Formal and informal context factors as contributors to student engagement in a guided discovery-based program of game design learning

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Version of record first published: 08 Apr 2013.

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This paper explored informal (after-school) and formal (elective course in-school) learning contexts as contributors to middle-school student attitudinal changes in a guided discovery-based and blended e-learning program in which students designed web games and used social media and information resources for a full school year. Formality of the program context did not substantially influence attitude changes but did appear to influence learning outcomes. While intrinsic motivation did not change in the aggregate from pre- to post-program among students, positive changes in intrinsic motivation were found to be associated with engagement in almost all areas of student engagement in *Globaloria*, with several at-home engagement changes measured. This finding challenges critiques of discovery-based learning as being de-motivating. Lower parent education among students was associated with positive changes in self-efficacy for online research indicating that disadvantaged students may stand to benefit from programs like this one. The study offers support for the need to more definitively explicate instructional design and context factors in educational technology research when investigating influences upon learning outcomes. The study holds implications for designing effective digital literacy interventions, and contributes to theory in the learning sciences and socio-technical systems research.

Keywords: game design; constructionism; design-based research; motivation; self-efficacy; digital divide; *wiki*; *Globaloria*; informal learning; educational technology; evidence-based practice; digital literacy

Introduction

According to the *U.S. Bureau of Labor Statistics*, the number of computing and information sciences jobs will grow at more than twice the rate of all other STEM disciplines combined through 2018 (Lacy and Wright 2009). The National Education Technology Plan of the *U.S. Department of Education*

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and U.S. National Broadband Plan of the *F.C.C.* have established educational technology, digital literacy, participatory culture, and digital divide concerns as key topics of the national policy agenda (e.g., Hobbs 2010; Horrigan 2011; Jenkins 2009; Mossberger, Tolbert, and McNeal 2007). Such educational priorities are also reflected by recent revisions to frameworks of standards endorsed by several national associations, including the *American Association of School Librarians*' (AASL) Standards for twenty-first century learners, and the *International Society of Technology* in Education's National Educational Technology Standards (NETS) technology literacy standards. While national frameworks recommend delivery of educational technology programs in schools that will cultivate students' technology expertise and dispositions toward active, constructive, creative technology uses, policy documents are scant in offering solutions recommending *how* such ends should be achieved.

By fall of 2008, every single public school in the country was using computing technology in some way as part of instruction and every school had at least one instructional computer with internet access (Gray, Thomas, and Lewis 2010). While findings indicate that 91% of computers in public schools are used for instruction and almost all of them – 98% – have internet access (Gray, Thomas, and Lewis 2010), national studies have not explicated instruction, neglecting to indicate for instance, the types of programs being offered, technologically mediated modes of delivery, subject domains such programs are supporting, and the grade-level specificity.

Further, public and policy debates on technology effectiveness are locked in a research paradigm that casts technology as an 'intervention' rather than an enabling ecological factor in the school environment (Zhao et al. 2002). Wellings and Levine (2009) discuss the dilemma of innovation outpacing research as a hurdle for school decision-makers:

> [A] lack of hard evidence leads some educators to question the efficacy of incorporating new technology-based learning experiences, such as those involving digital media and online social networking, and the urgency of investment in what they consider unproven strategies. Conversely, proponents of technology investment reason that digital media are already a prevalent fixture in the lives of contemporary students, so waiting for research to confirm the promise of digital innovation before committing to expanded experimentation is unwise. To proponents, the question is not whether technology should be used in classrooms, but *how* it should be used. (3)

A meta-analysis conducted by the *U.S. Department of Education* addresses the broad question of technology's effect upon learning (Means et al. 2010). Such studies are problematic in that they do not clearly explicate specific context factors that may be playing roles in measured effects, and which vary program to program. Means et al. (2010) suggest for instance that effects found for online courses were likely associated with other instructional conditions and mechanisms, such as increased learning time, different materials,

and enhanced opportunities for collaboration. Such research cannot adequately inform design or school stakeholder decision-making on instruction. There is a growing need to better understand varied contexts for implementation, adoption and diffusion of technology programs in schools, and the mechanisms by which results are being achieved. In the study of socio-technical systems for learning, context factors matter.

