Reducing Digital Divide Effects Through Student Engagement in Coordinated Game Design, Online Resource Use, and Social Computing Activities in School

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Participating in online social, cultural, and political activities requires digital skill and knowledge. This study investigates how sustained student engagement in game design and social media use can attenuate the relations between socioeconomic factors and digital inequality among youth. This study of 242 middle and high school students participating in the Globaloria project shows that participation eliminates gender effects, and reduces parent education effects in home computer use. Further, students from schools with lower parent education show greater increases in frequency of school technology engagement. Globaloria participation also weakens the link between prior school achievement and advanced technology activities. Results offer evidence that school-based digital literacy programs can attenuate digital divide effects known to occur cross-sectionally in the general U.S. population.

Introduction

Many studies document a digital inequality in the United States; young people with higher socioeconomic status (SES) show greater depth and breadth of daily Internet use, even after controlling for Internet access (Hargittai, 2010). Research further indicates that important social, cultural, and political activities occur in online environments, and participation in such activities requires digital skills and knowledge (Hobbs, 2010; Horrigan, 2011; Jenkins, 2009; Mossberger, Tolbert, & McNeal, 2007). Through Internet use, people can acquire news and information, and build and maintain social networks of family, friends, and acquaintances, which increases one’s cultural and social capital (e.g., Hargittai, 2010; Livingstone, Van Couvering, & Thumim, 2005). Conversely, inequalities in technology access may result in knowledge gaps, educational opportunity barriers, and disparities in groups’ socioeconomic potential, all of which impede fulfillment of democratic goals and ideals (Bonfadelli, 2002).

In this study, we investigate whether it is possible to reduce the link between sociodemographic factors and the digital divide, via a year long inquiry-based technology educational intervention in schools involving game design, inquiry, collaboration, and student use of information resources provided through a learning management system. Hundreds of U.S. middle school and high school students completed a game design course offered daily during a full year, for credit and a grade. Constructionism (e.g., Harel & Papert, 1991) informed the instructional design of this educational program. A nonprofit organization developed and delivered the game design curriculum and offered coinciding learning management system resources, as well as substantive professional development training to the teachers. This organization applies a framework of “six contemporary learning practices” to prepare students to actively participate in today’s online digital environments and cultures (Reynolds, 2015; Reynolds & Harel Caperton, 2009).

We hypothesize that family characteristics (e.g., parent education), school characteristics, and program participation are linked to computer activities (computer use at home and
at school, basic and advanced computer activities). If the results show that links between family characteristics and computer activities are attenuated or eliminated after participation, such a result would support the claim that interventions designed in this way can reduce the effects of the digital divide. This research contributes to sociological and information sciences scholarship on digital inequality, and its results can inform the ongoing design and deployment of inquiry-based instruction and learning innovations such as this one involving game design, informational resource use, and social media activities.

**Literature Review**

Sociological studies have examined the digital divide in the general population. Further, substantial research on educational technologies exists for instance in the field of the learning sciences. But rarely has links in the research literature been established between learning innovations, and possible digital divide effects. Here we consider both the digital divide research and the learning sciences perspective on educational technology development. Building on these studies, we discuss the theoretical perspectives that inform the intervention we have tested, and present the study’s research questions.

**Digital Divide**

The digital divide denotes the gap between those who use versus do not use computers and the Internet. Scholars have identified two levels of the digital divide; “level 1” is inequality stemming from unequal access to technology (because of cost or inadequate infrastructure), and “level 2” is unequal user expertise (also known as digital literacy) (Hargittai, 2002). Related to the digital divide is the “knowledge gap hypothesis” (Tichenor, Donohue, & Olien, 1970), which specifies that as the infusion of mass media information into a social system increases, higher SES people tend to acquire it at a faster rate than others, which widens the knowledge gap over time.

US policy-makers have argued that the digital divide can hinder democratic participation. In 2010, only two-thirds of Americans had broadband at home; 10% of the adult population was digitally distant and 7% were digitally uncomfortable (according to the Pew organization and National Telecommunications and Information Administration and Federal Communication Commission [FCC] data; Horrigan, 2011). Barriers to home adoption include high monthly service fees, lack of computer skills, lack of awareness of broadband’s utility and relevance, and infrastructure access (Horrigan, 2011). Mossberger et al. (2007) argue that although digital citizenship—the ability to participate in society online—promotes social inclusion and political participation, significant segments of the population are excluded from digital citizenship. Strand 2 of the U.S. FCC’s National Broadband Plan of 2010 notes such political and citizen uses of technology, and focuses on a need for digital awareness and literacy efforts, such as technology learning opportunities in schools.

Whereas early research on the digital divide focused on access-oriented thinking regarding infrastructure ownership, availability and affordability (level 1), recent research has moved away from technologically deterministic conceptualizations (Barzilai-Nahon, 2006) and increasingly focused on technology users, especially their frequencies and types of use (level 2). Theoretical perspectives on technology adoption and its barriers across populations include the Technology Acceptance Model (TAM) (Davis, 1986, 1989; Venkatesh & Davis, 2000), Unified Theory of Acceptance and Use of Technology model (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003), and the Model of Adoption of Technology in the Household (MATH) (Brown & Venkatesh, 2005). These theories argue that characteristics of individuals (e.g., sociodemographic factors and perceptions of technology) influence their adoption and use of information technology (IT).

