices

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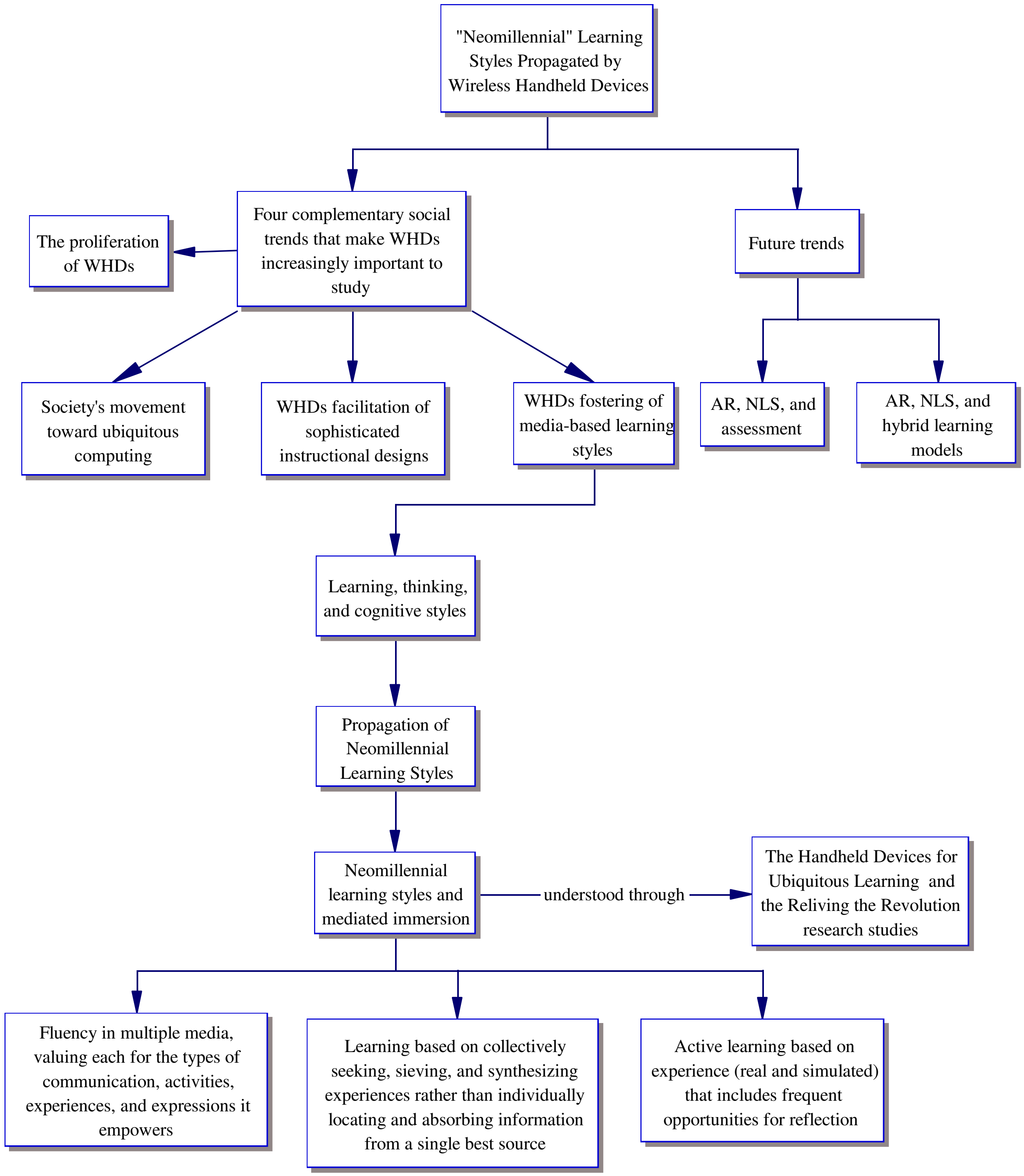
ABSTRACT

As the digital-aged learners of today prepare for their post-classroom lives, educational experiences within classrooms and outside of schools should reflect advances both in interactive media and in the learning sciences. Two recent research projects that explore the strengths and limitations of wireless handheld computing devices (WHDs) as primary tools for educational innovations are Harvard University's Handheld Devices for Ubiquitous Learning (HDUL) and Schrier's Reliving the Revolution (RtR). These projects provide rich data for analysis using our conceptual framework, which articulates (a) the global proliferation of WHDs; (b) society's movement toward "ubiquitous computing"; (c) the potential of WHDs to enable sophisticated types of instructional designs; and (d) WHD's fostering of new, media-based learning styles. In this chapter, our primary focus is the last of these four themes.

CHAPTER FRAMEWORK



INTRODUCTION

In the latter half of the twentieth century, first generation handheld computers left research laboratories and entered the marketplace (Polsson, 2005). Driven by advances in software, hardware, and networking, mobile computing has now moved beyond single purpose functionality (e.g., cellphones, gaming devices, personal digital assistants) to evolve and converge into a new generation of wireless handheld devices (WHDs) that combine the affordances of personal information managers, telephony, wireless Internet connectivity, and Global Positioning Systems (GPS). Familiar to users, computationally powerful, and often wirelessly networked, such devices routinely travel with students and educators into academic settings, making them ripe for utilization as part of formal and informal learning experiences.

Harnessing WHDs as powerful tools with which to think and learn provided the impetus for Harvard University's *Handheld Devices for Ubiquitous Learning* (HDUL) research project. Similarly, Schrier's study at MIT, *Reliving the Revolution* (RtR), designed and assessed a specific historical curriculum, analyzing WHDs as potential tools to facilitate learning. Collectively, these studies offer compelling models for this chapter's analysis of WHDs in an array of learning situations. Whereas HDUL offers a broad review of how WHDs can be used for teaching and learning in a university setting, RtR provides a deep investigation of a participatory simulation implemented using WHDs. To interpret our findings, we use a conceptual framework that incorporates the proliferation of WHDs, ubiquitous computing, instructional design, and media-based learning styles. After unpacking the first three themes of our four-part conceptual framework, we will focus the rest of the chapter on the fourth, media-based learning styles propagated and supported by WHDs. Finally, we consider the implications of our findings for the learning sciences, policy, and educational practice.

BACKGROUND

Nascent handhelds introduced in the late 1980s and early 1990s (e.g., Apple's *Newton*; Nintendo's *Game Boy*) have evolved considerably, gaining sophisticated computational and connectivity capabilities, morphing into smart phones, PDA-phone hybrids, and next generation handheld gaming devices (e.g., Sony's *Playstation Portable, Nintendo DS*). Beyond technical advancements are four complementary social trends that make WHDs increasingly important to study (Dieterle & Dede, 2006, in press): (a) the proliferation of WHDs, (b) society's movement toward "ubiquitous computing," (c) WHDs facilitation of sophisticated instructional designs based on situated and distributed perspectives on learning, and (d) WHDs fostering of media-based learning styles.