This study focuses on student learning in *Globaloria*, an educational technology program developed by a NYC-based non-profit organization, the *World Wide Workshop*, which offers an innovative model of technology integration in schools that merits scholarly investigation. In this model, the non-profit organization partners with schools, and offers participating students and teachers an intensive digital game design experience across an entire year, leveraging a *wiki*-based technology platform, program administration databases, software, ongoing professional development trainings and direct instructional supports for students. The program introduces students to project-based technology activities aiming to cultivate digital expertise and learning dispositions in alignment for instance with the *AASL* and NETS standards.

The level of formality in which technology-supported instruction is administered is the theme of this special issue volume, and is a key context factor warranting scholarly investigation. It is clear from Ito et al.'s (2009) digital youth ethnography research that students 'informally' use technology naturalistically on their own time on a self-driven basis at a range of levels of depth, and that learning is a significant phenomenon inherent to this naturalistic use, outside of the school context. Collins and Halverson (2009) propose that with the proliferation of computing technologies, and the habituation of people toward their use, informal contexts will begin to eclipse the formal (i.e., schools) as the central loci for teaching and learning in the coming decades. These authors highlight several concerning implications for the socioeconomically disadvantaged given what may become a boom in commercialization of digital and e-learning services. As services are commercialized and become available directly to individuals at a cost (allowing families who can afford it to supplement the education provided via the public school system), young people from lower-income environments continue to be left behind. The authors advocate for school-based solutions, but state that they are not entirely optimistic that schools can meet the digital divide inequity challenges they anticipate (Collins and Halverson 2009).

For these reasons, it is valuable to prioritize establishing a greater understanding of the ways in which schools can play a role in equalizing technology learning opportunities, and how formality of learning contexts influences teaching and learning. This study investigates differences between formal and informal learning contexts and their influence upon student experiences and outcomes in *Globaloria*. In this study, we define 'formal learning' as that which occurs within schools where *Globaloria* was implemented in computer labs as a daily elective game design class, for credit and a grade. We define 'informal learning' not as naturalistic leisure time engagement (as do Ito

et al. 2009), but rather, as that which occurs within an after-school program context in which *Globaloria* was offered in California community centers, characterized by less structure.

If context formality and other independent variables such as socioeconomic status (SES) influence the magnitude of changes in student attitudes and outcomes, such results may lead to insights and/or recommendations that can inform design of educational technology interventions. Further, the results may contribute pragmatic insights toward improvement of *Globaloria* itself. Findings may also contribute to discourse on equitable provision of technology learning opportunities in schools. Formality is one context factor among many. Examining how formality is conceptualized and implemented in the existing US educational technology programs, and, how it is operationalized and measured in research, is important instructional theory work to which this study contributes.

Literature review

Informal learning contexts

Collins and Halverson (2009) claim that in today's Information Age, youth are becoming active agents in the exchange and appropriation of new information and knowledge through their naturalistic uses of technology. Ito et al.'s (2009) ethnographic research bears out support for this claim. Collins and Halverson (2009) propose that given the autonomy that technology environments afford, education can and will become less institutionalized and more personalized. As it does so, they propose that the educational landscape will evolve to be more learner-centered and interest-driven, similar to home-schooling or apprenticeship models. Commercial educational technology alternatives will become more readily available, allowing young people to specialize in areas of inquiry and engagement that are not offered in the public school context (Collins and Halverson 2009). The authors propose that schools can 'cope' with this advancement by offering performance-based assessment and new curriculum designs employing technology. They suggest that such technologies 'may not be able to address the underlying economic distress that limits how students can travel outside their homes, but they can bring high quality academic experiences into local schools' (2009, 120). While not optimistic about the roles schools might play in mitigating social inequity overall, the authors advocate school-based efforts and other deliberate measures to reduce costs and increase opportunities for students most at risk.

The *U.S. Department of Education*'s National Education Technology Plan of 2010 offers a roadmap for technology innovation to play a key role in overall school reform, presenting an approach that if realized would represent a radical departure from traditional schooling. The document calls for 'revolutionary transformation rather than evolutionary tinkering', stating:

> Education is the key to America's economic growth and prosperity and to our ability to compete in the global economy. It is the path to good jobs and higher earning power for Americans. It is necessary for our democracy to work. It fosters the cross-border, cross-cultural collaboration required to solve the most challenging problems of our time …. Specifically, we must embrace innovation, prompt implementation, regular evaluation, and continuous improvement. The programs and projects that work must be brought to scale so every school has the opportunity to take advantage of their success. Our regulations, policies, actions, and investments must be strategic and coherent.