Meta-analytic synthesis of empirical research representing these three perspectives on technology adoption shows that gender and age have been the most prevalent sociodemographics investigated as contributing variables, followed by income and education level, and that people who are male, younger, richer or more educated have largely been found more likely than others to use technology (Niehaves & Plattefaut, 2013). As for digital skills, compared to women, men demonstrate higher levels (Hargittai & Hinnant, 2008). Further, the higher the level of education, the greater the self-reported digital skill, and those with higher levels of self-reported skill are more likely to visit the types of Web sites that may offer human and financial capital benefits (Hargittai & Walejko, 2008). Even among people with moderate to high levels of technology access, those with higher socioeconomic status or more schooling show more sophisticated forms of content creation, participatory engagement and digital knowledge (Pew Internet and American Life Project, 2007). Hargittai (2010) finds that those with more education and higher socioeconomic statuses have been shown to use Web-based technologies in more informed ways for a larger number of activities, and these activities have been identified for their social and cultural capital enhancing benefits, bearing implications for social mobility.

Although many studies have examined the digital divide at the country level (e.g., reporting extents of access and use in the population), few have studied digital inequality within the contexts of specific regions, communities, and social groups (Barzilai-Nahon, 2006; Dewan & Riggins, 2005). Moreover, many studies test whether a few explanatory variables are related to a dependent variable representing one aspect of the digital divide (monotopical measures) such as awareness, access, attitudes, or application—characteristic of TAM, UTAUT, and MATH (2006). Barzilai-Nahon (2006) argues that more research is needed employing integrative frameworks addressing how sociodemographic factors and governmental and social supports or constraints
are related to indices of the digital divide that include factors representing affordability, varying uses, and infrastructure accessibility (2006).

Youth. Among youth, creative activity and content sharing online have been found to be positively correlated to parental schooling (Hargittai & Walejko, 2008). However, African-American youth were found to be more likely than their white peers to use social network web services, after controlling for other factors (Ahn, 2011). Agosto (2002) and Agosto and Hughes-Hassell (2006a, 2006b) situate information seeking and technology use practices among youth in everyday life using qualitative methods, finding that information uses influence particular facets of low-income youth identity such as social selves, emotional selves, reflective, physical, creative, cognitive, and sexual selves. These results show how variation in digital uses contrast with trends that are seen in the aggregate, when the types of technology uses are more finely explicated (e.g., social network site usage vs. content creation) and when varying practices within different social groups and particular communities are investigated more deeply (supporting Dewan & Riggins, 2005).

Research on parent education shows that parents with more education often create more conducive learning environments for their children, foster better attitudes toward reading, and teach them more skills compared to other families (Davalos, Chavez, & Guardiola, 2005). Specifically, parents with more schooling typically value academic learning more and create better learning environments through rooms for quiet study, age-appropriate books, and educational resources, and suitable reward and discipline structures (Chiu, 2010). Parents with more education also place a higher value on academic achievement in school than other parents and can directly communicate this attitude to their children (e.g., Bradley & Corwyn, 2002). Through chatting with their children (e.g., about homework or recent political events), parents can serve as role models, ask provoking questions or give explicit instructions, all of which can help children learn useful linguistic, cognitive, behavioral, and social skills for school (Lee & Bowen, 2006; Pan, Perlmann, & Snow, 2000). For these reasons, and given known relationships among education level, socioeconomic status, and digital skills among adults (Hargittai, 2010), parent education could be expected to play a key role in youth digital divides.

Technology Learning in Schools

Educational technology, digital literacy, participatory culture, and digital divide concerns are central to U.S. education policy agendas (e.g., National Education Technology Plan of the US Department of Education, 2010; National Broadband Plan, 2010) and to the missions of several national education associations (e.g., American Association of School Librarians’ Standards for 21st Century Learners, and the International Society of Technology in Education’s technology literacy standards). These national frameworks recommend that schools’ educational technology programs cultivate students’ technology expertise and dispositions toward active, constructive, creative technology engagement. However, these policy benchmarks do not offer clear instructional guidelines or research-driven best practices on how schools and teachers may achieve their specified benchmarks.

As innovation often outpaces research, school leaders lack sufficient conclusive data and research-driven recommendations, which hinders technology integration in their schools (Wellings & Levine, 2009). Although 91% of computers in public schools are used for instruction and almost all of them—98%—have Internet access (Gray, Thomas, & Lewis, 2010), national studies have not clearly explicated appropriate instruction with computers such that clear cut curricular guidelines exist for teachers. Research has not specified best practices in (a) types of technology curricular programs, (b) technologically mediated modes of delivery, (c) subject domains such programs should supporting, or (d) grade-level specificity.

Moreover, public education’s funding inequities can increase disparities among students, and its slow pace of school change can be eclipsed by higher SES people’s access to advances in instructional design in informal educational contexts (Collins & Halverson, 2009). The pervasive use of computers and the Internet encompasses different social ecology contexts (e.g., home, school, and community), which offers many wide-ranging affordances for youth but also amplifies the impact of the digital divide (Barron, 2004).

Hence, reducing the digital divide can be seen to require schools offering research-driven learning interventions involving technology to diverse learners, not only privileged ones. Such technology-based learning interventions housed in mandatory formal curricular modules within public schools can aid student appropriation of technology and reach students more equitably (Collins & Halverson, 2009).

