Neomillennial Learning Styles and River City

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Abstract
Evidence for the present study derives from a sample of 574 middle-grades students that participated in the River City Project (RCP) in academic year 2006-07. Central to the RCP is an open-ended video-game-like learning innovation for teaching inquiry-based science and twenty-first century skills. Results of investigation into the students’ neomillennial learning styles revealed that, on average, students who (1) prefer creating and sharing artifacts through the Internet are well-suited for learning about disease transmission and scientific problem solving skills in the RCP; and (2) students who feel highly connected with the media, tools, and people they use for communication, expression, and problem solving in the RCP are more likely to believe they are able to complete activities common to practicing scientists. However, students who avoid the same activities and/or do not share the same predilections may not do as well in RCP.

Keywords: learning styles, multi-user virtual environments (MUVE), Millennials, neomillennial learning styles, River City Project, video games
Introduction

Nine of the ten best selling computer games of 2007, such as Blizzard Entertainment’s *World of Warcraft* and Electronic Arts’ *The Sims*, are multi-user virtual environments (MUVEs)—virtual spaces in which users control digital representations of themselves (avatars) to engage digital content and interact with fellow users to complete various kinds of tasks (Entertainment Software Association 2008). Immersion through MUVEs supports learning that is rooted in the activities, cultures, and theories of a discipline or community of practice (i.e., Situated learning) and distributed across external cognitive artifacts, groups of people, and space and time (i.e., distributed learning) (Dieterle and Clarke 2008). For these reasons, MUVEs are capable of engaging the situational and distributional nature of thinking, learning, and doing in ways that traditional educational computer innovations, such as PowerPoint slides and multimedia video clips, cannot facilitate (Dede et al. 2007). Consequently, a growing number of projects—based primarily at research universities—have been exploring MUVEs for teaching and learning.

Contemporaneous to the growth of MUVEs, educators and policy makers alike began to stress the need for students to develop scientific inquiry (National Research Council 2000, 2007), which is the art and practice of investigating the natural world empirically, and “twenty-first century skills” (Partnership for 21st Century Skills 2008), which are the skills students need to know to thrive in a twenty-first century democratic society. Harvard University developed its River City Project (RCP) with these guidelines at its core, striving to develop students’ understanding of science through the technology of a MUVE. For nearly a decade, funding from the National Science Foundation has allowed the RCP to develop and refine its MUVE while investigating the technology’s strengths and limits for teaching scientific inquiry and twenty-first century skills to middle-grades students (sixth to ninth grade). Through the RCP, researchers have gained understanding into human-computer interaction with regard to the River City interface (Dede, Ketelhut, and Ruess 2002), students’ beliefs in their abilities to do science and scientific investigations (Ketelhut 2007), emerging research methodologies (Nelson et al. 2005), and issues of scale—the challenges and opportunities of bringing River City to diverse schools, classrooms, and students across North America (Clarke and Dede 2008; Nelson et al. 2007).

An emergent area of MUVE research that has come out of the RCP considers the relationships between the immersive properties of MUVEs and their ability to support new learning styles, a psychological construct designed to help explain the learning process. “Neomillennial” learning styles (NLS) are characterized by (a) fluency in the use of and expression through multiple media; (b) learning based on collaboratively seeking, sieving, and synthesizing experiences rather than individually locating and absorbing information from some single best source or medium; (c) active learning based on real experiences, simulated experiences, or a blending of both; and (d) co-design of learning experiences personalized to individual needs and preferences (Dede 2005).

To understand how and why engagement with specific learning innovations might support NLS, previous empirical studies utilized interview and participant
observation data to develop case studies that illustrate, explore, and evaluate NLS in relation to different immersive learning innovations used in formal and informal learning environments (Dieterle, Dede, and Schrier 2007). The results of these case studies expanded and extended the NLS construct in general, but did little to describe or measure the extent to which individuals exhibit various dimensions of NLS. As a result, research necessitated the development of NLS profiles—compilations of individuals’ partiality or disposition on a collection of previously defined psychological constructs—to account for and accurately depict variation among individuals.

To explore the variation of NLS profiles among individuals, the present study utilizes a quantitative approach, including principal components analysis and multiple regression/correlation analysis, to understand the implications of when and to what extent middle-grades students prefer to think and learn with a variety of media while completing a range of tasks.

The paper first describes the River City Project and the state-of-the-art of research into learning styles generally, and media-based, neomillennial learning styles specifically. Subsequently, the research methods section describes who is included in the present study, the instruments used to collect data, and what the instruments intend to measure. The results section provides a multiple regression/correlation analysis of NLS and two dimensions of success in River City: science content understanding and self-efficacy in scientific inquiry. The discussion section summarizes findings from the study and reviews additional factors that contribute to NLS. Finally, the paper offers some concluding thoughts on the subject of the present study.

**River City**

The heart of the River City Project is “River City,” an interactive computer simulation of a river town in the late 1800s. The MUVE (Figure 1) contains middle school content developed from National Science Education Standards (National Research Council 1996), National Educational Technology Standards (International Society for Technology in Education 2007), and 21st Century Skills (Partnership for 21st Century Skills 2002). River City is a replacement curriculum designed around topics that are central to biological and epidemiological subject matter, spanning the domains of biology, chemistry, earth science, ecology, and health/life sciences, as well as history. From beginning to end, the RCP requires approximately 17 hours to complete.
Based on authentic geographical, historical, and sociological conditions, River City is a town besieged with health problems from three simultaneous diseases—Escherichia coli, malaria, and tuberculosis. The mayor of River City has commissioned students to travel back in time, bringing their twenty-first-century knowledge and technology to address the nineteenth-century epidemic. This situation allows students to be scientists in a learning environment of intermediate complexity. It is less complex than the real world, which can be overwhelming, but more complex, authentic, and nuanced than a "cookbook" lab.

In contrast to many of the other historically significant scientific discoveries middle school students might investigate, such as continental drift and classical mechanics, the study of germ theory and disease transfer are ideal subjects for study and investigation during the middle grades (American Association for the Advancement of Science 1993). Since the least sophisticated person from the twenty-first century knows more about disease and disease transmission than the most sophisticated person from the nineteenth century, all students have opportunities for success in River City regardless of prior academic achievement.

The affordances of the River City MUVE allow students to (a) traverse the virtual world, (b) communicate with River City residents and teammates, (c) manipulate virtual instruments (e.g., a microscope), and (d) collect, manipulate, and analyze data.
As depicted in Figure 2, the “View and Action Space” allows users to change their viewpoints (how they view the three-dimensional space inside the MUVE) and enables their avatars to perform different actions (such as spinning, jumping, and waving) in order to support a feeling of “being there” when immersed inside the virtual environment. Each avatar has a different set of emotive actions (emotes) he, she, or it can perform.