If this document is any indication, US policy-makers in the current presidential administration's Department of Education appear to support an imperative to transform education through technology innovation, addressing equity concerns in the process. In order to advance this bold agenda, we need to better understand what works.

This study investigates student learning in a game design learning program in which the design of the curriculum and e-learning platform were influenced by previous Constructionist and learning sciences research. A NYC 501c-3 non-profit organization launched 'the *Globaloria* program' in 2006, and since then it has been implemented with close to 5000 students and educators in 80 schools in seven states, predominantly among low-income populations. The program is currently being delivered in middle and high schools in West Virginia (since 20 July 2008), Texas (since 2009/2010), and New York City, and in middle and high schools and community centers in California (as of 2011/2012). The program is funded through grant support from government agencies and private and corporate foundations.

Constructionist influence on program design

The design of the *Globaloria* e-learning program is modeled upon earlier Constructionist initiatives in which game-making has been found to enhance students' meta-cognition, self-regulation, computational thinking, and content domain knowledge (e.g., Harel 1991; Harel and Papert 1991; Kafai 1995; Kafai and Ching 1998; Papert 1980). Constructionism draws upon both Piaget's constructivist theory and Vygotsky's social constructivist theory. Proponents of this perspective design and implement learning innovations and environments that foster learners' conscious creation of a meaningful, computational public artifact (e.g., a game), which students create and share in a reflective, workshop environment of peer and expert-guided scaffolding (Harel and Papert 1991).

The designers of *Globaloria* have established six key learning objectives for students and educators. Reynolds and Harel (2009) and Harel Caperton (2010) establish the theoretical bases for this six-dimension framework called 'the 6 contemporary learning abilities' or '6-CLAs.' Successfully achieving the CLAs requires certain classroom conditions, specified in the program founder's 'ten main principles of *Globaloria* instruction.' See Figure 1. CLAs 1–3 are the

more Constructionist dimensions in that they involve imagination and creation of digital artifacts. CLAs 4–6 relate more to use of the existing web services. The set of coordinated practices that students engage in to achieve the 6-CLAs include surfing online, searching online for design resources and content influencing the message of the game, communicating with others online, posting/publishing text and artifacts, planning and creating original digital artifacts individually and in teams, and conceptualizing the narrative and message of such artifacts, the message of which may or may not be linked to the school's core curriculum. The *Globaloria* founders propose that this experience builds student expertise across these dimensions, thereby preparing them to become more successful active participation in today's knowledge-based economies and digital cultures (which *Globaloria* simulates). The aim is to develop students' and teachers' expertise across all dimensions.

Formal and informal contexts

In this program's 'co-learning' approach, students and educators engage in self-driven learning together; educators are novices at the start. Therefore, the
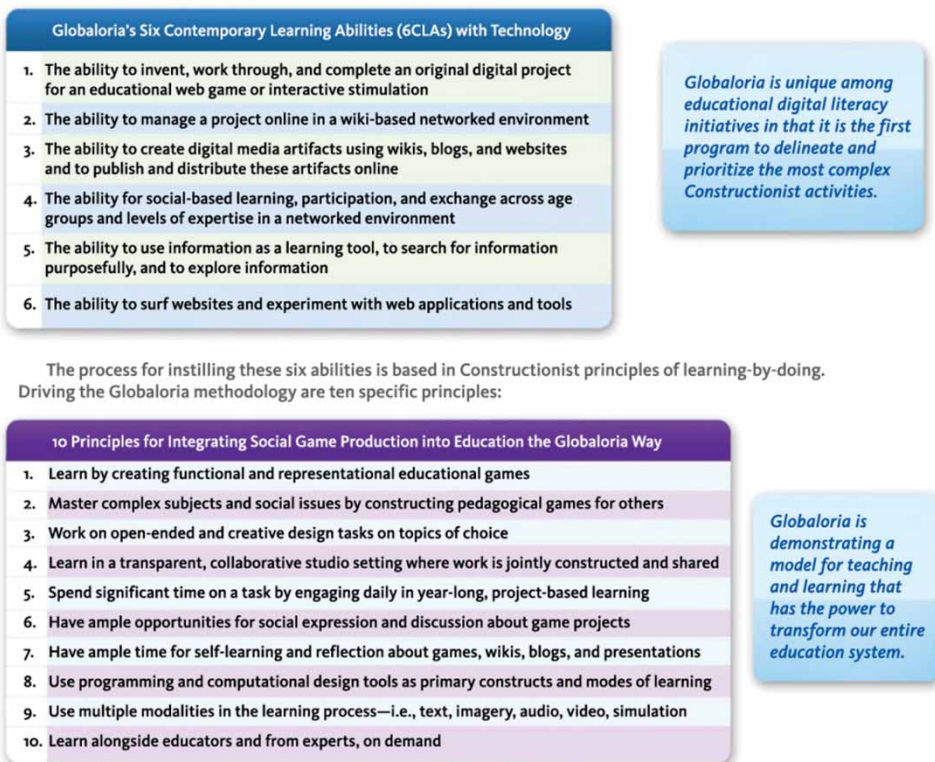