The implementation study we report upon here adopts Barzilai-Nahon’s (2006) dimensions of infrastructure access and affordability of ICTs, given that the participating schools all demonstrated prior availability in the affordance of necessary technology hardware and Internet connectivity. Thus, such an implementation is not outside the realm of that which is possible in today’s schools more broadly (in terms of infrastructure). The study does not directly address the dimensions of governmental and social supports or constraints, but does consider the implications for these dimensions in the discussion of the findings on sociodemographics and use, given school affordances and the promise of educational programs in public schools to foster greater digital literacy among youth, more equitably. The study offers a variation in the dimension of “accessibility” (Barzilai-Nahon, 2006) by providing innovative resources in a novel, game design learning intervention. Our central research variables fall largely under the dimensions of use and sociodemographic factors, (2006) in this novel school program context.
Research Questions

In this study, we test whether the participation of 242 middle school and high school students in the research-driven, theoretically-grounded, game design program Globaloria (specified in the methods) attenuates the digital divide present in this group. We address two research questions.

1. Do students’ frequencies of computer engagement differ after participating in Globaloria—specifically: (a) home computer use, (b) school computer use, (c) information-seeking or communicative computer activities, (d) collaborative/constructivist productivity-oriented computer activities?

Answering this question can provide insights into how Globaloria participation influences students’ self-reported digital practices. As Globaloria assigns no homework, potential changes in at-home computer engagement would indicate transfer of program activities from school to home.

2. Do the links between students’ sociodemographic variables (race, gender, SES) and their computer activities differ after they participate in Globaloria?

Given past cross-sectional research findings on the relationship between socioeconomic status and digital skills (e.g., Hargittai, 2010), answering this question shows how participation in Globaloria can attenuate known effects of the digital divide.

Methods

Here we consider the instructional theory that informed the game design intervention. We then present the methods used to investigate our research questions.

Theory-Based Game Design Intervention

The Constructionism philosophy and framework for learning and educative action (diSessa & Cobb, 2004; Harel & Papert, 1991; Papert, 1980) drives our game design intervention. Constructionism builds on Piaget’s ideas about constructivism, in which learners behave like active, creative scientists who build and test theories of how the world works. Consistent with sociocultural theory perspectives (e.g., Dewey, 1963; Vygotsky, 1978; ), learners benefit from social interactions and sharing while creating a computational artifact (often involving programming) that expresses conceptual knowledge in a dynamic way. Educators act as expert mentors and facilitators, while peers help guide one another in a workshop-based environment that increases the transparency of their creative processes.

In a study of children’s design of fraction simulations using the Logo programming language, Harel (1991) applied Constructionist principles and identified eight essential learning environment factors that fostered student learning:

1. Creation of a representational object that requires programming;
2. Open-ended, creative tasks that let students choose their problem-solving approach;
3. Collaborative group settings that help students share their work with one another;
4. The domain-specific mathematical subject of teaching fractions as representing a purpose for the design activity;
5. Purposeful nature of the activity—fourth-graders constructed Logo games for third-graders to use to learn fractions, which requires that the fourth-graders learn about learning, to implement the games successfully;
6. Significant free time for students to access and use computers, thereby creating a sense of ownership and responsibility;
7. Ample opportunities for students to express and discuss their ideas about their projects through talk and writing;

Engaging students in designing a game to teach others school subject material (e.g., mathematics) fostered deep epistemological thinking and offered students opportunities to learn how to learn (Harel, 1991; Papert, 1993). Harel (1991) showed that learning via this curriculum helps students improve in their:

1. Meta-cognitive capacities over time;
2. Complexity of narratives about the game topic;
3. Affective (emotional) development;
4. Self-regulation and sustained engagement in a project across time;
5. Interest in and motivation toward technology and the subject matter (mathematics).

Other Constructionist projects with different technology innovations have shown similar positive results (e.g., Bruckman & Resnick, 1995; Kafai, 1995, 2006; Kafai, Peppler, & Chiu, 2007; Kafai & Resnick, 1996; Klopfer, 2008; Reynolds, 2008).

Related situated learning approaches. Several related situated learning approaches also improve student attitudes and learning: project-based learning (e.g., Blumenfeld et al., 1991), problem-based learning (e.g., Hmelo-Silver, 2004; Hmelo-Silver & Barrows, 2006), inquiry-based learning (e.g., Kuhlthau, Maniotes, & Caspari, 2007, 2012) and Kuhlthau et al.’s guided inquiry design model (2007), and inquiry project-based learning (IPjBL) (e.g., Chu, 2009; Chu, Tse, Loh, & Chow, 2011). All of these situated approaches emphasize guided discovery, and scaffolding and facilitation are distributed among the tools, artifacts, and social resources of the learning environment. Although consistent with these approaches, Constructionism also requires the learner to create a computational digital artifact (e.g., game) as the primary task activity that drives the inquiry
process. In other instructional models, students often produce a written research report.

Designing games provides opportunities for learners to reify their thinking, making it visible and thus open to reflection and revision (Salen, Gresalfi, Peppler, & Santo, 2014). Salen et al. (2014) argue that games are systems and the same practices that are involved in understanding systems of STEM content are needed for designing games. Student conversations around designing science games aided engaging with the science content (Kafai & Ching, 1998). Furthermore, the nature and depth of the discussions varied across aspects of the design (Kafai & Ching, 1998). Peppler and Kafai (2007) found that “multiple aspects of creative production in informal settings empower youth as critical designers in a venue where their contributions are valued” (p. 15), where the input of the individual, group collaboration, and the mediation of the artifact itself contribute to their learning (2007). In addition to making thinking visible, game design, like other forms of project and problem-based learning, creates a purpose for inquiry—a need to know (Hmelo-Silver, 2004; Salen et al., 2014).