The “Virtual Space” (Figure 2) contains the three-dimensional world of River City, which users navigate and explore through control of their avatars. The Virtual Space includes interactive people, objects, and tools that carry information about River City. The “Chat Window” displays all dialogue between (a) a user and River City residents and (b) a user and his or her teammates. While in River City, users can see avatars of all other visitors and residents, but can only communicate with residents and teammates. The “Student Workspace” both collects and provides information through authentic tools (e.g., bug catcher nets), engaging characters, and an interactive map.

Students work in teams of three inside and outside the MUVE. Except in rare situations, such as incidents of excessive student absence, students remain on the same team throughout the class participation in the RCP. Early project implementations in schools revealed that teams larger than three often resulted in one or more student voices getting lost within the team. At the same time, teams of two frequently resulted in students having to work individually when their
teammate was absent, the consequence of which was student frustration and poor team performance. In addition to team size, researchers considered both formal and informal role assignments in the RCP. Conversations among project researchers and participating teachers concluded that students should not be assigned roles in River City. Many students find a new voice in mediated virtual experiences (Dede, Whitehouse, and Brown-L’Bahy 2002), and a free-form team structure better supports the development of emerging leadership and the distribution of activity among River City students.

Throughout the RCP, student teams collect data, form hypotheses, develop controlled experiments to test their hypotheses, and make policy recommendations to the mayor based on their empirical findings. The experiments that students construct, as dictated by their directive from the mayor, must be realistic, socially responsible, and help her chances for reelection. As student teams decipher and discern the conditions affecting River City’s health, they learn how disease spreads and how human actions in one place can produce positive, negative, or negligible effects far from the initial site. Teams of students within the same classroom follow multiple threads of inquiry that potentially lead to very different hypotheses, experiments, and datasets. Similar to the complexities of studying real-world phenomena, not all teams of students arrive at the same conclusions, even when provided the same conditions, tools, and opportunities. Variations among conclusions help students begin to learn that the world is a complex place in which multiple perspectives exist and “truth” is often a matter of evidentiary interpretation and point of view.

Learning Styles

Learning style is a psychological construct designed to help explain the learning process—a complex and nuanced phenomenon shaped by physical and mental development, personal interests, and sociocultural influences. Modern styles scholars have rejected earlier axioms that learning styles are inflexible and solely determined by ability and personality. Researchers now tend to view learning styles as (a) shaped by physical and mental development, personal interests, and sociocultural influences; (b) guided by preferences in the use of abilities, not abilities themselves; (c) existing within all people in varying degrees, resulting in profiles of styles; (d) variable across tasks and situations, having the potential to change over time; (e) measurable, teachable, and socializable; and (f) variable in terms of flexibility and adaptability within people (Dieterle 2008; Sternberg 1997; Sternberg and Zhang 2001; Zhang and Sternberg 2006).

Media-Based Learning Styles

Keefe (1987) defines learning styles as a composite of (a) cognitive styles, which consider concept formation and retention as well as sensory reception; (b) affective styles, which consider attention, expectancy, and incentive; and (c) physiological styles, which consider the functions and activities of human organisms, including all physical and chemical processes. Media-based learning styles, then, account for the impact of various media on cognitive, affective, and physiological preferences in how people think, learn, and come to understand their worlds—the real, the
augmented, and the virtual. Figure 3 illustrates the interconnectedness of various styles definitions and constructs (Dieterle and Murray in press).

**Figure 3. A nested categorization of various styles constructs and definitions**

### Learning Styles
- a composite of (a) cognitive styles, which consider concept formation and retention and sensory reception; (b) affective styles, which consider attention, expectancy, and incentive; and (c) physiological styles, which consider the functions and activities of human organisms, including all physical and chemical processes

### Media-Based Learning Styles
- psychological constructs that measure the impact of media on cognitive, affective, and physiological preferences in how people think, learn, and come to understand their worlds

### Neomillennial Learning Styles
- psychological constructs that measure the impact of immersive media on cognitive, affective, and physiological preferences in how people think, learn, and come to understand their worlds, the real, the augmented, and the virtual

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**Media-Based Learning Styles and Three Interfaces**

In the late 1990s, media-based learning styles scholars focused their attention almost exclusively on the world-to-the-desktop interface, which currently dominates human-computer interactions (Howe and Strauss 2000; Tapscott 1998). 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. Advocates of “Web 2.0” herald the affordances of this interface and the advances made in the ability to consume and construct within it (Hardman and Carpenter 2007).

This world-to-the-desktop interface, however, is but one of three complementary interfaces destined to shape and change the theory, design, policy, and practice associated with educational technologies (Figure 4). Participants accessing MUVEs, a second interface, may (a) access virtual contexts, (b) share virtual experiences, (c) see what cannot be seen by the unaided eye because it is too small, too large, too slow, or too fast, (d) visualize what is improbable or impossible, (e) hear what cannot be heard without amplification or filtration, (f) interact with and create digital artifacts, (g) represent themselves through “avatars,” which can be graphical or text-based, or (h) communicate with other participants synchronously, asynchronously, or both via text, audio, video, or a combination thereof.

Ubiquitous computing, a third human-computer interface, provides dynamic, temporal, and contextually specific tools and media in which computers are no longer perceptually foregrounded (Greenfield 2006). Instead, interactivity is integrated seamlessly and imperceptibly into daily activities. On a variety of scales, users obtain ever-present connectivity and access to capture, process, send, and
receive information through multiple devices anytime and anywhere. As computation and interconnectivity emerge among the countless devices in which we interact, our surround begins to “come alive” as partnerships develop between users and their devices, devices and augmented environments, and multiple users through their devices. Utilizing the affordances of this human-computer interface provides dynamic hybrid situations that blend virtual and physical resources supporting sophisticated instructional designs (Dieterle and Dede 2006). Early learning and teaching implications for ubiquitous computing have been realized through participatory simulations and augmented realities (ARs) made possible through wireless handheld computers (van ’t Hooft and Swan 2006; Dieterle 2006; Klopfer 2008).

**Figure 4. Three complementary human-computer interfaces that are reshaping thinking, learning, and instruction**

![World-to-the-Desktop](image1.jpg), ![Multi-User Virtual Environment](image2.jpg), ![Augmented Reality made Possible through Ubiquitous Computing](image3.jpg)

One primary difference among the world-to-the-desktop interface, MUVEs, and ubiquitous computing is immersion and its resultant “presence.” Presence is a perceived state of being present with others or in a place other than where the user is located physically (Winn 2003). Inducing presence depends in part on the ability to empower actions and activity while facilitating affective factors that influence learning, such as emotional awareness, self-control, and self-efficacy (Dede 1995). Given that the world-to-the-desktop interface is context-independent, it cannot bring about a sense of “being there” to the same extent that MUVEs and ubiquitous computing can. The sense of “presence” in a virtual world or an augmented reality facilitated by ubiquitous computing makes possible learning that goes beyond interaction with the world-to-the-desktop interface.
As an illustrative example contrasting learning through an immersive versus non-immersive interface, a student studying the American Revolutionary War with the
world-to-the-desktop might communicate with historians via email or join a listserv
devoted to the Revolutionary War, thus beginning an ongoing exchange of ideas
and questions. This ebb and flow of information through the world-to-the-desktop
interface, however, is not generally characterized as immersive. The learner is not
part of the events he or she is studying; he or she is a distant observer instead of
an active participant. Schrier’s (2007) “Reliving the Revolution” (RtR), on the other
hand, uses wireless handheld devices to support an augmented reality game that
teaches 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 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 device 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 devices 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.