The Proliferation of WHDs

Access and ownership of WHDs are expanding among all demographics and cultures throughout the world, especially among adolescents and young adults (Rheingold, 2002; Roberts, Foehr, & Rideout, 2005). A recent report, *Wireless Industry Indices: 1985–2005*, issued by the Cellular Telecommunications Industry Association (2005), illustrates this trend with cellular telephones, one of the first and most pervasive WHDs. In June 1985, the United States accounted for an estimated 200,000 wireless subscribers. Ten years later, the number of subscribers increased to just over 28 million. In June 2005, wireless subscriptions rose to just under 195 million;

described another way, approximately six in ten U.S. citizens holds a cellular telephone subscription. Similar growth trends in cellular telephony are taking place globally and, in some instances, more intensively than in the U.S. In Italy, the United Kingdom, and Taiwan, for example, the ratio of activated cellphones to residents is greater than one-to-one (International Telecommunication Union [ITU], 2005). Globally, the number of mobile phones surpassed 2 billion in mid 2005 (ITU, 2005).

Among U.S. teenagers, as Lenhart, Madden, and Hitlin (2005) have found, almost half report owning a cell phone, with a greater percentage of older teens owning a phone (nearly 3 in 5 teens aged 15-17) than younger teens (nearly 1 in 3 teens aged 12-14). More than 4 out of 5 teenagers report owning at least one personal media device, such as a cell phone, desktop, laptop, or handheld computer (Lenhart et al., 2005), and more than half own at least one handheld gaming device (Roberts et al., 2005).

As a result, students and instructors are increasingly likely to own one or more WHDs—often for reasons other than education—and to bring such devices to class. Through regular interaction and personalization, WHDs become more personally meaningful (Turkle, 2005) than traditional pedagogical tools such as graphing calculators, which are designed for academic exercises, but not much else (Perkins, 1992). Given the pervasiveness of WHDs, educators must understand the strengths and limitations of these devices as evocative objects with which to think and learn.

Society's Movement toward "Ubiquitous Computing"

"Ubiquitous computing" provides contextually specific, dynamic, and temporally aware media and tools that participate seamlessly and almost unnoticed as integral parts of our daily activities. As powerful computational devices such as WHDs pervade our physical surroundings, users can obtain ever-present connectivity and access to capture, process, send, and receive information through multiple devices anytime and anywhere. Recent research on the ubiquitous computing interface has led to the development of ambient technology systems that support elder care networks (Consolvo, Roessler, & Shelton, 2004); objects, such as chemical carboys, that assess and make decisions about their environments (Strohbach, Gellersen, Kortuem, & Kray, 2004); and noninvasive WHDs that coordinate destination and geospatial information to support navigation through public transportation systems (Patterson et al., 2004). However, as engineering and computer scientists continue to wrestle with the challenges of constructing ubiquitous computing environments (Satyanarayanan, 2001), the primary implementation barriers for the adoption of new learning devices are neither technical nor economic, but psychological, organizational, political, and cultural (Dede, 2001).

The affordances and psychosocial limitations of a tool, not just its construction, must be examined critically before, during, and after integrating that tool into a learning environment. If used improperly, for example, the mobility of WHDs can also be a barrier to learning. The personal nature and small size of handhelds may hinder collaboration by isolating users from meaningful social interactions (Mandryk, Inkpen, Bilezikjian, Klemmer, & Landay, 2001). On the other hand, Danesh and colleagues (2001) posit that the mobility of these devices can enhance inter-group collaboration: "Children can walk around, maintaining the flexibility of interacting with many other children, rather than limiting their collaboration to those on the computer beside them." Moreover, these devices support social interactivity, are sensitive to shifts in context, enable individualized scaffolding, and facilitate cognition distributed among people, tools, and contexts (Klopfer, Squire, & Jenkins, 2003).

WHDs Facilitation of Sophisticated Instructional Designs

Recent advances in the science of how people learn focus on the situated and distributed nature of cognition as applied to thinking, learning, and doing in workplace and community settings (Borgnakke, 2004; Engeström & Middleton, 1996; Wenger, 1998; Wenger, McDermott, & Snyder, 2002). Cognition is viewed as situated within both a physical and a psychosocial context and as distributed between a person and his or her tools (National Research Council, 2000; Sternberg & Preiss, 2005). Knowing, doing, and context are seen as intertwined and interdependent (Dede, Whitehouse, & Brown-L'Bahy, 2002). The learner's environment is essential to the learning process, since the context can alter, improve, and support certain types of performances, approaches to problems, or learning activities.

When used in conjunction with constructivist learning principles (Brooks & Brooks, 1993) and guidelines for differentiating instruction (Tomlinson, 1999), handhelds have the potential to change both what and how we teach and learn. Untethered by cords, cables, and power sources, WHDs provide resources so that students can effectively solve problems in the environment where they would typically occur. As Staudt (2005) explains:

> Teachers will guide student learning experiences and, particularly in our standards-based environment, will align learning experiences to meet those standards. What the new technology [of WHDs] allows is for students to meet those standards in individual ways, collect personally meaningful data, and use it to gain understanding of a large inquiry process that begins to replicate the thinking and learning process of real work or advanced study. (p. 2)

Predetermined learning experiences are replaced with students following their own trails of interest, scaffolded by teachers, peers, and tools. Instead of receiving piecemeal information, students are supplied with relevant conditions and authentic problems to help them focus on large ideas while socially constructing deep understandings. As a result, students can navigate their own self-defined learning paths, engage with multiple modalities with varying degrees of complexity, make new contextually relevant connections, reformulate ideas and preconceived notions, and create their own conclusions.

WHDs Fostering of Media-Based Learning Styles

Technological advances are reshaping the learning styles of many students (Dede, 2005), in part because of progress in three complementary human-computer interfaces (Dede, 2002). First, the *World-to-the-Desktop* interface currently dominates human-computer interactions. Typically facilitated through laptop and desktop computers connected to the Internet, this interface provides access to distant experts and archives and enables collaborations, mentoring relationships, and virtual communities-of-practice. *Multi-User Virtual Environments* (MUVEs), the second interface, are commonplace to gamers (i.e., players of Sony's *EverQuest* and id software's *Doom*). Participants use avatars (i.e., digital representations of themselves) to guide action within this interface and to interact with computer-based agents and digital artifacts in a 3-D virtual context. For example, Harvard University's *River City Project* (http://muve.gse.harvard.edu/rivercityproject) is exploring the MUVE interface for learning scientific inquiry and 21st century skills (Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005).

Ubiquitous computing, a third human-computer interface, imbues computation and interconnectivity in countless devices on varying scales of connectivity and interactivity (Weiser, 1993). Digital information superimposed onto the real world can be supported by ubiquitous computing, generating augmented realities, examples of which are described in greater detail later in the chapter. Augmented reality blends the physical and virtual world so that, as Oblinger (2006) describes, "sometimes we are interacting with the real world and sometimes with the virtual world," leading to hybrid environments created by the juxtaposition of the two worlds. Utilizing the affordances of this human-computer interface amplifies the five senses (e.g., seeing microorganisms, hearing inaudible phenomenon), while distorting time (i.e., looking into the past or future, speeding up or slowing down simulated phenomena) and space, at least partially within the real world rather than a purely virtual context.

"Millennial" learning styles are media-based shifts in the learning process that stem primarily from extensive use of the World-to-the-Desktop interface (Howe & Strauss, 2000; Tapscott, 1998). For example, by its nature, the Internet rewards critically comparing multiple sources of information, individually incomplete, and collectively inconsistent. This predicament encourages learning based on seeking, sieving, and synthesizing, rather than on assimilating a single validated source of knowledge as from books, television, or a professor's lectures.