Learning Objectives of Globaloria: The Six Contemporary Learning Abilities

The Globaloria program’s learning objectives for students include six “contemporary learning abilities” (“6-CLAs”) (Harel Caperton, 2010; Reynolds & Harel Caperton, 2009):

1. Invention, progression, and completion of an original digital project idea.
2. Project management both individually and with a team, using a networked environment for productive planning, execution, documentation, and archiving of work.
3. Posting, publishing, and distributing digital media in a networked e-learning community and online more broadly.
4. Social-media based engagement for productive purposes, involving reflection, participation, and exchange using CMC tools.
5. Information-based inquiry, purposeful web research and mindful online exploration, use and application of knowledge.
6. Surfing websites and web applications with a critical eye to experiment and tinker with tools and games, and applying ideas in remixed form in one’s own artifact.

The curriculum aims to cultivate these dimensions of expertise. The nonprofit organization in New York City that developed Globaloria (the World Wide Workshop) provided professional development for teachers and real-time virtual game design expert help and feedback via tech support and webinars for both students and educators.

Content creation activities. The first three CLAs center on the design and creation of a game in computational software. In the school year in which we conducted this study, students used Adobe Flash to program and edit games. Globaloria is structured as a year-long curriculum comprising over 100 hr of instruction, with six instructional units including the following:

a. Unit 1. Getting Started: Introduces the course structure, helps learners set up their own Profile and Blog, and learn rights and responsibilities as a member of this online learning community.

b. Unit 2. Hidden Object Game: Working as individuals, learners conceive and design a specific type of game that allows the player to find a hidden object, to learn introductory Flash programming skills. They make a paper prototype, gain an introduction to Flash, draw a background, add hidden objects, add scores and message boxes, add game ingredients, and finally, present their game.

c. Unit 3. Action game: This unit introduces more advanced Flash programming features and includes activities such as actions, game loops, keyboard controls, collectables, scoring, adding enemies, and other game ingredients.

d. Unit 4. Team game concept: In this module, teams of students begin conceptualizing and planning a more advanced game.

e. Unit 5. Team game demo: Here students develop their paper prototype and create a Flash-based demo for their game. They add scenes, buttons, and keyboard inputs.

f. Unit 6. Final team game: Students transform their demo into a working, playable interactive web game in this module, drawing upon the more advanced Actionscript tutorials, combining team member Flash files, tuning their game, and presenting it at the annual game design competition.

Social media and information resource uses. The latter CLAs 4–6 represent inquiry and collaborative tasks. The learning management system contains both information resources and social media tools. The environment also contains the game design curriculum, weekly syllabus assignments, and tutorial resources to facilitate student project management, file-sharing, communication, and documentation/presentation of both in-progress and final work. Each participating school receives a common set of resources. Students and teachers create member accounts, online profile and project pages, team pages, and file galleries that contain shareable code, output game files, documentation and game asset archives.

In summary, the content creation activities in which students engage in Globaloria are sophisticated technology uses that have been associated with cultural and political participation benefits in the general population, and have been discussed for their potential to enhance social mobility (Hargittai, 2010; Hargittai & Walejko, 2008). The guided inquiry and social learning supports augment and facilitate the central content creation goals. Students’ experiences engaging in these practices throughout the school year provide the basis for the hypothesis that this sustained, coordinated and purposeful participation may attenuate digital divide effects.
Participants and Data Sources

During the 2011/2012 school year, 38 middle schools and high schools in West Virginia participated in this study. According to the 2010 U.S. census, the state of West Virginia has a lower median household, a lower per capita income and a higher proportion of persons living in poverty compared to the United States overall ($41,043 < $53,046; $22, 966 < $28,155; 17.9% > 15.4%; respectively). As a rural and mountainous state with high poverty, residential broadband diffusion is limited in some areas because of access and cost, so many homes do not have broadband.

The participating schools self-selected into the program. Schools elected to participate through the West Virginia Department of Education’s and nonprofit’s recruiting initiatives. Criteria for school involvement included teacher interest and time availability, school administration approval, and requisite hardware infrastructure in a computer lab enabling 1:1 student/computer ratio. The nonprofit organization provided the needed software through grant funding support. All participating schools were located in counties that had lower household income and proportionately more households in poverty compared to the United States overall.

Data sources consisted of pre- and postprogram student survey data. Surveys were conducted online in August of 2011, January of 2012, and May/June 2012, depending on students’ participation modality (first semester only, second semester only, or full year), with at least 100 hr of class time registered for all participants. Survey links were distributed to students via each pilot location wiki, with educator administration. Participation in the survey research was voluntary, and data collection was conducted with full university IRB approval and parental consents.

A total of 386 students participated in the program and completed the presurvey at the 38 middle schools and high schools included in the sample; 242 students completed both surveys, reflecting a 63% response rate. Findings reported here reflect the 57 middle school and 185 high school students who completed both pre- and postsurveys. Students did not complete surveys because of absences on the days the postsurvey was implemented, voluntary opt-outs, and transfers to other schools. Additionally, a small number of students discontinued their survey completion mid-way through; incomplete responses were omitted.

Dependent Variables

The outcome measures include single-item frequency of computer use at home and at school measures, and composite measures for engagement in a range of basic and advanced computer activities, pre- and postprogram. Survey items regarding frequency of computer use were based on the Pew Internet and American Life project surveys (e.g., Lenhart, 2011).