Figure 1.   The 6 contemporary learning abilities and 10 principles of workshop-based instruction.

activities can be characterized as 'guided discovery', because while supports are offered by teachers, peers, and the e-learning system, students must also search for resources autonomously as design and programming hurdles emerge. This invocation of student autonomy is true for both formal and informal contexts, but we expect that the formal, in-school context offers students a greater extent of structure and support than the informal. Key differences between the two contexts include extent of time on task, presence of grades as an extrinsic motivator or reward, the extent and quality of educator support, and the consistency of program administration.

Kirschner, Sweller, and Clark (2006) critique 'discovery-based learning' on the whole for its lack of structure, citing that such experiences create excessive cognitive load, frustration and de-motivation due to distraction in the resource search process, and over-taxation of working memory. Reynolds and Harel Caperton (2011) found that West Virginia middle- and high-school students in the formal in-school version of *Globaloria* reported their experiences with discovery-based learning and less-structured program attributes such as resource search and collaborative teamwork as being at times challenging, frustrating, and in many cases, enjoyable as well. A follow-up study in the in-school context (Reynolds and Chiu 2012) indicates that intrinsic motivation contributes positively to West Virginia middle- and high-school students' knowledge outcomes which were measured through content analysis of the quality of students' games, whereas extrinsic motivation does not. Theoretically, these results offer evidence indicating a possible need to qualify Kirschner, Sweller, and Clark's (2006) blanket critique of discovery-based learning, considering motivational orientations of learners.

The present study builds on Reynolds and Chiu (2012) to investigate how formality (i.e., greater and lesser structure) influences student engagement and self-efficacy in a year-long game design project. Given the literature, on the one hand we may expect that greater structure will elicit positive outcomes because it reduces cognitive load (per Kirschner, Sweller, and Clark 2006). On the other hand, given what we know about the roles of autonomy, perceived competence and social relatedness as drivers of intrinsically motivated behavior and fulfillment from self-determination theory (Deci and Ryan 1985, 2008; Ryan and Deci 2000), it may be that the less-structured informal location is more autonomy-supportive, and thus could also elicit positive effects. Our research questions are as follows:

(1) To what extent does the context in which *Globaloria* was administered (informal vs. formal) contribute to changes from pre- to post-implementation in students' self-reported *frequency* of engagement in *Globaloria* activities within the 6-CLA categories, both at home and at school?

(2) To what extent does the context in which *Globaloria* was administered (informal vs. formal) contribute to changes from pre- to

post-implementation in students' *self-efficacy* (feelings of confidence) in *Globaloria* activities within the 6-CLA categories?

Here, we focus on student changes in attitudes and dispositions as they relate to each CLA category as outcomes. Changes in students' self-reported frequency of engagement in *Globaloria* activities at home and at school and, changes in students' self-efficacy (Bandura 1994) toward *Globaloria* activities indicate a level of motivated engagement and confidence toward the activity. An individual's self-efficacy is defined as 'beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives' (Bandura 1994). Bandura (1994) writes:

> People with high assurance in their capabilities approach difficult tasks as challenges to be mastered rather than as threats to be avoided. Such an efficacious outlook fosters intrinsic interest and deep engrossment in activities. They set themselves challenging goals and maintain strong commitment to them. They heighten and sustain their efforts in the face of failure. They quickly recover their sense of efficacy after failures or setbacks. They attribute failure to insufficient effort or deficient knowledge and skills that are acquirable. They approach threatening situations with assurance that they can exercise control over them. (1994, 71)

Self-efficacy assessment can be used to examine perceptions in multiple domains related to the domain of functioning (Bandura 1994). Self-efficacy can be generalized and domain specific, for instance efficacy for self-regulated learning, self-assertive efficacy, academic achievement self-efficacy, and self-efficacy for enlisting social resources, among other domains. Researchers at Johns Hopkins identified middle school as the pivotal time for affecting students' academic success or failure (Balfanz 2009), which is the age of most students in our California sample. We rely on attitudinal self-reports measuring self-efficacy and frequency with respect to domain-specific *Globaloria* activities, adapting validated instruments when available.