“Neomillennial” Learning Styles
Research on various types of immersive, personalized, and interactive media led
Dede (2005) to propose new media-based learning styles. “Neomillennial” Learning
Styles (NLS), made possible by the advancements in immersive human-computer
interfaces, are present in varying degrees in learners of all ages (Dede et al. 2007).
The sections that follow unpack each of the following characteristics of NLS as they
relate to the RCP (Dede 2005):

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

• Learning based on collectively seeking, sieving, and synthesizing experiences
rather than individually locating and absorbing information from some single
best source; preferring communal learning in diverse, tacit, situated
experiences; valuing knowledge distributed across a community and a
context, as well as within an individual.

• Active learning based on experience (real and simulated) that includes
frequent opportunities for embedded reflection; valuing bicentric, immersive
frames of reference that infuse guidance and reflection into learning-by-
doing.

• Expression through nonlinear, associational webs of representations rather
than linear stories (for example, authoring a simulation and a Web page to
express understanding rather than writing a paper); using representations
involving richly associated, situated simulations.

• Co-design of learning experiences personalized to individual needs and
preferences.

Fluency in Multiple Media
Across their experiences in the RCP, students work with a range of media (e.g.,
online laboratory notebook, a synchronous chat tool, a virtual world, paper-based
materials, simulated tools) for varying purposes, which capitalizes on the distributed and situated nature of learning. Dieterle and Clarke (2008) provide a detailed discussion and analysis of how educators and designers can use MUVEs to support the situated and distributed nature of cognition within an immersive, psychosocial context, using River City as an informative case study.

Activity in the RCP involves students shifting their mental concentration between different media, while learning the strengths and limits of each medium. In previous years, students used a paper-based Laboratory Notebook to navigate the River City curriculum. In academic year 2007-08, the RCP team overhauled the paper resource, integrating “The Guide” into the River City MUVE. Students use “The Guide” as their primary resource for navigating the River City curriculum. The online notebook is housed within “The Guide.” Students are prompted to record ideas, observations, inferences, and reflections directly into the MUVE via the online notebook. Students are easily able to review and retrieve their responses at anytime during the project from any computer connected to the Internet with the River City MUVE installed.

In contrast to the reflective responses included in the online notebook, the team chat tool affords student teams to “instant message” with one another and with residents of River City synchronously. The interface is constrained so that students on different teams cannot see each other’s text. In addition, students on the same team cannot see the conversations their teammates have with River City residents.

Students devote approximately two-thirds of the 17-hour curriculum using a computer to access the River City MUVE, complete surveys, or analyze data collected from the simulation. The rest of the time, students are working face-to-face, either with their team or as a whole class. Within their face-to-face team meetings, students are provided structured time to reflect on the activities they have completed and strategize next steps.

Each of these media—“The Guide,” the online notebook, the team chat, and face-to-face—have both strengths and limits when it comes to working with and collaborating on the different experiences developed for River City. To maximize their participation in the MUVE, students must move fluidly between media and optimize their ability to gather and interpret information from each medium. In this way, students realize the opportunities of each medium without overly relying on any single source of information.

Collectively Seeking, Sieving, and Synthesizing
As students progress through the RCP, they advance through four different seasons chronologically and two different worlds. During their first four trips to River City, students learn (a) the differences between observations and inferences, (b) how to use scientific tools, (c) specialized language used within the scientific community, (d) the scientific method, (e) how to articulate a testable research question, and (f) the steps for constructing and completing a controlled experiment. By the end of summer (July 1879), teams of students have agreed on a research question and have described in detail their controlled experiment. On entering the control world,
students complete the controlled portion of their experiment. During their final trip to River City, students enter the experimental world and test their experiment.

**Table 1. Informational sources available in the River City Multi-User Virtual Environment by location and functionality**

<table>
<thead>
<tr>
<th>Information Source</th>
<th>Location</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admissions Chart</td>
<td>Hospital</td>
<td>Lists dates and symptoms for admitted patients. Differences in patients’ residency and symptoms help students to identify diseases.</td>
</tr>
<tr>
<td>Bug-Catchers</td>
<td>Scattered throughout River City. Near water sources.</td>
<td>Allows students to determine the mosquito density of different geographic areas over time. Areas near standing water in the summer, for example, have greater mosquito density than areas near rapidly moving water in the winter.</td>
</tr>
<tr>
<td>Clue Pictures</td>
<td>Scattered throughout River City. Found on walls of building.</td>
<td>Illustrates events of the 1880s. Information on Dr. Richards and Dr. Koch, for example, can be found by clicking on pictures on the walls of the University. These are authentic historical figures in science and their research is portrayed accurately in River City.</td>
</tr>
<tr>
<td>Environmental Health Meter</td>
<td>Travels with student</td>
<td>A dynamic tool for measuring the general environmental health of an area. Areas near the dump, the tenements, and horse droppings are much less healthy than other areas.</td>
</tr>
<tr>
<td>Library Books</td>
<td>Library</td>
<td>Includes an online dictionary and “Introduction to Scientific Research.” Students access the online dictionary by clicking on the dictionary at the main desk in the River City library when they are unsure of a word’s meaning. In the book titled “Introduction to Scientific Research,” students can find more information on such topics as (a) an observation and an inference, (b) independent and dependent variables, and (c) control and experimental groups.</td>
</tr>
<tr>
<td>River City Residents</td>
<td>Scattered throughout River City</td>
<td>Can be interviewed to find out clues to why residents are falling ill. Residents provide a single piece of information in each season and/or world, but that information varies between seasons and worlds.</td>
</tr>
<tr>
<td>Sights and Sounds of River City</td>
<td>Throughout River City</td>
<td>Vary from season to season and world to world. The intensity of coughing residents is greater in the tenements during wintertime. The leaves on trees, on the other hand, are rich and green in the spring and summer, multi-colored in fall, and absent in winter.</td>
</tr>
<tr>
<td>Water Sampling Stations</td>
<td>Scattered throughout River City. Near water sources.</td>
<td>In the microscope field, students observe two kinds of microbes, water borne anthrax and E Coli. To analyze the water, students count the number of each microbe. Afterward they repeat the procedure until they have collected enough samples for their experimental purposes. Areas near the dump and bog during the warmer seasons have greater numbers of microbes than other areas and seasons.</td>
</tr>
</tbody>
</table>
The MUVE includes eight tacit sources for information that students use to
determine why residents are becoming sick, each of which is described in Table 1. The multivariate problems that students study in River City are too complex for
students to explore individually within the allotted time. Therefore, teams
collectively seek, sieve, and synthesize experiences from multiple sources, rather
than individually locating and absorbing information from some single source.