For basic versus advanced computer activities constructs, we combined items for home and school use, so the measures reflect more generalized engagement. We used factor analyses (Jöreskog & Sörbom, 2004) to create two indices from surveys of media and technology use: Information-seeking and communicative computer activities that map onto CLAs 4–6 (basic computer activities), and more productivity-oriented computer activities that map onto CLAs 1–3 (advanced computer activities). Each survey item begins with the prefix, “how often do you . . .” Basic activity items include: surfing online, and searching online, emailing and instant messaging with fellow students for Globaloria project purposes. Advanced activity items include coming up with an original digital game idea, creating digital design projects, creating graphics, creating music files, programming, engaging in teamwork both online and face-to-face, posting files to a wiki, and blogging. The Likert scale responses were: 1 = never, 2 = a few times a month, 3 = about once a week, 4 = a few times a week, 5 = about once a day, 6 = several times a day.

Independent Variables

Independent variables include family and student demographics, school characteristics, and student behaviors. Demographics include race (Black, Hispanic or Latino, Asian, Native American, or Alaskan—White), parent education, student gender, and student age. Parent education was each student’s self-reported highest level of education by their parent(s) from the following choices: 1 = Did not complete HS; 2 = Completed HS; 3 = Completed HS, attended some college; 4 = Completed college; 5 = Completed college, attended some graduate school; 6 = Completed graduate school. Parent education level is a proxy for socioeconomic status (Lien, Friestad, & Klepp, 2001; Sewell, 1971). Girl indicated a student’s gender (girl = 1; boy = 0). Age was measured in years.

School level variables comprise grade level (middle school vs. high school) and school means of the above ethnicity, parent education, gender, and age variables. For example, school mean of Blacks is the percentage of Black students in a school.

Self-reported grade was a student’s responses to the question: “What grades do you usually receive on your report card?” We provided the following categories, measured on a five-point scale (all A’s (or 4’s); mostly A’s and some B’s (or 4’s); mostly B’s and some C’s (or 3’s); mostly C’s and some D’s (or 2’s); mostly D’s and F’s (or 1’s).

Analysis

To address the study’s research questions with this data set required proper statistical modeling of nested data (students within schools), multiple outcomes, indirect effects (mediation), and possible false positives (see Table 1). As applying ordinary least squares regressions to nested data (students within schools) biases the standard errors, we conducted a multilevel analysis, which models the nested data properly (Goldstein, 1995). As an ordinary regression would ignore the potential correlations among outcomes, a
multivariate multilevel analysis is needed (Goldstein, 1995). To test for indirect, mediation effects, we use a multivariate mediation test (Krull & MacKinnon, 2001). Lastly, to reduce the likelihood of false positives, we use a two-stage linear step-up procedure (Benjamini, Krieger, & Yekutieli, 2006).

We modeled home computer use, school computer use, basic computer activities, and advanced activities with multivariate, multilevel models (Goldstein, 1995). A variance components model tested for significant differences at each level.

\[
\text{Computer_Activities}_{ij} = \beta_{i00} + e_{ij} + f_{ij} 
\]

In the vector Computer_Activities, each outcome variable \( y \) of student \( i \) in classroom \( j \) had a grand mean intercept \( \beta_{i00} \), with unexplained student- and classroom-level components (residuals) \( e_{ij} \) and \( f_{ij} \). We entered explanatory variables in sequential sets to estimate the variance explained by each set (Kennedy, 2008). First, students’ computer activities might differ across time (before or after Globaloria). As families might choose their children’s schools, family demographics might affect school variables. Also, both demographics and school variables might affect student behaviors. All of these might affect student’s computer activities. Hence, we entered the variables as follows: time, family, school, and student.

\[
\text{Computer_Activities}_{ij} = \beta_{i00} + e_{ij} + f_{ij} + \beta_{ij} \text{Post-Globaloria}_{ij} 
\]

First, we tested whether students’ computer activities differed across time by entering the variable, Post-Globaloria. The baseline is Pre-Globaloria. Then, we entered a vector of demographics variables: race (Native American/Alaskan, Asian, Black/African American, Hispanic/Latino) parent education, girl, age (Demographics). We tested whether sets of explanatory variables were significant with a nested hypothesis test (\( \chi^2 \) log likelihood, Kennedy, 2008) and removed nonsignificant variables.

Next, we applied this procedure to school characteristics: high school (vs. middle school) and the school means of race, parent education, gender, and age (School). Then, we applied this procedure to student behavior: self-reported grade (Student Grade). We tested whether the significant regression coefficients differed before versus after game design activity by using interaction terms with Post-Globaloria (Interactions). For significant interactions, we examined 2-way tabulations to determine whether the interaction is localized in a specific subsample of the students and applied paired \( t \)-tests (Kennedy, 2008).

We reported how a ten percent increase in each continuous variable above its mean was linked to the outcome variables (\( \text{result} = b * \text{SD} * [10\% / 34\%] ; 1 \text{SD} = 34\% \)). As percent increase is not linearly related to standard deviation, scaling is not warranted.

### Results

See summary statistics in Table 2 and correlation-variance-covariance matrix in Table A2 in the Appendix.

As Table 3 indicates, before Globaloria activities, some demographics were correlated with computer uses and activities. Students who had educated parents, who attended schools with more educated parents or who attended high school were more likely than other students to use computers at home. When using computers, boys or older students, especially those attending high school were more likely than girls or younger students, respectively, to engage in basic computer activities. Hispanic students were less likely to use computers at school. Meanwhile, students who attended schools with more educated parents are less likely to engage in advanced computer activities, in particular if their own parents were not as educated.