Given the findings of Reynolds and Chiu (2012), it may be that one's motivational orientation interacts with formality to influence measured effects. Therefore, we also investigate the following.

(3) To what extent do changes in individual's motivational orientation (intrinsic and extrinsic) mediate or moderate the relationship between context (informal vs. formal) and changes in students' *frequency* of engagement in *Globaloria* activities within the 6-CLA categories?

(4) To what extent do changes in an individual's motivational orientation (intrinsic and extrinsic) mediate or moderate the relationship between context (informal vs. formal) and changes in students' *self-efficacy* in *Globaloria* activities within the 6-CLA categories?

Cross-sectional research in the general population indicates that even among those with moderate to high levels of technology access, more sophisticated forms of content creation, participatory engagement and digital knowledge have been associated with higher SES and level of education (Pew Internet and American Life Project 2007). Hargittai and Walejko (2008) find that creative activity and content sharing online are positively correlated with young persons' SES as measured by parental schooling, indicating that the greater one's socioeconomic resources, the more likely they are to engage in more sophisticated types of technology uses and their associated cultural benefits. Hargittai and Hinnant (2008) find that 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 websites that may contribute to improving their life chances and from which their human and financial capital may benefit. Hargittai (2010) finds that those from more privileged backgrounds use web-based technologies in more informed ways for a larger number of activities. Given this cross-sectional research, it may be that SES interacts with the measured effects of *Globaloria*, from pre- to post-participation. For instance, those with higher SES may express higher confidence and frequencies of at home engagement prior to participation, but subsequently, we might expect shifts. Thus, we also explore interaction effects due to SES, measured using the proxy of parent education.

(5) To what extent does an individual's *parent education* mediate or moderate the relationship between context (informal vs. formal) and changes in students' *frequency* of engagement in *Globaloria* activities within the 6-CLA categories?

(6) To what extent does an individual's *parent education* mediate or moderate the relationship between context (informal vs. formal) and changes in students' *self-efficacy* in *Globaloria* activities within the 6-CLA categories?

Methods

Intervention

Globaloria is offered as an instructional program for STEM learning and Constructionist digital literacy development in which participating educators and youth are provided with access to an online *wiki*-based e-learning platform containing a year-long academic curriculum, game design and programming tutorials, game-content resources, and virtual support systems, built upon open source *MediaWiki* tools. Working independently and in small teams, students develop an original idea for a game and take it from the early planning stages, to a final game product. Students create games and simulations on a chosen social issue or educational content area (e.g., mathematics, science, civics, health, and the environment).

The program is offered primarily to minority student populations in low-income communities, and most students take the class during the school day as a credit-bearing elective game design class taken for a grade. Schools enroll with a commitment of participation for three years. In California, the program is also offered informally at community centers as an after-school program. Professional development training for educators is offered during a two-day in-person academy, and includes ongoing mentoring sessions with seasoned educator participants, and virtual webinars throughout the year. Educators create games themselves, and also learn about class management of a workshop-style course, and how to cultivate the conditions specified in Figure 1. Over the three years, the in-person supports taper and become entirely virtual by the third year. Educators complete quarterly progress reports requiring them to reflect qualitatively and quantitatively on their own learning, their support of students, and class progress.

California formal contexts, 2011/2012

The *AdVENTURE STEM* program at one Silicon Valley intermediate school offers an alternative education experience for students in fifth to eighth grade with a focus on 'twenty-first century skills' (Figure 2). Thirty-three students in the sixth grade at 'SJSV1' participated in a *Globaloria* game design elective course meeting five days/week for 50 minutes each session. The class created games about the ancient Romans, linked to their history/social studies coursework. Their teacher is a veteran social studies educator and highly involved participant; her absence in the last weeks of the school year for a maternity leave was one obstacle for participants. Nonetheless, most teams at SJSV1 produced final games (Figure 3).

A second middle school, 'SJSV2' serves students from kindergarten through seventh grade. The program was delivered to the entire cohort of 34 seventh-grade students. The math teacher served as educator and was also highly involved. Final games focused on math topics. The class met five days a week for 60 minutes per class (Figure 4).