Together, teams of students use their collective knowledge and understanding to
formulate, enact, and interpret their controlled experiments to understand why
residents are becoming sick. Each teammate does not need to become an expert in
all aspects of the project as long as he or she understands who on the team can
address specific problems.

The media by which each generation records and transmits information decisively
determines the character of that culture (McLuhan and Gordon 2003; Jenkins
2006). On the one hand, mass media—including, but not limited to magazines,
newspapers, radio, and television—are produced primarily by a few controlling
sources and consumed by many. Emergent media such as blogs, wikis, podcasts,
and videoblogs, on the other hand, easily allow the masses to produce new artifacts
or rework existing materials into something unique and consume such media that
they and others have produced (Jenkins 2006). Activity with such media is the
foundation upon which Jenkins and colleagues (2006) have defined the
“participatory culture.” Participatory culture is built: (1) with relatively low barriers
to artistic expression and civic engagement, (2) with strong support for creating
and sharing one’s creations with others, (3) with some type of informal mentorship
whereby experienced participants pass along knowledge to novices, (4) where
members believe that their contributions matter, and (5) where members feel some
degree of social connection with one another.

The participatory culture is of special interest to educators because of its potential
to cultivate a learning community. Bielaczyc and Collins (1999) define a learning
community as having: (1) diversity of expertise among its members, who are
valued for their contributions and given support to develop; (2) a shared objective
of continually advancing the collective knowledge and skills; (3) an emphasis on
learning how to learn; and (4) mechanisms for sharing what is learned. As
Bielaczyc and Collins (1999, 272) argue,

If a learning community is presented with a problem, then the learning
community can bring its collective knowledge to bear on the problem. It is
not necessary that each member assimilate everything that the community
knows, but each should know who within the community has relevant
expertise to address any problem.

Active Learning with Metacognition
People who are not professional writers report that they learned to write on the job,
not in school (Anderson 1985). Through a curriculum that models workplace
settings in which writing is an expected and valued form of communication,
students in River City learn by doing, completing increasingly complex tasks that
put their understanding to work. Students demonstrate and deepen their understanding of the phenomena studied in River City by frequently writing about what they know and why they think they know it through “Time to Reflect” activities, memos to the mayor, and a report to the mayor.

At the end of each season, students first complete a “Time to Reflect” activity and then write a memo to the mayor, providing her with an update of the group’s work. The “Time to Reflect” activities are completed individually and recorded in the online notebook. To think about what they know and what they want to learn, students use sentence starters like: “What I know about my problem so far is,” “I wonder why,” “I’m curious why there is,” “I still have questions about,” and “When I visit River City again I want to find out.” Afterward, students synthesize their reflections into a memo to the mayor, providing her with a brief report of what they have done so far.

All students demonstrate their understanding of scientific inquiry and disease transmission by independently writing evidence-based, scientific reports to the Mayor of River City. Their reports include explanations of why so many residents are becoming ill and recommendations of how to alleviate the problem by drawing on their River City experiences. As a result of this performance assessment, students both demonstrate and deepen their understanding of this complex socioscientific situation.

**Expression through Webs of Representations**

Many of the assessments used to capture what students know that are found in current practice are: set in a standardized format of multiple choice questions and brief constructed responses; administered to test individual, unaided knowledge instead of team-based understandings; and phrased as a collection of questions without continuity or context, with limited connections to situational authenticity or meaning to the students completing the assessment. Overcoming each of these shortcomings, River City students are given an opportunity for apprenticeship and reflection of their understanding through interactions with Kent Brock, an investigative reporter who is symbolic of the “wise fool”—someone who asks obvious questions that bring about reflection and reexamination of beliefs or understandings.

Students’ exchanges with Kent allow for expression and performance of understanding through multiple representations. On the one hand, Kent interviews students to find out what they know and how they are making meaning of their experiences. As a good reporter, he is concerned by more than just the facts, asking students to explain, interpret, and apply what they are learning, as well as to empathize with residents and to engage in metacognition about their ideas (based on Wiggins and McTighe 2005). On the other hand, Kent provides students with information to make sure they have interviewed important residents and accessed significant tools and artifacts found through the town of River City. Optional homework assignments ask students to review and edit articles written by Kent before they go to press at the River City Telegraph. Sprinkled throughout the
articles are key ideas that students may have missed as well as misconceptions that students are intended to correct.

**Co-Design of Learning Experiences**

Inquiry-based science is fundamental to the River City curriculum. Throughout the process of inquiry-based learning, River City students accomplish four core goals. First, River City students are engaged by scientifically oriented research questions that they develop as a team, which seek to help the town determine why residents are becoming sick. They test these questions in a controlled experiment facilitated by the River City MUVE. Second, students give priority to evidence, which allows them to develop and evaluate explanations that address their research questions. Third, students formulate explanations from evidence that address their research questions in a report to the mayor. Fourth, students evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding, at the end of project through a research conference in which each team shares its findings with other teams.

To attain these goals, River City’s student-centered curriculum involves orchestration among members of the research team and participating teachers and students; this can be understood through a music metaphor: the research team are the composers, teachers are the conductors, and students are the musicians. All three groups work in harmony to co-design learning experiences that are personalized to individual needs and preferences, while adhering to the spirit of the curriculum.

As composers, the research team has invested almost a decade of time and effort developing and refining River City by means of design-based research methods, blending empirical educational research with theory-driven design of learning environments (The Design-Based Research Collective 2003).

Teachers, in turn, receive the curriculum and act as conductors, using knowledge of the local culture and school setting to get the most out of their students. The teachers’ role in River City is to guide students’ performance through an immersive scientific inquiry experience. Teachers act as twenty-first century experts who encourage students to problem-solve rather than as sages who provide answers. Since teachers do not travel back in time with students, they can admit to not know why residents are ill. Day-to-day, teachers orient students to the day’s activities, help students prioritize the day’s activities based on class needs, check that students have achieved goals before progressing, and assess student progress.

Diversity of prior knowledge among students provides a wealth of experience and knowledge upon which teams can draw to engage the complexities River City provides. Just as musicians tend to specialize, not all students need to master every aspect of the project equally well. Instead, teammates play off each other’s strengths while buoying up their collective weaknesses to produce the best team performance possible.
The Present Study
To explore the variation of NLS profiles among individuals, the present study utilizes principal components analysis and multiple regression/correlation analysis to understand the implications of when and to what extent middle-grades students prefer to think and learn with a variety of media while completing a range of tasks. The sections that follow summarize who participated the study, the instruments they completed, what the instruments measured, what analysis of the data generated from the instruments reveal, and a discussion of the relevance of the findings.