### Explanatory Model

The results show much greater variance within classrooms rather than across classrooms (home computer use: 96% within classrooms vs. 4% across classrooms; school computer use: 89% vs. 11%; basic computer activities: 90% vs. 10%; advanced computer activities: 95% vs. 5%). Figure 1 shows the pathways of relationships in the multilevel analysis results (see Appendix Table A3 for details). All results discussed below describe first entry into the regression, controlling for all previously included variables.

Parent education is a proxy for both types of technology access. Highly educated families are more likely to have both (a) the economic resources to support computer and Internet access at home and (b) the understandings of its value and of the skills to use it.

### School computer use DV

Game design activity and school characteristics were linked to students’ school computer use. Students averaged 84% greater school computer use after the game design intervention than before it. In schools in which students’ parents were 10% less educated, students averaged 64% more school computer use after participating in Globaloria. Hence, the impact of the game design activity on school computer use is greater in schools whose students

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<th>Explanatory variables</th>
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<td>Indirect, mediation effects (X ( \rightarrow ) M ( \rightarrow ) Y)</td>
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<td>False positives (Type I errors)</td>
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### TABLE 1. Statistic strategies for addressing analytical difficulties.
have less educated parents. This significant interaction term is almost entirely because of schools in which students’ parents on average did not attend any college (difference = 0.64; paired *t*-test = 6.51, *p* < .001). These students sharply increased their computer use at school, whereas other students’ school computer use did not differ significantly. These variables accounted for 18% of the variance in students’ school computer use.

**Home computer use DV.** Game design activity, family characteristics and school characteristics were linked to students’ home computer use. Before the game design intervention, students whose parents had 10% more schooling above the mean showed 4% greater home computer use than students whose parents had the mean level of schooling (4% = 0.122 × 1.253 × 10% / 34%; = b * SD * [10% / 34%]; in Appendix Table A3, model 2). After the game
design intervention, however, parent education was not significantly linked to home computer use, \(-0.036 = 0.122 \pm 0.158\) (see Appendix Table A3). This significant interaction term is almost entirely because of students whose parents only completed high school, difference = 0.87; paired \(t\)-test = 3.36, \(p < 0.001\). These students sharply increased their computer use at home, whereas other students’ home computer use did not differ significantly.

Meanwhile, high school students used their home computers 11% more often than middle school students \((0.11 = .319/34\%)\). These variables accounted for 4% of the variance in home computer use.

**Basic computer activities DV.** Game design activity and students’ self-reported grades were linked to students’ basic computer activities. Students averaged 30% greater basic computer activity after the game design intervention than before it. This increase is smaller for students with higher self-reported grades. This significant interaction term of self-reported grades \(\times\) post-GLOBALORIA is largely because of students who self-reported some grades of C’s or lower, difference = 0.24; paired \(t\)-test = 2.12; \(p < 0.05\). These variables accounted for 1% of the variance in students’ basic computer activities.

**Advanced computer activities DV.** Game design activity and students’ self-reported grades were linked to students’ advanced computer activities. Students averaged 49% more advanced computer activities after the game design activity than before it. Before the game design activity, students who reported grades 10% higher than the mean averaged 6% more advanced computer activities than students who reported grades at the mean. After the game design activity however, self-reported grades were not significantly related to their frequency of advanced computer activities \((−0.068 = 0.240 + −0.308\); see Appendix Table A3). This significant interaction term of self-reported grades—post-GLOBALORIA is largely because of students who self-reported some grades of C’s or lower, difference = 0.22; paired \(t\)-test = 1.97; \(p < 0.05\). These variables accounted for 4% of the variance in students’ advanced computer activities. Other variables and interactions were not significant.

**Discussion**

Overall, these results show that participation in the GLOBALORIA program influences technology engagement in schools. It does not appear to be enough to provide technology resources in schools, which all schools had prior to participating in this program. Instead, the results suggest that increases in technology uses and outcomes in dispositions to engage in technology use emerge through the provision of designed experiences for students and teachers to be productive, organized, coordinated, creative, and sustained in their engagement, during school hours. In this case, the demonstrated results were achieved through the full-year, daily class and the research-driven curriculum involving game design, information resource uses and social computing activities of GLOBALORIA.

**Parent Education**

Results indicated that the education level of students’ parents as a school mean was positively associated with home technology uses prior to program participation, as expected. The relationships between parent education (at
both individual level and school level) and frequency of computer use for both the home and school measures were weaker after students participated in the game design program. Globaloria participation appears to attenuate effects of differences in parent education upon students’ home computer engagement. Moreover, the increase in students’ home- and school-based computer use after participating is greater in schools whose students have less educated parents than schools in which students have more educated parents. Together, these results suggest that student participation in this program can reduce digital divide effects stemming from parental education, a proxy for socioeconomic status in this younger population, for whom individual level socioeconomic data is more difficult to acquire.

Gender, Race/Ethnicity

Prior to participation, gender was associated with basic computer activities. Regardless of gender, students’ prior baseline means for basic computer activities appeared higher than those for advanced computer activities. Among these younger students, the results indicate that gender effects had already filtered into their more common “basic computer activities” (but not yet for advanced activities, which were low on the whole). Importantly, after participation in Globaloria, this gender gap for basic activities was no longer significant. Further, for “advanced computer activities,” after participation, gender did not then become significant, which we might have expected, given what we know about gender effects on digital literacy in cross-sectional research (e.g., Hargittai, 2010). These findings offer evidence that in the program implementation of Globaloria, girls were empowered to participate on a par with boys. As for the race and ethnicity results, there was low variation in the study’s sample of rural West Virginia students, where the majority of the population is White. The results did show an effect for Hispanic students prior to participation for the dependent variable of school computer use, and this effect was no longer significant after participating in Globaloria. Note that 75% of the Hispanic students attended three schools near the capital city, so these results might be specific to these schools. Given these results, though, we may expect to see a gap-closing finding for race and ethnicity in a more diverse sample. This question needs further testing.