Informal contexts, 2011/2012

The 'SJSV3' Clubhouse, part of the Boys and Girls Clubs of Silicon Valley, had 50 registered *Globaloria* participants segmented into three class groups (mostly in middle school, with a few high-school students). Participation levels varied; about 30 participants remained active throughout the year. Each of the groups met for 60 minutes, three times a week on average. Two staff members facilitated the experience; both had other instructional and supervisory roles at the Club, at times they reported it was challenging to devote full attention *Globaloria*.

The 'SJSV4' Clubhouse, also part of the Boys and Girls Clubs of Silicon Valley, enrolled 15 participants at the start of the year. Because SJSV4 does

Figure 2.   Thumbnails highlighting genres of games created by youth in *Globaloria*.

Figure 3.   *World Wide Workshop*-provided graphic highlighting the learning process in *Globaloria*.

Figure 4.   *World Wide Workshop*-provided graphic highlighting the *Globaloria* game design curriculum topics.

not have a middle school nearby, the majority of its members are students from nearby elementary schools (i.e., fifth-grade students and younger) – subsequently, many of the original *Globaloria* participants at SJSV4 were fourth-and fifth-grade students who struggled with *Flash* and other aspects of the *Globaloria* program (Figure 4). SJSV4 ultimately decided to drop all fourth- and fifth-grade students from *Globaloria* and focus on the remaining middle-school and high-school participants. Three 8th graders and one 10th grader continued to participate over the course of the year.

Both centers struggled with program implementation due to their drop-in nature, which required students to constantly re-acclimate to projects, taking up valuable time. Though students at SJSV3 produced only two final, interactive games, about half posted *Flash* demos and game design plans and
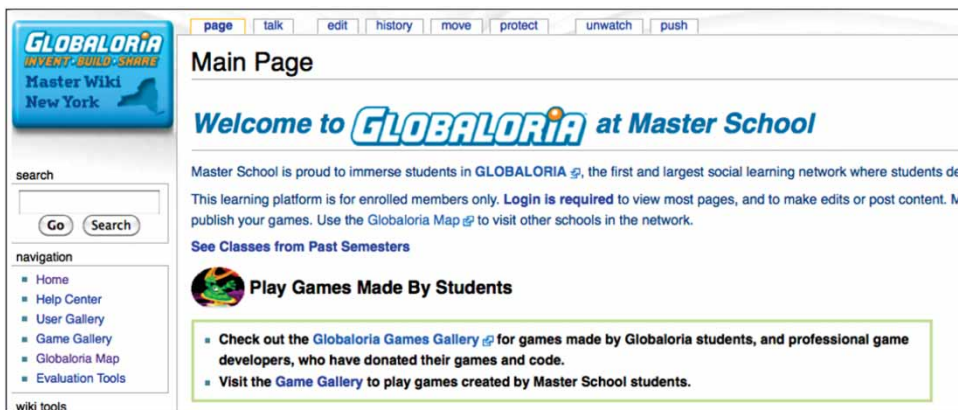
Figure 5.   Screenshot example of a class *wiki* home page.
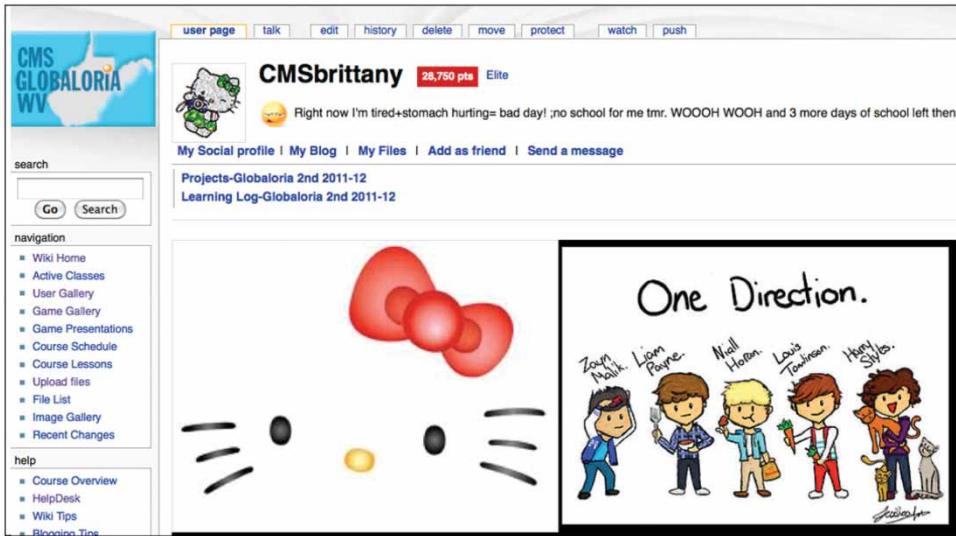
Figure 6.   An example of a student's 'Profile Page' on the *Globaloria* platform.