Sampling Method
Evidence supporting the arguments laid out in this article derives from a sample of middle grades students who participated in the RCP in academic year 2006-07. From a convenience sample of approximately 800 students, approximately 30 percent of students were removed from the dataset, primarily because they did not complete all parts of the RCP. The final dataset, as illustrated in Table 2, includes 574 students from diverse geographic regions (urban, suburban, and rural school settings), school grades (spanning grades 6-9), genders, and race or ethnicity. The average age of participating students when they begin the RCP is just under 13 years ($M = 12.98$, $SD = 0.98$). In relation to all of the students that participated in the RCP in academic year 2006-07 ($n \approx 3,000$), the sample included in the present study is a reasonable cross-section of those who participated in the larger project.

Table 2. Demographic information for 574 River City students in the present study

<table>
<thead>
<tr>
<th>Demographic Characteristic</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>304</td>
<td>52.96</td>
</tr>
<tr>
<td>Male</td>
<td>270</td>
<td>47.04</td>
</tr>
<tr>
<td><strong>Race or Ethnic Background</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian or Alaska Native</td>
<td>22</td>
<td>3.83</td>
</tr>
<tr>
<td>Asian</td>
<td>25</td>
<td>4.36</td>
</tr>
<tr>
<td>Black or African American</td>
<td>102</td>
<td>17.77</td>
</tr>
<tr>
<td>Native Hawaiian or Other Pacific Islanders</td>
<td>1</td>
<td>0.17</td>
</tr>
<tr>
<td>Hispanic or Latino (of any race)</td>
<td>110</td>
<td>19.16</td>
</tr>
<tr>
<td>White or Caucasian</td>
<td>255</td>
<td>44.43</td>
</tr>
<tr>
<td>Multiracial</td>
<td>59</td>
<td>10.28</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th</td>
<td>298</td>
<td>51.92</td>
</tr>
<tr>
<td>7th</td>
<td>141</td>
<td>24.56</td>
</tr>
<tr>
<td>8th</td>
<td>121</td>
<td>21.08</td>
</tr>
<tr>
<td>9th</td>
<td>14</td>
<td>2.44</td>
</tr>
<tr>
<td><strong>School Setting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural Schools</td>
<td>72</td>
<td>12.54</td>
</tr>
<tr>
<td>Suburban Schools</td>
<td>175</td>
<td>30.49</td>
</tr>
<tr>
<td>Urban Schools</td>
<td>327</td>
<td>56.97</td>
</tr>
</tbody>
</table>
Data Collection Methods
Three web-based measurement instruments completed individually by students captured all of the student-level data used in the present study. All three measurement instruments are housed on Survey Monkey (http://www.surveymonkey.com), a commercial online surveying tool. The interface structure draws on Schonlau, Fricker, and Elliott’s (2002) design recommendations for conducting survey research through the Internet.

All students participating in the RCP complete the first two measurement instruments, the River City Pre- and Post-Surveys. The third measurement instrument, the Media-Based Learning Style Inventory (MBLSI), is specific to the present study. Collectively, these three measures assess (a) access to, frequency of, and activity associated with various technologies and media; (b) students’ preferences in thinking about and engaging in different activities with a range of technologies in a variety of situations; (c) thoughtfulness of inquiry; (d) self-efficacy in science; (e) collaboration; (f) self-efficacy in scientific inquiry; and (g) science content understanding. A detailed explanation of what the instruments measure follows.

Measures of Success
At the beginning of the RCP, all participating students independently complete an online pre-survey. Students complete a similar post-survey autonomously at the end of the project. Both surveys are comprised of question items that measure five dimensions of success in River City: (1) collaboration measures students’ beliefs about the importance of collaboration when completing tasks; (2) science content understanding assesses students’ understanding of disease, disease transmission, and scientific problem-solving skills; (3) self-efficacy in science measures students’ belief in their ability to do science and do well in science class; (4) self-efficacy in scientific inquiry measures students’ belief in their ability to complete activities common to practicing scientists; and (5) thoughtfulness of inquiry measures the extent to which a student uses inquiry and reflection when performing science-related activities.

The fundamental goal of RCP is to increase students’ understanding of disease and disease transmission while facilitating opportunities for students to think and act like scientists. Of the five measures of success, science content understanding and self-efficacy in scientific inquiry most closely align with RCP’s mission and are presented here. Full analysis of all five measures of success are available elsewhere (Dieterle 2008). Tables 3 and 4 include sample questions used to measure science content understanding and self-efficacy in scientific inquiry.

1 Access to the online instruments is limited to students with active RCP usernames and passwords.
Table 3. Sample science content understanding questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Option</th>
</tr>
</thead>
</table>
| 1. Which of the following statements best states the difference between an observation and an inference? | a. An inference is what you see and an observation is what you conclude based on your inference.  
                              b. An observation is a conclusion based on your inference.  
                              c. An inference is a conclusion based on your observation.  
                              d. An observation is an opinion and an inference is a known fact. |
| 2. Which of the following statements contain three ways you can catch a disease? | a. eating contaminated food, being coughed on, drinking coffee  
                              b. insect bite, microbes, being sneezed on  
                              c. bee sting, sharing needles, sharing a cup with someone who is sick  
                              d. walking in the rain, smoking, sharing needles |
| 3. One hot afternoon in July, Joan noticed that water droplets formed on the outside of a glass of iced water. Joan said, “I think that water vapor in the air is condensing on the cold glass.” What part of a scientific method was Joan’s statement? | a. forming a hypothesis  
                              b. identifying a variable  
                              c. making an observation  
                              d. analyzing data |

Table 4. Sample self-efficacy in scientific inquiry items

<table>
<thead>
<tr>
<th>Question</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I know how to use the scientific method to solve problems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I can use graphs to show what I found out in my experiment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. When I do my work in science class, I am able to find the important ideas.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I can design an experiment to test my ideas.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

Media-Based Learning Style Instrument

Social science literature abounds with instruments and theories devoted to understanding learning styles. In a recent report, for example, Coffield and colleagues (2004) evaluated some 70 learning-styles instruments and theories, spanning more than 90 years of scholarship and research. Among this collection, however, is a common lack of consideration for the effect of media, especially interactive and immersive media, on learning styles. Therefore, a Media-Based Learning Styles Inventory (MBLSI) was developed for the present study to capture (1) access to, frequency of, and activity associated with various technologies and media; and (2) individuals’ preferences in thinking about and engaging in different activities with a range of technologies in a variety of situations.

The final MBLSI is a 155-item instrument with seven additional demographic items. Construction and validation of the MBLSI follows DeVellis’ (2003) scale development and validation guidelines, an eight-step plan for the construction, piloting, and validation of instruments that measure latent variables. MBLSI items that measure access to, frequency of, and activity associated with various technologies and media
were adapted from two surveys: Lenhart, Madden, and Hitlin’s (2005) *Teens and Technology: Youth are Leading the Transition to a Fully Wired and Mobile Nation* and Roberts, Foehr, and Rideout’s (2005) *Generation M: Media in the Lives of 8–18 Year-Olds*. Items in the form of telephone-based questionnaires, opened-ended diary prompts, and paper-based surveys were scaled into Likert-like statements using Fowler’s (1995; 2002) survey research methods.