Prior school achievement. The basic and advanced computing activities results also showed that the game design curriculum benefits students with lower rather than higher past traditional school achievement. Before participating in Globaloria, traditionally higher-achieving students (as measured by self-reported grades) reported a greater extent of advanced computing activity frequency than those at the mean. After participating in Globaloria however, self-reported grades were no longer significantly related to advanced computing activities. These results may indicate that the game design program offers students who perform less successfully in traditional schooling contexts the chance to participate in an alternative-learning domain in which to experience success, and to overcome some of the proficiency gaps they usually experience. Students’ engagement in team work, their creative endeavors during game design building on play, and the social constructivist work context embodied in the innovative curriculum, may tap student interests and learning domains in ways that they do not experience in traditional classrooms.

In summary, because women, Blacks, Hispanics, and those of lower socioeconomic status have shown lower computer and Internet skills than others in cross-sectional research (Hargittai, 2010), the findings presented here are notable. The results also indicate that participating students increased in their school, basic and advanced computer activity overall. Gender’s contribution to basic activities disappeared, and although almost all students were new to advanced activities, no new gender effects emerged postparticipation. After participating in Globaloria, the links between parent education (at both the student and school levels) and computer uses (at both home and school) were also weaker. More research is needed to investigate how computer use varies at home and school by different activity types, and in particular, the specific ways in which the students whose parents had not completed college are engaging with computers differently, as a result.

Limitations and Future Research

The potentials and limitations of survey research are noteworthy; Hargittai (2013) highlights sampling methodology, online surveys, and design as key areas for consideration. As our survey pre- and postmethodology did not employ a control group, maturation effects might be an alternative explanation for our results. Furthermore, the study sample is from a state in which the schools sampled fell below national income averages and above national poverty rate averages, and the race and ethnicity sample was lower than the national average. We also note the drop-off rate in the survey completion as another limitation, though a 63% response rate for voluntary survey research is quite high, and some of this gap is because of students who were absent, or moved, which is natural for a school environment.

Because of differences in survey measures, comparing the results in this study to that of previous digital divide studies is difficult. For instance, measures used in this study were not identical to those used in cited works such as Hargittai (2010), whose survey outcome measures assess students’ perceived level of understanding of 27 Internet-related items on a 5-point scale. In contrast, our frequency outcome constructs were situated in the specific activities prescribed in the curriculum, and its research-driven learning objectives framework (the CLAs). For the generalized at-home and at-school use items, we recognize that past research has highlighted the limitations of single-item measures. Our basic and advanced computing activity measures were more multidimensional and registered effects for
gender and school achievement, whereas the single-item measures for at-home and at-school frequency of use registered parent education effects. It is perhaps parsimonious that the broader sociodemographic variable of parent education (a proxy for socioeconomic status) was associated with differences in more generalized dependent variables of use (home and school), whereas the prior school achievement variable rooted in instructional design related to outcomes specific to instructional design features in Globaloria (the activities they engaged in, that were quite different from regular school). Finally, more longitudinal research beyond the immediate postprogram timeframe would strengthen this evidence.

This study contributes to the literature by establishing an evidence base that gender, socioeconomic, achievement, and perhaps race and ethnicity gaps can be reduced through direct interventions such as these. We invite more research in this area from other learning and instructional design researchers, to better understand what are the necessary and sufficient conditions in the intervention design for achieving such successes (e.g., program duration and frequency, activity structure and sequencing, resources provided, teacher involvement, etc.), and what might we expect for the lower and upper limits of the effects that may be realized, and the sustainability requirements for making such effects lasting, and for influencing real social mobility potential—which is a central objective for this particular intervention’s implementation in today’s public schools.

Conclusion

Although modest in their effect sizes, the results of this study indicate that substantive digital literacy interventions like this one can help mitigate the effects of sociodemographic factors such as parent education levels on computer uses, at least as measured in the immediate term after their implementation. Notable shifts occurred, which if implemented on a greater scale, could present sizable changes in larger populations. Barzilai-Nahon’s (2006) model of the digital divide includes a role for social and government constraints and supports; such a model might further explicate this dimension to include education policy affordances for school-based programs such as this one. This program was implemented with existing school hardware and connectivity resources, and required school administrators to find space for one extra class period a day for the students to learn game design in a Constructionist way. Although time in the public schoolday block schedule is considered sacred in the quest for achieving school testing accountability goals, the activities the students engaged in herein reflect a more contemporary learning ecology involving inquiry, collaboration, and creation with technology—activities and abilities required in many higher education and professional contexts, but not yet frequently addressed in K-12. These data offer insight into some of the effects.

Our ongoing design-based research agenda investigates the processes and dynamics of student learning throughout participation in this guided discovery-based game design context. More comparative work is needed between and across different types of interventions, to arrive at a greater understanding of best practices that can further inform pragmatic educational technology recommendations. Overall, this study offers support for the claim that in-school models for digital literacy development can measurably reduce digital divide effects.