The growing prevalence of MUVE and ubiquitous computing interfaces supported by virtual environments and WHDs is fostering a media-driven shift to what Dede (2005) terms "neomillennial" learning styles (NLS). The crucial factor leading to the incorporation of neomillennial characteristics into millennial learning styles is that the World-to-the-Desktop interface is not psychologically immersive, while, in contrast, virtual environments and augmented realities induce a strong sense of "presence." "Immersion" is the subjective impression that one is participating in a comprehensive, realistic all-encompassing experience (Witmer & Singer, 1994). Today, immersion in virtual environments and augmented realities shapes and supports participants' learning styles beyond what using sophisticated computers and telecommunications have generated thus far, with multiple implications for K–12 education.

Other researchers and scholars have contributed to advancing the first three themes of our four-part framework. Few studies, however, have explored the fourth component of NLS, the focus of this chapter. We use findings from the HDUL and RtR research projects to further illuminate media-driven shifts in students' learning preferences and strengths and to explicate how WHDs can support their preferred pathways of learning.

Overview of the Handheld Devices for Ubiquitous Learning (HDUL) Research Study

During the 2003–2004 and 2004–2005 academic years, HDUL integrated WHDs into eight diverse courses at both the Harvard Graduate School of Education (HGSE) and the Harvard Extension School (HES). Participants in HDUL included faculty and graduate students in education, many of whom were seasoned teachers and researchers who did not have prior experience with educational usage of handhelds. Course subjects included distributed learning, math methods, online learning, qualitative methods and interviewing, science methods, teaching with emerging technologies, team learning, and technology and assessment. Class sizes varied from approximately 20 to 50 students.

Seeking to maximize both students' and professors' experiences, the HDUL team—comprised of faculty, students and staff from HGSE—strove to guarantee that participants: (a) had appropriate opportunity to use the handhelds, (b) recognized and comprehended the affordances of the devices (Dieterle, 2005a, 2005b), and (c) through authentic tasks and activities, were motivated to take advantage of the device's capabilities. Based on individual experiences in relation to the assigned task (e.g., using WHDs in the field to collect survey information from participants), students spent a subsequent class in a facilitated discussion about their perceptions of the strengths and limitations of handheld computers for learning, teaching, and researching in that subject area.

HDUL research demonstrated that WHDs can be highly useful as (1) portable research assistants and (2) traveling conduits for online learning (Dede & Dieterle, 2004; Dieterle & Dede, in press). As research assistants, WHDs enabled users to: (a) capture what users have learned through various educational software packages designed for formative and summative assessments, (b) retain and project learners' opinions in real-time during face-to-face, whole-class discussions, (c) conduct surveys in the field, and afterwards aggregate data to be analyzed by the whole class, (d) log and analyze real-time data through probeware and calculation software that makes use of a menu-driven interface, and (e) record interviews digitally and capture digital images.

As traveling conduits for online learning, WHDs serve as tools that enhance thinking and as vehicles through which information can pass between individuals and their surroundings. For example, students enrolled in a distributed learning course completed *Environmental Detectives* (Klopfer et al., 2003), an augmented reality game using WHDs. Working in groups, participants role-played as environmental scientists investigating a toxic spill on the MIT campus. As students explored the augmented environment, their WHD alerted them to virtual characters that they can interview and site-specific data to determine whether the spill has contaminated ground and surface water. After collecting field data, students analyze their data to provide an informed decision to the president of the university.

Barriers and insights encountered in scaling up the use of WHDs include:

1. Logistics for use of the WHDs. Straightforward procedures for checking out and returning equipment streamlined distribution and collection of hardware; otherwise, equipment would likely have been lost or underutilized, and scheduling conflicts would have led to frustration and disinterest in the HUDL project.
2. Effective instructional design. To maximize experiences, implementation design requires that participants have appropriate access, understanding, and motivation to take advantage of the device's affordances.
3. Instructors' perceptions of new technologies. The instructors' beliefs affected the students' initial perceptions. A lack of advocacy of new technologies by instructors could lead to an initial lack of interest in students.
4. Lack of connections between "online learning" and learning with Internet-connected WHDs. Participants, even after rich experiences with WHDs, do not automatically make these connections and associate online learning strictly with laptop and desktop computers connected to the Internet. Some participants exhibited characteristics of functional fixedness: the tendency to limit an object to pre-established belief system, which inhibits the usage and thinking of the same object in novel ways (Dieterle & Dede, in press).
5. Teachers' concerns about students' use of the WHD technology. Teacher-participants shared concerns regarding: (a) new technologies, especially those their students have already mastered, (b) students engaging in off-task behaviors, and (c) students using computational devices without an understanding of the underlying domain knowledge.

Overview of the Reliving the Revolution (RtR) Research Study

During the 2004–2005 academic year, Schrier (2005) developed and tested “Reliving the Revolution” (RtR) as a model for using WHDs in augmented reality games to teach historic inquiry, effective collaboration, media fluency, decision-making, and critical thinking skills. RtR enables participants to traverse the present-day site of the Battle of Lexington, equipped with WHDs, to “relive” this historic battle from the American Revolution through the eyes of one of four historic figures present at the Battle. Participants use their WHDs to collect information or “evidence” to determine who fired the first shot in the Battle, a source of continued debate in American history. GPS-enabled WHDs provide participants location-based “virtual” information on the social, historical, economic, geographic, and political processes relevant to both the Battle of Lexington and the American Revolution.

Evidence comes from two sources. First, participants can encounter virtual historic figures (e.g., Paul Revere), called non-playing characters (NPCs), in pre-programmed locations. NPCs provide evidence that explains their perception of what happened at the Battle. Second, virtual game items and descriptions of buildings help participants evaluate their evidence and gain a deeper understanding of their location and the context for the Battle. Each user receives evidence tailored to his or her alter ego’s background and social status. For example, a “virtual” spy for the British Regulars would provide very different information to a Minuteman soldier than he would to a British soldier.

After participants collect various forms of evidence from fragmentary, inconsistent, and possibly biased sources, RtR scaffolds the reasoning and procedural skills required of a historian so that participants working in pairs can interpret data to construct an overall historical narrative and can provide an evidence-based opinion about which side fired the shot that initiated the Battle. After immersing themselves in the simulated events leading up to and following the gunshot, the roles come together and, using the evidence collected and stored in their WHDs throughout the game, collectively debate what they think happened at the Battle of Lexington.

Although designed for junior high, high school, and college-aged students, field tests suggest that RtR appeals to an even wider range of ages. Schrier did not design RtR as a standalone, teacher-proof educational experience; rather, she created it as an innovation that a teacher could integrate into a broader history curriculum while acting as a guide, mentor, and resource for the simulation. Having this type of scaffolding is particularly important during the third part of RtR (i.e., the debate period). A teacher, for example, can pose additional questions and ensure that alternative views are considered.

Schrier’s analysis of RtR’s effectiveness suggests that properly designed WHD-enabled augmented reality-based participatory simulations can enhance the learning of: (1) historical figures, sites, and issues; (2) historical methodology and the limits to understanding the past; and (3) alternative views of the past, the construction of new versions of history, and critiques of authoritative interpretations. Participants practiced critical thinking skills such as managing and navigating information, deeply evaluating evidence, finding creative solutions, framing and subdividing problems, and devising thoughtful arguments. Most importantly, the participants were excited, engaged, and enthusiastic.