Items considering thinking styles were drawn from Sternberg, Wagner, and Zhang’s (2003) revised *Thinking Styles Inventory* (TSI). Multiple cultures and different groups have used and validated the TSI both inside and outside schools (Zhang and Sternberg 2006). However, no researcher had previously applied the TSI to middle school students in North America, the subjects of the present study. To measure Dede’s (2005) neomillennial learning styles construct, additional items were developed with the input of scholars and researchers with relevant substantive expertise to get at (a) fluency in multiple media and whether students value each for the types of communication, activities, experiences, and expressions it empowers; (b) learning based on collectively seeking, sieving, and synthesizing experiences rather than individually locating and absorbing information from a single best source; and (c) active learning based on both real and simulated experiences that include frequent opportunities for reflection.

Principal components analysis was used to develop and study eight theoretical constructs that comprise neomillennial learning styles, as summarized in Table 5. The resulting principal components were then used in subsequent correlation and multiple regression analyses.

**Table 5. Component-score principal components of neomillennial learning styles with descriptions and descriptive statistics (n=574)**

<table>
<thead>
<tr>
<th>Principal Component</th>
<th>Description</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Interquartile Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TMC_1</strong></td>
<td>Traditional Media Consumption Construct – frequently accesses and consumes an array of different traditional media—books, magazines, movies, music, newspapers, and television</td>
<td>1.37</td>
<td>-3.66</td>
<td>3.61</td>
<td>1.85</td>
</tr>
<tr>
<td><strong>TMC_2</strong></td>
<td>Traditional Media Consumption Construct – preferences in reading books, magazines, and newspapers</td>
<td>1.17</td>
<td>-2.37</td>
<td>4.06</td>
<td>1.61</td>
</tr>
<tr>
<td><strong>GVGC_1</strong></td>
<td>General Video Game Consumption Construct – frequently plays video games with different interfaces in a range of</td>
<td>1.83</td>
<td>-2.83</td>
<td>4.48</td>
<td>2.60</td>
</tr>
</tbody>
</table>
settings either individually or with others

General Connectedness with Media Construct – feels highly connected with the media, tools, and people he or she uses for communication, expression, and problem solving

<table>
<thead>
<tr>
<th>Construct</th>
<th>Description</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWM_1</td>
<td>Connectedness with Media</td>
<td>1.85</td>
<td>-6.78</td>
<td>4.00</td>
</tr>
<tr>
<td>CWM_2</td>
<td>Connectedness with Media</td>
<td>1.03</td>
<td>-3.84</td>
<td>2.81</td>
</tr>
<tr>
<td>SAS_1</td>
<td>Seek and Sieve Construct</td>
<td>1.69</td>
<td>-2.42</td>
<td>5.64</td>
</tr>
<tr>
<td>SYN_1</td>
<td>Synthesize Construct</td>
<td>1.89</td>
<td>-1.98</td>
<td>5.31</td>
</tr>
<tr>
<td>COM_1</td>
<td>Communicate Construct</td>
<td>1.67</td>
<td>-2.51</td>
<td>3.66</td>
</tr>
</tbody>
</table>

In the interest of space, only one NLS construct, "synthesize," is presented here. All other constructs are available elsewhere (Dieterle 2008).

**The Synthesize Construct**

"Synthesize" (SYN) is a theoretical construct measuring how frequently students construct or “mashup” digital artifacts. Students who construct digital artifacts tend to combine life experiences into personal or school-related webpages, blogs, artwork, photos, stories, or videos shared online. Mashups involve the reworking of existing material to form products that are more complex. A standout example of a mashup is Brian Burton’s *The Grey Album*. In 2004, Burton remixed Jay-Z’s *The Black Album* and the Beatles’ *The White Album* into a unique performance, which received much critical acclaim as well as industry backlash (Gunkel 2008). Knobel and Lankshear (2008) discuss other examples of mashups including using image processing software to blend multiple images (“Photoshopping”) and using three-dimensional video games and video-capture software to create short films (“Machinima”).
Frequency of \( \text{SYN} \) is scaled into six categories: \( 1 = \) never or almost never, \( 2 = \) once every few weeks, \( 3 = \) one to two days a week, \( 4 = \) three to five days a week, \( 5 = \) about once a day, and \( 6 = \) several times a day. Internal consistency of six items from the MBLSI relevant to \( \text{SYN} \) was assessed by Cronbach’s alpha and calculated to be 0.86. Principal components analysis was then applied to the same items using 1s as prior communality estimates. The principal axis method was used to extract the components. Only the first component exhibited eigenvalues greater than 1; results of a scree test also suggested that only the first component was meaningful. Therefore, only the first component was retained and interpreted. Component 1 accounted for 59.65 percent of the total variance of the six items. Eigenvectors of first principal component and final communality estimates are presented in Table 6.

Table 6. Eigenvectors of first principal component and final communality estimates from principal component analysis of the “synthesize” construct (\( n = 574 \))

<table>
<thead>
<tr>
<th>Items</th>
<th>( \text{SYN}_1 )</th>
<th>( h^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take material you find online—like songs, videos, text, or images—and remix it into your own artistic creation</td>
<td>0.39</td>
<td>0.54</td>
</tr>
<tr>
<td>Create or work on webpages. Such as your personal webpage, for school or class, groups you belong to, etc</td>
<td>0.39</td>
<td>0.54</td>
</tr>
<tr>
<td>Modified a computer game to be played on your own terms</td>
<td>0.41</td>
<td>0.61</td>
</tr>
<tr>
<td>Share something online that you created yourself, such as your own artwork, photos, stories or videos</td>
<td>0.44</td>
<td>0.69</td>
</tr>
<tr>
<td>Created a short video or movie from videogame play</td>
<td>0.41</td>
<td>0.61</td>
</tr>
<tr>
<td>Create or work on blogs (online journals or weblogs). Such as your personal blog, for school or class, groups you belong to</td>
<td>0.40</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Percent of variance explained individually 59.65%

Item weights on disposed to creating, mashing up, and sharing information on the internet are about equal, so each of the six items is about equally represented in the linear composite. Correspondingly, examination of final estimates of communalities reveals that all items are well-summarized by the construct. The first principal component is interpreted as a general measure of synthesizing information accessed through the Internet. A student who scores high on disposed to creating, mashing up, and sharing information on the internet frequently constructs and/or reworks digital artifacts to form more complex products through the Internet.