Acknowledgments

We would like to thank Dr. Idit Harel, President and Founder of the Globaloria educational innovation that is the focus of this study, and her design and management team, including Vice Presidents Shannon Sullivan and Amber Oliver, for their active involvement and interest in our design-based research collaboration, and their generosity in partnership management as we conducted the research. We would also like to thank the Institute for Museum and Library Services for grant funding and support of this project, under a Laura Bush 21st Century Librarian Early Careers grant. We appreciate the research assistance of Yik Ting Choi.

References


Appendix A

Ancillary Tables and Results

TABLE A1. Statistical power analysis for effect sizes at different levels.

<table>
<thead>
<tr>
<th>Level</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Classroom</td>
<td>0.086</td>
<td>0.197</td>
<td>0.379</td>
<td>0.596</td>
</tr>
<tr>
<td>1) Student</td>
<td>0.184</td>
<td>0.441</td>
<td>0.885</td>
<td>0.988</td>
</tr>
</tbody>
</table>

TABLE A2. Correlations, variances, and co-variances are along the lower left triangle, diagonal, and upper right triangle of the matrix, respectively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Home computer use</td>
<td>0.998</td>
<td>0.035</td>
<td>0.385</td>
<td>0.086</td>
<td>-0.017</td>
<td>0.095</td>
<td>0.049</td>
<td>0.056</td>
</tr>
<tr>
<td>2 School computer use</td>
<td>0.035</td>
<td>0.998</td>
<td>0.217</td>
<td>0.210</td>
<td>0.193</td>
<td>-0.012</td>
<td>-0.046</td>
<td>0.066</td>
</tr>
<tr>
<td>3 Basic computer activities</td>
<td>0.384</td>
<td>0.216</td>
<td>0.998</td>
<td>0.449</td>
<td>-0.001</td>
<td>-0.048</td>
<td>-0.012</td>
<td>0.035</td>
</tr>
<tr>
<td>4 Advanced computer activities</td>
<td>0.086</td>
<td>0.210</td>
<td>0.450</td>
<td>0.998</td>
<td>0.068</td>
<td>-0.042</td>
<td>-0.084</td>
<td>0.071</td>
</tr>
<tr>
<td>5 Post-Globaloria activity</td>
<td>-0.034</td>
<td>0.386</td>
<td>-0.001</td>
<td>0.137</td>
<td>0.250</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>6 Parent education</td>
<td>0.076</td>
<td>-0.107</td>
<td>-0.038</td>
<td>-0.033</td>
<td>0.000</td>
<td>1.567</td>
<td>0.184</td>
<td>0.223</td>
</tr>
<tr>
<td>7 School mean parent education</td>
<td>0.114</td>
<td>-0.107</td>
<td>-0.028</td>
<td>-0.197</td>
<td>0.000</td>
<td>0.343</td>
<td>0.184</td>
<td>-0.043</td>
</tr>
<tr>
<td>8 Self-reported grade</td>
<td>0.069</td>
<td>0.082</td>
<td>0.043</td>
<td>0.088</td>
<td>0.000</td>
<td>0.220</td>
<td>-0.125</td>
<td>0.653</td>
</tr>
</tbody>
</table>
TABLE A3. Summary of regression coefficients of two two-level regression models predicting students’ frequencies of home computer use, school computer use, basic computer activity and advanced computer activity. (with standard errors in parentheses).

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Predicting home computer use</th>
<th>Predicting school computer use</th>
<th>Predicting basic computer activity</th>
<th>Predicting Advanced Computer Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Post-Globaloria</td>
<td>−0.067</td>
<td>0.355</td>
<td>0.771***</td>
<td>2.455***</td>
</tr>
<tr>
<td></td>
<td>(0.086)</td>
<td>(0.274)</td>
<td>(0.077)</td>
<td>(0.574)</td>
</tr>
<tr>
<td>Parent education</td>
<td>0.122*</td>
<td>0.049</td>
<td>−0.158*</td>
<td>−0.524**</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.069)</td>
<td>(0.241)</td>
<td>(0.177)</td>
</tr>
<tr>
<td>High school</td>
<td>0.319*</td>
<td>0.154</td>
<td>0.112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.154)</td>
<td>(0.207)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom (4%)</td>
<td>0.000</td>
<td>0.860</td>
<td>0.000</td>
<td>0.117</td>
</tr>
<tr>
<td>Student (96%)</td>
<td>0.001</td>
<td>0.005</td>
<td>0.169</td>
<td>0.184</td>
</tr>
<tr>
<td>Total variance explained</td>
<td>0.001</td>
<td>0.041</td>
<td>0.150</td>
<td>0.177</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom (11%)</td>
<td>0.000</td>
<td>0.117</td>
<td>0.000</td>
<td>0.040</td>
</tr>
<tr>
<td>Student (89%)</td>
<td>0.169</td>
<td>0.184</td>
<td>0.231*</td>
<td>0.103</td>
</tr>
<tr>
<td>Total variance explained</td>
<td>0.150</td>
<td>0.177</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
<th>Explained variance at each level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom (5%)</td>
<td>0.000</td>
<td>0.004</td>
<td>0.000</td>
<td>0.009</td>
</tr>
<tr>
<td>Student (95%)</td>
<td>0.000</td>
<td>0.010</td>
<td>0.020</td>
<td>0.039</td>
</tr>
<tr>
<td>Total variance explained</td>
<td>0.000</td>
<td>0.009</td>
<td>0.019</td>
<td>0.042</td>
</tr>
</tbody>
</table>

Note. A constant term was included for each dependent variable in this regression.

* \( p < 0.005 \), ** \( p < 0.01 \), *** \( p < 0.001 \).