Participants applied the concepts they learned to other disciplines and critiqued their own preconceived notions and beliefs. Schrier’s results suggest that this learning occurs in RtR in part because of the following affordances for WHDs in supporting neomillennial learning styles:

1. Collaboration: WHDs’ portability and size increased collaboration among participants, which

concomitantly enhanced opportunities for reflection. Participants greatly enjoyed working as a team and learning from each other.

2. Authenticity: WHDs granted access to an authentic "practice field" (Klopfer et al., 2003) for solving problems and implementing real-world contexts and tools.
3. Role-playing: WHDs enabled participants to play as and experiment with unique roles, and then to share those identities with others.
4. Mobility: WHDs encouraging participants to explore a physical site and experience interactions between the real and virtual worlds.
5. Self-directed learning: WHDs' functionality allowed participants to control their navigation of the game, and discover new information at a pace with which they were comfortable.

PROPAGATION OF NEOMILLENNIAL LEARNING STYLES

Learning, Thinking, and Cognitive Styles

Sternberg and Zhang (2001) differentiate learning styles, thinking styles, and cognitive styles thusly: *learning styles* characterize "how one prefers to learn about"; *thinking styles* characterize "how one prefers to think about material as one is learning it or after one already knows it"; and *cognitive styles* characterize "ways of cognizing [i.e., knowing, perceiving, and recognizing] the information." Collectively, they are qualitatively different from one another and distinct from *abilities*: the natural or acquired skills and talents that result in being able to do something. "Abilities," as Renzulli and Dai (2001) explain, "are not the only thing important for successful learning, and surely not the only contributing factor for the development of cognitive and learning styles" (p. 31). For example, a student may have the ability to navigate the Internet and read a newspaper to find information, but might prefer learning about her favorite professional athletes by watching sports television shows, receiving Rich Site Summary (RSS) feeds on her blog, or getting Short Message Service (SMS) text updates on her cell phone.

Building on Sternberg's (1997) approach to styles, Biggs (2001) notes that, "Preferences are a matter of degree, not of category, so that individuals may have a profile of styles, with one or more dominant." Although abilities may overlap with preferred pathways for establishing new connections and assimilating new information, they do not necessarily have to align. Performance on a given task is amplified when a person's dominant style coincides with his or her abilities, but typically erodes when the two do not overlap (Biggs, 2001). For educators, designers, researchers, and policymakers, it is clear that aligning styles and opportunities for learning is paramount.

Of the learning, thinking, and cognitive styles aforementioned, learning styles are the most activity-oriented and of the greatest utility to educators. Keefe (1979) defines learning styles as "cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment." Three learning styles widely accepted as standards include: sensory-based (e.g., visual, auditory, kinesthetic); personality-based, measured using instruments such as the Myers-Briggs inventory; and aptitude-based, which draws on categorizations such as Gardner's multiple intelligences (Gardner, 1983). As discussed earlier, Dede (op cit) proposes a fourth style: media-based learning.

The Millennials and Millennial Learning Styles

During their formative years, millennials — the cohort born after 1982 — have had unprecedented access to a broad range of media in the United States (Roberts et al., 2005) and abroad. Especially profound are their gains in access to interactive media (e.g., video game consoles, computers) and information and communication technologies (e.g., instant messenger). Pervasive availability of interactive media has helped contribute to nearly 9 in 10 U.S. teens regularly accessing the Internet and more than half going online daily (Lenhart et al., 2005). More interesting than access is what millennials do once they go online. Of those who access the Internet, 4 in 5 play online games, 3 in 4 gather news, and just under 1 in 3 seek out health information (Lenhart et al., 2005). Besides consuming information, nearly 3 in 5 U.S. teenagers contribute to the content of the Internet by creating blogs and web pages; posting original artwork, stories, and photos; and remixing existent content in novel ways (Lenhart & Madden, 2005).

Oblinger (2004) has argued that the learning preferences of the millennial cohort are geared toward "teamwork, experiential activities, structure, and the use of technology. Their strengths include multitasking, goal orientation, positive attitude, and a collaborative style." As Oblinger continues, students today are accustomed to negotiating among various media sources and working in "a digital environment for communication, information gathering, and analysis." Whereas Oblinger connects these characteristics to those born after 1982, we and others [e.g., Dede and colleagues (forthcoming)] assert that these qualities are observable to varying degrees in learners of all ages who make extensive use of modern interactive media.

Neomillennial Learning Styles and Mediated Immersion

What learning styles might these media-based lifestyle shifts induce? Research on educational MUVEs and augmented reality learning experiences suggests that the following may emerge as cross-age learning styles:

1. Fluency in multiple media, valuing each for the types of communication, activities, experiences, and expressions it empowers.
2. Learning based on collectively, seeking, sieving, and synthesizing experiences rather than individually locating and absorbing information from a single best source.
3. Active learning based on both real and simulated experiences that includes frequent opportunities for reflection.

In the sections that follow, we consider each of these themes as they relate to work conducted in HDUL and RtR, delving deeply into the first of these three neomillennial learning styles and providing summary examples of the other two. Discussion of other neomillennial learnings styles — such as (a) expression through nonlinear, associational webs of representations and (b) co-design of learning experiences personalized to individual needs and preferences — will be addressed in future works. Mediated immersion likely has other influences on learning styles yet to be discovered, but these initial findings have a variety of implications for strategic planning, investment, and professional development at all levels of education.

1. Fluency in multiple media, valuing each for the types of communication, activities, experiences, and expressions it empowers.

Fluency in multiple media goes beyond millennial learning styles, which center on working within a single medium best suited to one's style and preferences. In contrast, the majority of U.S. teenagers tend to use multiple media at any given time. Roberts, Foehr, and Rideout's (2005) research finds that more than half of 7th–12th graders report accessing at least one additional medium either "most of the time" or "some of the time" when watching TV (53%), reading (58%), listening to music (63%), and using a computer (65%). In contrast to multitasking, "the proportion of kids who say they 'never' use other media in response to these questions ranges from a low of 12% when listening to music to a high of 19% when watching TV" (p. 36). This is also reinforced by a recent report issued by the Pew Internet and American Life Project investigating when and how kids use IM, email, cellphones, and telephones (Lenhart et al., 2005).

In Dede's "Learning Media that Bridge Distance and Time," HGSE students explore various immersive technologies (e.g., groupware, threaded discussion sites, videoconferencing, virtual environments, WHDs) as vehicles for socially constructing knowledge. As Dede, Whitehouse, and Brown-L'Bahy (2002) report, students' learning styles tend toward distributed interaction across multiple media and feel their learning experiences are lessened by only engaging in activities and media found in traditional classroom settings.