Results
Results of students’ pre-RCP and post-RCP surveys on dimensions of Science Content Understanding (CONTENT) and Self-Efficacy in Scientific Inquiry (SEISI) were standardized to a ten-point scale and then analyzed using a paired-samples \( t \) test. This analysis revealed a significant difference between mean levels of CONTENT and SEISI in the pre- and post-surveys (\( t(573) = 7.98, p < 0.01; \) \( t(573) = 3.47 ; p < 0.001 \)). The sample means (Figure 5) show that the mean post-survey scores were higher in the CONTENT and SEISI condition (\( M = 6.33, SD = 1.75; \) \( M = \)
6.97, $SD = 1.09$) than in the pre-survey condition ($M = 5.88, SD = 1.64; M = 6.84, SD = 1.08$). The observed 95 percent confidence interval for the difference between means extended from 0.33 to 0.55 and 0.05 to 0.19 respectively. The effect size for CONTENT was computed as $d = 0.26$; the effect size for SEISI was computed as $d = 0.11$. According to Cohen's (1992) guidelines for $t$ tests, this represents a small to medium effect for CONTENT and a negligible to small effect for SEISI. Although one might expect to see significant changes in students' science content understanding after participating in the RCP, the positive change in students' beliefs in their ability to complete activities common to practicing scientists was a less obvious result—and a testament to the benefit of participation in RCP.

Figure 5. Pre- and post-survey means of 574 River City students’ science content understanding and self-efficacy in scientific inquiry

Full and partial correlation analyses and multiple regression model fitting were performed to understand the relationships between NLS and (a) science content understanding and (b) self-efficacy in scientific inquiry. Instead of using the difference between pre- and post-surveys as dependent variables in the regression tests, the post-survey is used as the dependent variable and the corresponding pre-survey as the first independent variable entered into the hierarchical model (Cohen et al. 2003).
Full and Partial Correlation Analysis of Neomillennial Learning Styles and Dimensions of Success in River City

Table 7 summarizes the relationships between the CONTENT and SEISI post-surveys and the NLS principal components as measured by (1) the Pearson correlation coefficients of neomillennial learning styles and the two dimensions of success in River City, and (2) the Pearson partial correlation coefficients with the effect of the corresponding pre-survey removed.

Table 7. Pearson correlation coefficients of neomillennial learning styles and two dimensions of success in River City compared with Pearson partial correlation coefficients with the effect of the corresponding pre-survey removed (n= 574)

<table>
<thead>
<tr>
<th>Pre-Survey</th>
<th>TMC_1</th>
<th>TMC_2</th>
<th>GVGC_1</th>
<th>CWM_1</th>
<th>CWM_2</th>
<th>SAS_1</th>
<th>SYN_1</th>
<th>COM_1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Science Content Understanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>0.70***</td>
<td>-0.13**</td>
<td>0.13**</td>
<td>-0.18***</td>
<td>0.13**</td>
<td>-0.09*</td>
<td>-0.24***</td>
<td>-0.31***</td>
</tr>
<tr>
<td>Partial</td>
<td>——</td>
<td>-0.04</td>
<td>0.04</td>
<td>-0.15**</td>
<td>0.00</td>
<td>-0.05</td>
<td>-0.20***</td>
<td>-0.22***</td>
</tr>
<tr>
<td>Post Self-Efficacy in Scientific Inquiry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>0.70***</td>
<td>-0.01</td>
<td>0.18***</td>
<td>0.01</td>
<td>0.36***</td>
<td>-0.18***</td>
<td>0.02</td>
<td>-0.03</td>
</tr>
<tr>
<td>Partial</td>
<td>——</td>
<td>-0.03</td>
<td>0.11**</td>
<td>-0.05</td>
<td>0.17***</td>
<td>-0.07~</td>
<td>-0.05</td>
<td>-0.08~</td>
</tr>
</tbody>
</table>

Regression Model Fitting of Neomillennial Learning Styles and Dimensions of Success in River City

Using multiple regression, the post-survey for each dimension of success in River City—science content understanding and self-efficacy in scientific inquiry—was regressed on the corresponding pre-survey and neomillennial learning style constructs that revealed weak (or stronger) and significant correlations with the relevant post-survey. Each predictor was tested for significance using a general linear hypothesis (GLH) test.

Subsequently, a student’s age in years (AGE) followed by his or her academic history (AsBs), key control predictors, were introduced into the model and tested with GLH to determine whether addition of the predictor significantly improved (or failed to improve) the model. Afterward, the analyst conducted a GLH test for two-way interactions between the research question predictor(s) and subsequent predictors. Interactions were only retained if both parent predictors were significant. Predictors that had no impact on the model were removed for parsimony.

Model Fitting of Science Content Understanding Regressed on NLS

The fitted model that best measures the relationship between science content understanding and neomillennial learning styles parsimoniously for the present study is as follows (Dieterle 2008):
\[ POST\text{CON}TENT = 0.64\text{PRECON}TENT + 0.83\text{SYN}_1 - 0.08\text{AGE} - 0.99\text{SYNxAGE} \]

The overall $F$ test of the science content understanding post-survey regressed on the neomillennial learning styles constructs indicates that the final model is significant (156.75; $p < 0.0001$), with $R^2 = 0.52$.

Figure 6 is a rendering of the fitted regression model in which student’s age and pre-content survey score have been controlled. As a student’s propensity toward a synthesized style increases, his or her ability to learn the science content of the RCP also increases. In other words, such findings suggest that students with a propensity toward creating, mashing up, and sharing information on the Internet through webpages, blogs, machinima, and artistic creations are well-suited for learning about disease, disease transmission, and scientific problem solving skills. However, this analysis reveals that River City does not serve all students equally well.

**Figure 6.** Standardized, fitted regression of POSTCONTENT on SYN_1, controlling for pre-survey and age

\[ \text{Model Fitting of Self-Efficacy in Scientific Inquiry Regressed on NLS} \]

The fitted model that best measures the relationship between self-efficacy in scientific inquiry and neomillennial learning styles parsimoniously for the present study is as follows (Dieterle 2008):

\[ POST\text{SES}I = 0.62\text{PRESES}I + 0.07\text{TMC}_2 + 0.11\text{CWM}_1 + 0.11\text{AsBs} \]
The overall $F$ test of the self-efficacy in scientific inquiry post-survey regressed on the neomillennial learning styles constructs indicates that the final model is significant ($153.92; p < 0.0001$), with $R^2 = 0.52$.

Figure 7 illustrates a fitted regression model where students’ academic history, pre-content survey score, and tendency toward reading books, magazines, and newspapers have been controlled. As a student’s propensity toward a media style increases, his or her self-efficacy in scientific inquiry also increases. Such findings suggest that students who feel highly connected with the media, tools, and people they use for communication, expression, and problem solving will further their belief in their ability to complete activities common to practicing scientists by participating in River City. However, the slope of the plot reveals that, although the effect of connectedness with media is significant, it is small.

**Figure 7. Standardized, fitted regression of POSTSESI on CWM_1, controlling for pre-survey, previous academic history, and preferences toward reading books, magazines, and newspapers**

**Discussion**

This study identified two NLS profiles. First, students who prefer creating, mashing up, and sharing information on the Internet through webpages, blogs, machinima, and artistic creations are well-suited for learning about disease, disease transmission, and scientific problem-solving skills in the RCP. Second, students who prefer reading magazines, newspapers and books and, in general, feel highly connected with the media, tools, and people they use for communication, expression, and problem solving will strengthen their belief in their ability to
complete activities common to practicing scientists by participating in the RCP. However, the same conditions may undercut students who avoid those activities and do not share the same predilections.