mock-ups on the *wiki* (Figure 5). Others created profile pages, uploaded graphics, accessed *wiki* resources and experimented in Flash, completing some curriculum assignments (Figures 6 and 7).

Data sources

Data sources include pre- and post-program student survey data from this first year of this program implementation in California. Surveys were conducted online in September 2011 and May/June 2012. Links were distributed to students via each pilot location *wiki*, with educator follow-up. Research was conducted on a voluntary basis achieving full parental consent and child assent, and Institutional Review Board approval.

   Content analysis of student artifacts. In addition to surveys, we conducted content analysis of all teams' final games to better understand the extent of
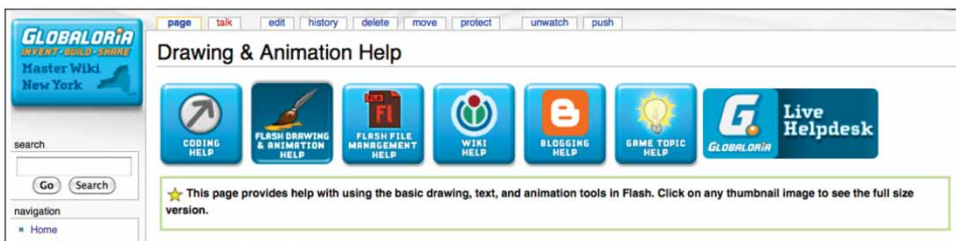
Figure 7.   An example of the *Globaloria* platform and curriculum help-desk resources on drawing and animation.

knowledge team members gain about game design. Team is the unit of analysis. 'Game' is defined as: a file that goes beyond a mere image, to include some level of interactivity, in which, at minimum, the file provides response to the player, based on a player action. Defining games at this minimal level of inter-activity allows us to code the full range of game files produced by students, basic to advanced. The final coding scheme comprises (a) ActionScript programming codes that could reasonably be expected to be included in the. FLA file from introductory game design students (12 items evaluated as $1 =$ present, $0 =$ absent through analysis of the. FLA project file) and (b) evaluation of three main domains of design attributes built into the game eval-uated more qualitatively using these categories: $1 =$ not present/insufficient representation; $2 =$ basic/introductory representation; and $3 =$ well-developed representation, coded by evaluating the playable. SWF output file. For (b), the design domains evaluated are: visual and sound design (five codes), game-play experience (five codes), concept development (seven codes). The team scores in the CA locations ranged from 2 to 61, out of a total of 63 possible points. Acceptable inter-rater reliability kappas for each item in the coding scheme were achieved among coders who evaluated a 50-game sub-sample of the total population of 759 games created across the multi-state network in the 2011/2012 school year.[1] The N of team games was too low in the California sample to include this variable in our statistical models, but we include descrip-tive statistics.

Participants

Out of 33 total participants at SJSV1, 29 students completed the pre-survey, and 27 completed the post-survey (93%). Out of a total of 34 total participants at SJSV2, 32 students completed the pre-survey and 29 students completed both the pre- and post-survey (91%). Out of a total of 30 participants at SJSV3, 18 students completed the pre-survey and 16 completed the pre and post-survey (88%). Out of a mixed total of SJSV4 participants, seven students completed the pre-survey and the four remaining full-year students completed the pre- and post-survey (57%).[2]

Dependent variables

Frequency

Increases in students' self-reported frequency of engagement in *Globaloria* practices representing the CLA categories from pre- to post-program will provide initial evidence that student behaviors have shifted as a result of par-ticipation (to the extent that frequency self-reports hold construct validity with their actual behavior). To measure frequency we used criteria employed by the *Pew* Internet and American Life Project in their national surveys of media and

technology use, presenting students with the prefix, 'how often do you. . .', a list of *Globaloria* activities, and item categories 1 = never, 2 = a few times a month, 3 = about once a week, 4 = a few times a week, 5 = about once a day, and 6 = several times a day. We separated items for each CLA into at-home and at-school measures. The at-home measures are also an indicator of student motivation and voluntary transfer of engagement from the school or community setting to home on their own time. The @home measures are a stronger indicator of engagement than the @school measures, where increases are to be expected. Instruments are available upon request from the authors.