From our HDUL research, 20 future math teachers in a graduate course on teaching mathematics compared and contrasted WHDs to TI graphing calculators as tools for computation, modeling, and visualization. A week prior to a whole class discussion, participants checked out WHDs (i.e., Toshiba e750 Pocket PCs) and were instructed to focus on the general functionality of the devices and the computation, spreadsheet and visualization capabilities of Microsoft's *Pocket Excel* and MRI Graphing Calculator software, a calculation application that makes use of a menu-driven interface. In general, participants shared concerns about the learning curve that must be overcome with the WHDs they investigated. While they felt that teachers would need detailed professional development to understand and properly utilize the instructional functionality of the devices, they felt that students would easily navigate them. As one future math teacher stated:

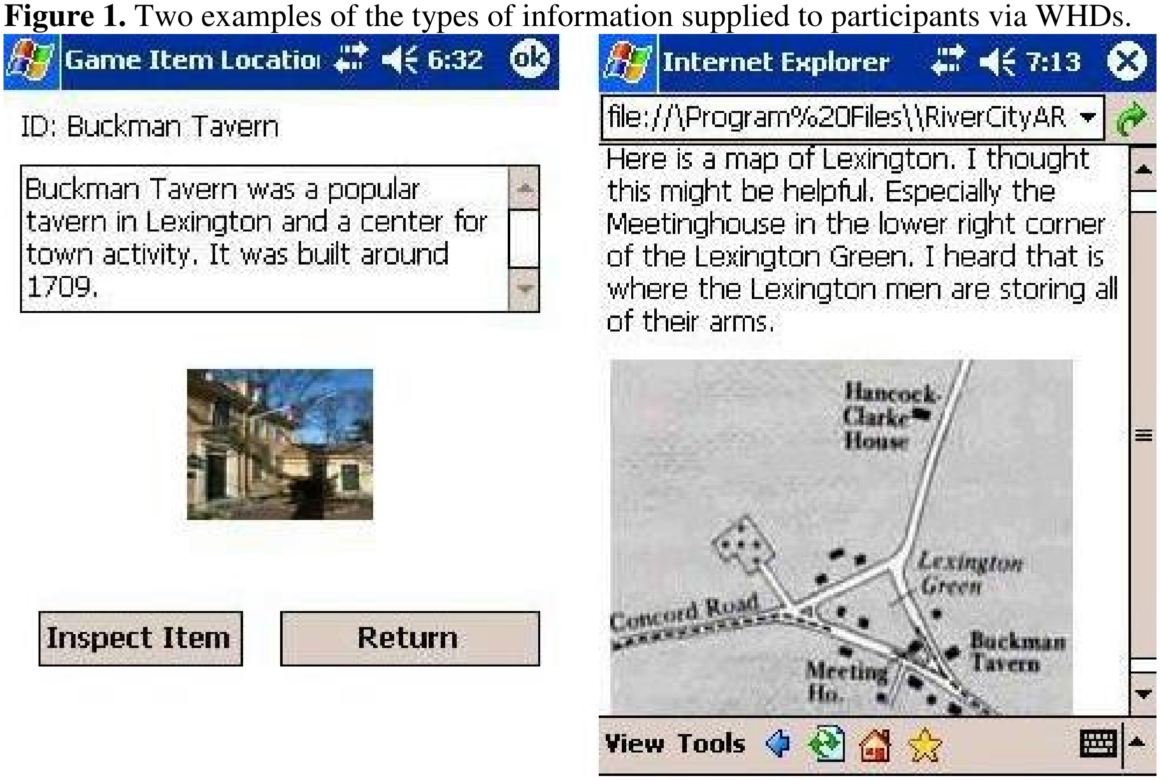
> I think sometimes when you look at students, they gravitate toward this [type of device]. They grew up on Gameboys. They walk around with cell phones taking pictures of each other, so maybe they have greater patience. Maybe they're willing to fumble through this even more so than we as teachers.

This description is characteristic of a shift in the classroom and highlights the malleability and adaptability associated with NLS, in which tech-savvy students have surpassed their more technologically limited teachers. Although some in the test group expressed initial frustration with the devices, others suggested it was no more challenging to master than a graphing calculator interface when both are new and unfamiliar.

Indeed, graphing calculators support the understanding of expressions and equations (National Research Council, 2001) and, as tools for thinking with data, graphing calculators facilitate the visualization and analysis of data (National Research Council, 2000). Correspondingly, about 7 in 10 U.S. high school students use calculators almost everyday (U.S. Department of Education, 2000). Despite reports by some of using graphing calculators outside of math and science classrooms (e.g., Parker & Mills, 2004), such instances force graphing calculators beyond their core competencies of computation and visualization, resulting in very limited utility. WHDs, on the other hand, include the functionality of graphing calculators and go beyond being task-oriented and school-specific. For example, using WHDs with *Pocket Excel* helps bridge the gap between what kids are using at school and what they might potentially use in the outside world. As one math methods participant stated, “They’re not going to use a graphing calculator to do finance.” By using a WHD and Excel “You’ve done two things: you’ve taught them new math, and you’ve also given them that skill that they’re going to need when they get to college or the world place.” These uses, and others described later in the chapter demonstrate how teachers and students will likely find everyday use and functionality for their WHDs beyond formal educational pursuits inside of school settings.

With RtR, Schrier sought to design an educational experience that would spark novel connections and perspectives through the interplay of multiple media sources. Such a seamless integration of text and images with the physical world could potentially support and enhance students’ neomillennial multimodal learning styles. Thus, while playing RtR, participants used WHDs to retrieve location-based graphical and textual information on the Battle of Lexington, the historic site of Lexington, and the historic figures involved in the Battle, as well as evidence about who might have fired the first shot and initiated the battle. Figure 1 shows screen captures of the types of information participants received.

Figure 1. Two examples of the types of information supplied to participants via WHDs.



For example, participants encountered “virtual” historic figures who offered visual documents, such as diary entries, letters, maps, and newspaper articles. Participants inspected these images to consider their validity and, when necessary, compared them to other images and texts they received. Participants also used their WHDs to access photographs and descriptions of physical monuments or buildings that were involved in the Battle and are still present in current-day

Lexington. This activity encouraged participants to inspect thoroughly the physical structures and sites at Lexington, to support their hypotheses about who fired the first shot. Results of trials of RtR suggested that the opportunity for multimodal learning and thinking helped the participants better absorb, interpret, and recall the information, as well as enjoy learning it.

As an illustration, participants would consider the type of media (diary entry, testimonial, photograph) when assessing bias and validity of data. They would also pull apart the visual and textual elements of the evidence, such as the tone or language of a testimonial, to consider whether a source was trustworthy or reliable. Moreover, participants would look at how the virtual data and physical world complemented or contradicted each other. For example, when participants read Captain John Parker's words first on their WHDs and then on a monument on the actual Lexington Common, they felt the corroborating evidence bolstered Parker's character and made his testimony more believable The confluence of both virtual and corresponding physical information further motivated participants to delve more deeply into the historic site, to think more creatively about the virtual evidence, and to compare their reflections with others.

The interaction with multiple modes of information also helped participants better navigate, categorize, remember, and integrate content. Stopping to read virtual information at a physical site and then interpreting the information to understand its relationship to other virtual or physical information helped participants recall specific details more easily. In fact, when comparing, sharing, and corroborating evidence, participants would often point to the physical location where they retrieved virtual evidence. Explaining why RtR helped him learn about the Revolutionary War better than how he learned in his history classroom, a student remarked, "I re-learned U.S. History One…this recapped it and I relearned it and now I know more about history. … the pictures, and the items [helped make it clearer]." This participant's experience demonstrates the interrelation of activity, concept, and culture via physical and social contexts for knowing and understanding (Brown, Collins, & Duguid, 1989), which traditional classrooms tend to overlook.