Quantitative findings about students’ learning within the River City Project indicate that the River City MUVE can significantly impact students’ *science content understanding* and *self-efficacy in scientific inquiry*. Such findings are encouraging and suggest that on average, participation in the RCP yields increases in students’ understanding of disease transmission, the scientific method, and their belief that they can complete activities similar to those undertaken by scientists. Yet, not all students are equally benefited by participation in such open-ended learning innovations. By better understanding how MUVEs such as River City converge with individuals’ preferences for thinking and learning with various media, the educational community can better understand the strengths and limits of immersive educational innovations to maximize the learning of all students.

**Diversity within the Millennial Cohort**
The Millennial cohort consists of those born after 1982, totaling more than 100 million people living inside the U.S. (U.S. Census Bureau 2007). Put another way, about seven in 20 people currently living in the U.S are Millennials. “The most diverse group in the United States,” as Hodgkinson (2003) reports, “is our youngest children, and they will make the nation more diverse as they age.” Growing numbers of students receiving specialized services also exemplifies the Millennials. For example, of K-12 public school students in California and Texas, who account for 22.2 percent of all students in U.S. public schools, nearly half (49.0 percent and 47.7 percent, respectively) are eligible for free or reduced price lunch, about one in ten (10.8 percent and 11.8 percent) has an Individualized Educational Program, and about two in five (25.2 percent and 15.7 percent) receive English Language Learner services (Sable and Hill 2006).

**Millennials and Media**
Despite differences in race, culture, family income, and students receiving specialized services, Millennials—and U.S. teenagers in particular—share the characteristic of being highly connected to the Internet, with ready access to a variety of personal media devices. Nearly nine in ten U.S. teenagers use the Internet, and over half go online daily (Lenhart, Madden, and Hitlin 2005). In addition to access and connectivity, the majority of U.S. teenagers use multiple media simultaneously at any given time. As Roberts, Foehr, and Rideout’s (2005) work indicates, more than half of U.S. teenagers report accessing at least one additional medium either “most of the time” or “some of the time” when watching television (53 percent), reading (58 percent), listening to music (63 percent), and using a computer (65 percent). In contrast, as Roberts et al. continue, “the proportion of kids who say they ‘never’ use other media in response to these questions ranges from a low of 12 percent when listening to music to a high of 19 percent when watching TV” (36).

More interesting to educators, however, is what teenagers are doing once they get online. Among U.S. teenagers who go online, four in five play online games, three
in four access news, and just under one in three seeks out health-related
information (Lenhart, Madden, and Hitlin 2005). Besides consuming information,
nearly three in five U.S. teenagers contribute to the content of the Internet by
creating blogs and webpages; posting original artwork, stories, and photos; and
remixing existent content in novel ways (Lenhart and Madden 2005).

Millennials use the affordances of current information and communication
technologies to “meet, play, date, and learn. It’s an integral part of their social life;
it’s how they acknowledge each other and form their personal identities” (Brown
2002, 70). Nascent technologies now allow Millennials (and others) to keep track of
one another through a single website. Network aggregators, such as Spokeo
continuously search a user’s contacts across social networking sites (e.g., LinkedIn,
MySpace, Facebook), blogs (e.g., Blogger, WordPress), and online photo
management and sharing sites (e.g., Flicker, Picasa), giving up-to-the-minute
accounts of online activity.

**Millennial Learning Styles and the Brain**
The actions and activities of the Millennials have led some scholars and researchers
to suggest their media activity constitutes unique, cohort-specific effects. Raines
(2003), for example, has argued that the learning preferences of the Millennials are
gear toward entertainment, excitement, experiential activities, structure,
teamwork, and the use of technology. Their communication preferences, as Raines
continues, are characteristically electronic, goal-focused, motivational, positive,
respectable, and respectful. Today’s students are accustomed to negotiating among
various media sources and working in “a digital environment for communication,
information gathering, and analysis” (Oblinger 2004, 2). Whereas Raines connects
these characteristics to those born after 1982, this author and others assert that
these qualities are observable to varying degrees in learners of all ages who make
extensive use of modern interactive media (e.g., Dede et al. 2007).

Prensky, who characterizes those born after 1982 as “digital natives” (2001; 2006),
summarized recent advances in brain science to support an argument that
Millennials’ brains may be fundamentally different than those born after 1982,
whom he terms “digital immigrants.” Everyone associated with the education
enterprise should examine these assertions cautiously. As Bruer (1997) and Fischer
(2008) warn, overly enthusiastic educators commonly misapply and generalize
findings from neuroscience, making recommendations where only observations and
correlations, not causal explanations, exist. For example, a common misconception
holds that students who jump from one instant messaging conversation to another
while responding to an email and writing an essay for history class are processing
information in parallel. However, Millennials who are efficient multitaskers are not
running parallel processes. Instead, they are rapidly toggling between cognitive
tasks (Wallis 2006).

In a recent review of the concerns and opportunities facing the interdisciplinary
research among the education and neuroscience communities, Varma, McCandliss,
and Schwartz (2008) conclude that “even if the four scientific concerns—about the
commensurability of the methods, data, theories, and philosophies of the two
disciplines—can be surmounted in principle, the four pragmatic concerns [i.e., costs, timing, control/esteem, and payoffs] suggest that doing so will be difficult in practice.” Yet, they and other researchers are cautiously optimistic about what future collaborations between disciplines may yield for both communities (e.g., Battro, Fischer, and Léna 2008; Szűcs and Goswami 2007).

Conclusions
Adolescents in the United States today are more diverse than any previous generation in terms of race, ethnicity, and need for special services (i.e., free or reduced price lunch, Individualized Educational Program, and English Language Learner services). Despite these differences, this generation shares unprecedented exposure and access to personal and interactive media. Such media saturation has led many in the education community to draw conclusions about media’s impact on thinking and learning based on limited or missing empirical evidence, unsophisticated understandings of how people learn, misapplications of brain science, or a combination therein.

“Neomillennial” learning styles, proposed by Dede (2005) and expanded by others (Dieterle, Dede, and Schrier 2007; Dunleavy, Dede, and Mitchell 2009; Dieterle 2008; Dede et al. 2007), consider the interaction of modern styles theories with immersive and interactive technologies such as MUVEs. The NLS construct is important to educators, learning scientists, and anyone interested in the unique media-based learning styles profiles present in all learners. Although MUVEs are primarily used for entertainment purposes, a growing number of researchers are studying this interface as a tool for substantive teaching and learning because MUVEs support the situational and distributional nature of cognition with respect to thinking, learning, and doing in ways that traditional educational computer innovation cannot facilitate.

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References