By situating RtR as an authentic experience, the participant is able to comprehend the nature and significance of concepts that before were abstract and unconnected. These findings suggest that continued experience with games and simulations like RtR could produce similar effects. In RtR the inclusion of multiple media added more depth and complexity to the participants' conception of the historic period, their reconstruction of the historic moment, as well as to their own interpretations of what happened at Lexington. Multimodal learning helped the participants better synthesize and articulate arguments, make novel connections, and analyze sources.

2. Learning based on collectively seeking, sieving, and synthesizing experiences rather than individually locating and absorbing information from a single best source.

Collective learning goes beyond millennial learning styles in preferring communal learning in diverse, tacit, situated experiences to the solo integration of divergent, explicit information sources, as well as in valuing knowledge distributed across a community and a context as well as within an individual.

Examples of this neomillennial learning style from HDUL research included:

1. Graduate students in a distributed learning course investigated MIT's (2005) *Virus*, in which participants simulate the spread of infectious disease with WHDs to determine the causes, distribution, and control of disease in populations. Participants completed multiple rounds of play, repeating the same 5–10 minute simulation with the same parameters, using facilitated

reflection between games. Instead of a linear transmission of information, participants heuristically and socially constructed meaning.

2. Participants in an online learning course brought their WHDs into the field, and each participant conducted surveys of approximately 10 participants and collected results using Microsoft's *Pocket Excel*. Afterward, participants uploaded their data from the WHD, the datasets were aggregated, and participants analyzed the resulting collective database as an entire class. Surveys generally take place in the field, over the phone, online, or through the mail (Fowler, 2002), wherein researchers typically wait until they return to their desktop or laptop computers to begin analysis. Although analysis with WHDs is not as detailed or thorough as is possible with laptops or desktop computers, the strength of using WHDs for rapid and rudimentary evaluation of data in the field enables formative shifts in research approaches. An additional strength of WHDs is the power to quickly expand dataset samples. In this class implementation, 12 student participants independently surveyed approximately 10 random participants with their WHDs. On aggregation of the data, the collective sample size expanded to 120 participants.

Through the processes outlined in both examples, HDUL participants learned that real world phenomena are complex, multiple perspectives exist, and "truth" is often a matter of how meaning is constructed.

Similarly, RtR encourages participants to seek, incorporate, sift through, and synthesize information from multiple sources, as well as to rely on each other to collectively interpret, edit, and categorize information. While gathering evidence the participants worked in pairs and played one of four historic roles. Each role received different — complementary or contradictory — information from virtual people, digital items, and the physical environment, compelling participants to depend on each other to get a more detailed and holistic view of the full situation. The distinctiveness of each role provided an impetus for the participants to collect and analyze deeply their evidence, knowing they would have to share and contribute their findings and insights with the group during the debate period. The relatively compact space of the game and the mobility and size of the WHD, allowed for verbal exchanges of evidence among the various roles. Participants could ask each other for advice, share discoveries, and make connections based on serendipitous exchanges. The WHDs also further enabled the physical sharing of information, because participants could literally "beam" evidence from one WHD to another, and they could hand over WHDs to other roles to show them relevant evidence. The WHD was small enough to be passed around in groups, shown to other individuals for comparison or corroboration of evidence, and carried to specific locations for further inspection of an area.

During the debate period, the participants shared and compared their unique evidence and collaboratively drew conclusions. Thus, the game encouraged participants to not only access and gather information, but also to discuss, analyze, and question material, as well as to rely on the collective intelligence of the group. Said one participant in the game trial, comparing this learning experience to what she normally does in her middle school history class: "A history class is like data, but this was like data and then you had to interpret or analyze it on top of it."

Thus, game play elements (such as the inclusion of roles, the collective debate, the role-specific evidence and mini-objectives), coupled with the use of WHDs, supported and encouraged the participants' negotiation of multiple sources of information and creation of a distributed learning community, which further led to the consideration of alternative perspectives on the Battle of Lexington. Said a participant in the game trials: "I learned about all the different sides. Normally you would just think of the American soldiers and the British soldiers, slaves, the wives, the people at the bar, the Minutemen, there are people frustrated here for personal reasons, patriotic reasons, you get a sense of the different roles of that time period." While playing the game, the participants began to have a more complex, nuanced understanding of the various points of view of the historic moment of the Battle of Lexington. They did not just interpret the tensions involved in the Battle as a simple dichotomy, but as a more multidimensional social issue with "many different factors" involved, as another participant noted. The participants became more aware of subtle variations in views and the spectrum of agendas for the people involved in the Battle of Lexington, while also challenging assumptions and preconceived notions about the past, in part because they were authentically "doing history" within a community of practice. Results of RtR suggest that creating WHD activities where students can distribute intelligence and problem solving, while considering multiple views, sources, and opinions, can support and enhance neomillennial learning styles and may lead to deeper understanding and engagement.

3. Active learning based on experience (real and simulated) that includes frequent opportunities for reflection.

This type of active learning goes beyond millennial learning styles in valuing immersive frames of reference that begin with experiential participation, and then infuse guidance. Drawing parallels between interpersonal interactions facilitated by media and how people interact, Reeves and Nass (1996) have demonstrated that engagement with various forms of media are "fundamentally social and natural, just like interactions in real life" (p. 5).

Examples of this neomillennial learning style from HDUL research include:

1. Participants in a team learning course and a technology and assessment course used WHDs and WiFi connectivity to complete online Likert Scale surveys and answer open-ended questions in "thought grabbing" exercises. Immediately after participants submitted their responses, the data were aggregated and displayed on a computer projector in real time to facilitate immediate class discussion of the findings.
2. Participants explored the use of WHDs in science using Data Harvest's (2005) probeware to collect and analyze data in real-time. Participants explored and discussed various examples of probeware (e.g., temperature probe), the benefits of probeware for teaching and learning science (Staudt, 2001; Thornton, 1999), and a software interface for processing information.

Through iterative thought grabbing and data analysis experiences, participants continuously reflect on and reevaluate their understanding of complex concepts and ideas with fellow students toward deeper understandings.

Results of RtR suggested that the game encouraged active, participatory and reflective learning through appropriate pedagogy surrounding the affordances of WHDs. Throughout the game, participants were continually invited to act like historians, rather than passively receiving historic information or accepting an institutionally-vetted narrative of the past. Participants needed to actively collect evidence, analyze evidence, and formulate hypotheses. The combination of game play, content, and WHD mobility, interactivity, and ease of use helped compel participants to discover new information, explore a historic site, and create their own novel narratives of the past. The participants' newly formed sense of entitlement to construct their own interpretations and conclusions is echoed in one participant's statement that "Reliving the Revolution" differs from other games. She said, "You had to research and then figure something out for yourself. It wasn't like a set like 'you have to click on this conclusion now.' You have to come up with whatever."

The participants in the Redesign trial especially enjoyed being able to physically walk around and learn, rather than sitting passively in a classroom. This is reflected in the following conversation between two participants in the study:

> **Participant 1:** Yeah, if we sat in a classroom and did this and I would walk away and be like "Yeah, okay."
>
> **Participant 2:** But when you are actually moving around to do it….I think it's definitely more interesting to do it this way than to sit in the classroom.

Results also suggested that RtR motivated reflective learning through the sharing of findings and ideas with other participants. Playing a role as a pair helped the participants more deeply consider the information they gathered; they needed to collaboratively digest, discuss, and draw conclusions about each piece of information. They could gain immediate feedback for their mini-hypotheses and conjectures from their peers. Collaborating as a role also helped participants practice critical skills such as decision-making and teamwork: the participants needed to work together to decide which virtual historic figure to find next, how to analyze the evidence they received, or whether they should trust some data and not other information. For instance, one participant said she "liked playing with others because you could get corrected and get new ideas," while another commented "if you talk things out, you can remember them better than just writing them down."

The collaborative debate period of RtR also encouraged active, reflective learning. Participants were constantly brainstorming collectively, asking other roles about the documents and testimonials they gathered, questioning authorial intentions and pointing out biases, and evaluating each other's conclusions. For example, during the debate, one participant would offer a hypothesis and a few pieces of evidence, such as a diary entry or a testimonial, and then another participant would counter with a contradictory piece of evidence or offer supporting evidence. Finally, the participants would incorporate each other's versions of the past to create a collective interpretation of who fired the first shot at Lexington, while simultaneously reflecting on their process in creating this narrative.

In the following exchange from the debate period of a game trial of RtR, participants explained how they reached their conclusions about who fired the first shot:

> **Participant 1 (British soldier):** There wasn't one piece of evidence, but it was the mentioning of one name over and over again. Like you can never really trust one firsthand account, because of course they are going to be biased by their side. But if you get like four or five people mentioning Edward Mitchell [a British soldier], it kinda leads you to believe that he did something.
>
> **Participant 2 (Slave/Minuteman):** Like whenever we found a British person, they were too busy to talk to people, they were only busy looking for something and doing something.
>
> **Participant 1 (British soldier):** Well that could have just been you, since you are a slave and a minuteman soldier, they wouldn't have talked to you anyway. (looking through her handheld) Because a lot of British soldiers talked to us because we are British. Like this guy said, "Those Lexington Minutemen asked for it. The Minutemen were out for revenge. They should surrender."
>
> **Participant 3 (Loyalist):** Yeah, we found a hat that had been marched on. So that probably means that…the British were in pursuit, that they probably came here looking for a fight, and they were willing to pursue it.

Participant 4 (Loyalist): That they were prepared to pursue it.

Thus, the participants did not just collect and offer evidence, but they reflected on the challenges in constructing their argument and explained the rationales for their decisions. The participants explored deeply each other's arguments by exposing possible biases or offering contradictory or supportive evidence. Throughout the debate, all of the participants were actively engaged, by explaining their ideas, listening to others' opinions, or searching through their WHDs to find compelling evidence to share with the group.

In RtR, the WHDs, together with appropriate levels of guidance, constraints, and scaffolding, motivated the participants to direct their own learning, take responsibility for completing the game's tasks, and reflect on their participation as historians and game players. This seemed to enhance and complement the participants' neomillennial learning style of active, participatory, self-guided learning.

FUTURE TRENDS

Innovations that use WHDs to leverage NLS, such as HDUL and RtR, will shape and change what and how students learn. As we explore the implications of NLS for learning, we must also consider future effects NLS will have on policy and educational practice. Although an array of future trends could be considered, in this chapter we forecast NLS in relation to issues of assessment and hybrid learning models, as these important topics are generalizable from HDUL and RtR to similar projects.

AR, NLS, and Assessment

Salomon and Perkins (2005) describe three levels by which technology affects thinking and learning. The most straightforward and immediate results of a technology's influence on thinking, learning, and doing are the *effects with* a technology, which result in expanded cognitive capacity and amplified perception while a technology is coupled with an activity. After considerable experience with a technology, users exhibit the *effects from* a technology, the residual impact of a technology when it is no longer present. The most profound effects are the *effects through* a technology, which fundamentally reorganize cognitive activity. Brown and Thomas (2006) describe this type of effect as, "learning to be… as opposed to learning about." Schrier's RtR and HDUL's investigation of *Environmental Detectives* illustrate WHD-enabled innovations that develop NLS in support of participants of various ages as they acquire *through* technology the reasoning and procedural skills of historians and environmental scientists, respectively.

How can we measure sophisticated effects such as these? As Sheingold and Frederiksen (1994) have noted, "to change our expectations about what students should know and be able to do will involve also changing both the standards by which student achievements are judged and the methods by which student's accomplishments are assessed." Accurately assessing effects with, from, and through technology requires measurement methodologies and objectives that match our evolving expectations for students' educational outcomes, as well as new ways in which they learn. Russell (2006) identifies, "A major challenge to assessing the impact of technology on student learning is identifying learning measures that are aligned with and sensitive to the types of learning that may occur when students work with computers." Many current assessments, however, measure what students have learned from technology (i.e., *effects* *from* a technology), not what students are capable of doing with access to technology (Perkins, 1993) or through technology.

Educational MUVES such as *River City* (Ketelhut, Dede, Clarke, Nelson, & Bowman, in press) and intelligent tutoring systems (ITSs) (Anderson, Corbett, Koedinger, & Pelletier, 1995) have the ability to record and store every user action and utterance. WHDs that support AR do not yet have the capacity to keep as detailed records of student activities, but hybrid simulations that shift between virtual and real-world experiences, such as RtR and *Environmental Detectives*, can create rich histories of students' learning processes. Parallel to MUVEs and ITSs, WHDs can use a data-tracking system that generates log files stored in a relational database (Ketelhut et al., in press). Designers can collect, store, and retrieve information on the activities of each team of students as they participate in the simulation, a feature impossible to replicate in purely face-to-face learning. The level of detail in these records is extensive: the logs indicate exactly where students went, with whom they communicated, what virtual artifacts they activated, and how long each of these activities took. This richly varied store of data can couple with other types of student learning products to develop novel, performance-based assessments of complex performances such as NLS or learning disciplinary reasoning and procedural skills. Such performance-based instruments "gauge a person's understanding at a given time" and "ask the person to do something that puts the understanding to work," with the intention that "what learners do in response [to the assessment activity] not only shows their level of current understanding but very likely advances it" (Perkins, 1998, p. 41).

AR, NLS, and Hybrid Learning Models

As information and communication technologies advance, various forms of "hybrid" learning models are now emerging. For example, "distributed learning" is a term used to describe educational experiences that combine the use of face-to-face teaching with synchronous and asynchronous mediated interaction (Dede et al., 2002). This "hybrid" or "blended" instructional strategy distributes learning across a variety of geographic settings, across time, and across various interactive media. Millennial learning styles flow in part from the different ways in which each type of medium shapes its messages and its users. As an illustration, some students silent in face-to-face instructional settings "find their voice" in one or another type of mediated discussion.

AR enables another type of "hybrid" learning: immersive simulations that combine the real world and the virtual world. We speculate that, parallel to distributed learning, students in such virtual/real hybrid models experience forms of learning and engagement different than either purely real or purely virtual simulations. Designing successful hybrid learning conditions requires a balance between the experiences encountered in the real world and the information overlaid on the real world. Learning that positively transfers from one situation to a novel situation is reliant on a learner's ability to *discriminate* important and trivial features of the new situation (Sternberg & Frensch, 1993), whether in the real world or the virtual world. Simulations and models necessarily must selectively reduce the complexity of the real world in order to provide learning experiences that are not confusing, but still capture the core of knowledge and skills involved. Preserving too much complexity can reduce a learner's ability to differentiate what is significant and what is insignificant. Instead of filtering out information, augmented realities weave information into surroundings that enhances the senses, time, and space. Critical to AR design is determining how much information to include, which sense to engage, and how long the experience should last. Maximizing learning opportunities in hybrid environments, therefore, requires scaffolds that help filter the real world while enhancing it through AR, as learners *learn to be* instead of *learn about*.

As Norman (1993) cautions about all new technologies, before hybrid learning models are introduced and studied in practice "it isn't always obvious just which parts are critical to the social, distributed nature of the task, [and] which are irrelevant or detrimental." As this form of learning model becomes available, much work will be needed to determine how to best blend real world and virtual experiences. Research is needed to deeply understand the affordances and psychosocial limitations of hybrid learning models based on AR technologies.

CONCLUSIONS

Overall, as the findings in this chapter illustrate, WHDs support emerging media-driven learning styles, which Dede has dubbed "neomillennial" because they go beyond the popular conception of millennial learning styles. Contributing to NLS are (a) WHDs proliferating among all demographics, (b) "ubiquitous computing" gradually infusing WHDs into many aspects of everyday life, and (c) WHDs' potential to enable sophisticated types of instructional designs based on situated and distributed theories of learning. Examples from Harvard's HDUL and Schrier's RtR advance evidence for NLS in three distinct ways.

First, fluency in multiple media, often used concurrently, is characteristic of NLS. Each medium, moreover, is valued for the types of communication, activities, experiences, and expressions it empowers, evading functional fixedness and over-reliance on one preferred medium. From our HDUL research, future math teachers explored the expanded functionality of WHDs as tools for computation, modeling, and visualization, compared to the limited academic purposes of graphing calculators. In RtR, WHDs' integration of text and images with the physical world engaged multimodal learning and encouraged analyzing and comparing different types of media, supporting NLS.

Second, NLS captures learning based on collectively seeking, sieving, and synthesizing experiences rather than individually locating and absorbing information from a single best source. Although HDUL participants individually gathered survey data with their WHDs, the total data sample was expanded when these individual datasets were aggregated, allowing participants to unpack and analyze the observed phenomena as a whole class and draw conclusions collectively. Disparate evidence from virtual people, digital items, and the physical environment caused RtR participants to sift through and synthesize information from multiple sources. No single role provided a complete or fully accurate account of what happened at Lexington. Afterward, participants relied on one another to collectively interpret, edit, and categorize information in determining who might have fired the first shot and initiated the battle. Providing opportunities for collective learning and multiple sources of data helps to enhance NLS.

Third, NLS value active learning based on experience (real and simulated) that includes frequent opportunities for reflection. HDUL participants used WHDs to completed exercises that summarized and displayed perceptions and beliefs. Similarly, HDUL participants used WHDs and probeware to collect and analyze scientific data in real-time. By making this information visible, participants were provided opportunities to reflect on and reevaluate their understanding of complex concepts and ideas with fellow students. Through the facilitation of the instructor, participants reexamined their meaning making by reflecting on prior knowledge, observations, and explanations put forth by peers, moving toward deeper and more complete understandings. Results from RtR show participants were motivated to reflect on their learning through the sharing of findings and ideas with other participants. Participant pairs considered evidence and drew conclusions; collaborating as a role supported critical skills such as decision-making and teamwork. By planning for NLS, educators, researchers and designers have the opportunity to harness WHDs inside and outside of formal and informal learning environments creatively.

As evidenced by this chapter, handheld devices enabled by wireless connectivity have the ability to engage neomillennial learning styles in people of all ages. Although HDUL and RtR provide rich contexts for exploring NLS, additional work is needed to more fully understand immersive learning that blends the real and virtual worlds.

CASE STUDY — *Ms. Clarke's Seventh Grade Class Visits an Augmented Zoo*

To provide insight and make concrete the design and research heuristics we discuss in this chapter, we provide the following vignette to help educators, designers, and researchers plan for NLS.

Ms. Clarke passed out WHDs to her middle school science class as they traveled to the nearby city zoo to study variation in form and function of legs, eyes, ears, and teeth of different animals. Some kids preferred to use their own personal devices, which were repurposed for the day's activities; others were content to use the school's devices. While the majority of the students had previously worked with handhelds, many had not, but found the interface similar enough to navigate easily through standard applications (e.g., a web browser, a word processor, a spreadsheet).

On arrival, students disbanded into random groups to explore various exhibits. As Brian, Diane, and Jody, a trio of seventh graders, set off to find the panda exhibit, they activated their devices and quickly found the zoo's interactive website. Pulling up a map of the zoo, Brian noticed a series of small, slowly moving dots, which he assumed to be his classmates, and one that began pulsing, which he assumed represented him. Built into each of the devices was a GPS receiver that showed the location of all the students. Since Brian was only interested in his teammates' locations, he designated them with a different color. Ms. Clarke, prior to arrival, had enabled the devices to show only the members of the class while ignoring everyone else in the zoo with similar devices. This feature also allowed her to keep track of everyone in the class, whom they were with, which exhibits they went to visit, and for how long.

As Brian leaned over to show Diane the flashing dot on his handheld screen, Diane was ready to show Brian and Jody that she had figured out how to use the device to locate all of the animal exhibits at the zoo, including the pandas. Hearing this news, the three set off and quickly found themselves in front of the panda exhibit. After reading the standard placards, Jody mentioned that she had visited the zoo's panda exhibit online prior to their trip. As Ms. Clarke requested, each kid then used their device to capture at least one digital picture of various animals and record a brief audio summary of their initial thoughts and reflections of the animal's mobility, reach and grasp, vision, hearing, and eating habits. After collecting panda information together, the trio split up and each explored different animals throughout the zoo. Periodically, they used VoIP and SMS to communicate and share findings they found particularly interesting.

At the crocodile exhibit, Diane used her WHD to simulate the audio and visual senses of a saltwater crocodile—the largest living crocodilian species—above and below water. Diane was struck by the animal's keen sight and hearing, especially at night and underwater. The feature she liked best, however, allowed her to construct her own crocodilian species. As she manipulated the dimensions of her super croc, she realized how and why nature selectively determines proportions and functions. The first eight crocodiles she constructed immediately died because they were either too heavy, couldn't swim, or weren't able to eat nourishing foods. Based on her deepened understanding of why a saltwater crocodile looks, acts, and moves the way it does, she saved the new species's parameters and added them to the class database. Diane looked forward to the class discussions of the database, as it would give her a chance to reexamine her and other's discoveries.

As the visit ended, each of the participants transferred their images, audio files, and other data to a remote server via FTP for later use. As the participants traveled away from the zoo, Ms. Clarke asked what students would like to do with their collected information, having several plans in mind, but encouraging students to debate their own ideas. After some discussion, Jody suggested a collective digital diary that could be shared online with friends, family, and next year's group. This, when put to a vote, won by a landslide.

In this case study, we provide a vignette in which a group of middle school students visit a local zoo augmented with virtual data and experiences.

Questions:

1. Based upon your understanding of neomillennial learning styles, what are the strengths and limits of the type of learning in this vignette?
2. In what ways could the learning environment better address neomillennial learning styles?
3. How would this case be similar and different if WHDs were removed from the story?
4. What other ways could the WHDs have been used to support critical inquiry, and to apply the students' learning to other disciplines?

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