Self-efficacy

Self-efficacy measures employ Bandura's (2006) recommended operationalization for domain-specific confidence, asking students 'How confident are you in your ability to:' and presenting them with a list of *Globaloria* activities as reported in the Analysis section, with item categories 1 = cannot do at all, 2 = probably cannot do, 3 = maybe, 4 = probably can do, and 5 = definitely can do. Items are reported in the results' tables.

Intrinsic and extrinsic motivation

Changes in student intrinsic and extrinsic motivation were measured drawing upon Ryan and Connell's (1989) validated questionnaires. In this earlier operationalization, each questionnaire asks why the respondent does a behavior (or class of behaviors) and then provides several possible reasons that have been preselected to represent the different styles of regulation or motivation. These authors found good discriminant validity in their measure for two main self-regulation dimensions (autonomous regulation or intrinsic motivation, vs. controlled regulation or extrinsic motivation). That is, factor analysis of items related meaningfully to the external criteria, wherein two factors emerged, with expected items on the extrinsic side of a four-category continuum falling into a factor the authors label 'controlled regulation' (external, introjected) and the other expected items falling into another factor the authors label 'autonomous regulation' (identified, intrinsic) (Ryan and Connell 1989). The first questionnaire was developed for late-elementary and middle-school children, and concerns school work (Self-regulation Questionnaire-Academic). The adaptation we used here draws upon more recent refinements in the measure (Black and Deci 2000; Williams and Deci 1996) and indices were created (Jöreskog and Sörbom 2004). Alpha reliabilities for intrinsic and extrinsic motivation were .80 and .75 respectively. Instruments are available upon request to the authors. An example of four items is provided in Figure 8, demonstrating the domain-specific prefix and the validated question text (Black and Deci 2000; Williams and Deci 1996).

6. I participate actively in the Game Design class:

Figure 8.   Example of intrinsic/extrinsic motivation survey items.

For all dependent variables, we computed differences between pre- and post-variables for individuals.

Independent variables

Parent education

Parent education was the highest of both parents on a scale of: 1 = did not complete HS; 2 = completed HS; 3 = completed HS, attended some college; 4 = completed college; 5 = completed college, attended some graduate school; and 6 = completed graduate school. The relationship between adolescents' self-reports and parents' actual reports of parental education has been found in a previous study to be in fair agreement; kappa statistics were .30 and .38 for fathers' and mothers' education, respectively (Lien, Friestad, and Klepp 2001).

Formality of learning context

For the variable 'learning context', informal learning was given a value of 1; formal learning was given a value of 0.

Other variables

Further, individual-level variables of gender (male/female) and Race (Asian, Black/African-American, Hispanic/Latino, White vs. other races) were included in our models.

Methodological challenges and strategies

Answering the above research questions requires addressing analytic difficulties regarding the data-set, the outcome variables and the explanatory variables (see Table 1). Data-set issues include missing data and measurement errors from survey responses. First, missing questionnaire response data can reduce estimation efficiency, complicate data analyses, and bias results. Markov Chain Monte Carlo multiple imputation estimates the values of the

Table 1. Statistics strategies to address each analytic difficulty.

Analytic difficulty	Statistics strategy
Data set	
• Missing data	• Markov chain Monte Carlo multiple imputation (Peugh and Enders 2004)
• Survey measurement errors	• Factor analysis (Jöreskog and Sörbom 2004)
Outcome variables	
• Multiple outcomes	• Systems of equations (Kennedy 2008)
Explanatory variables	
• Omitted variable bias	• Differences-in-differences (Angrist and Krueger 1999)
• False positives	• Two-stage linear step-up procedure (Benjamini, Krieger, and Yekutieli 2006)
• Indirect, mediation effects	• Mediation tests (Kennedy 2008)

missing data, which addresses these missing data issues more effectively than deletion, mean substitution, or simple imputation, according to computer simulations (Peugh and Enders 2004). To minimize survey measurement error, we use multiple measures for each construct to create an index that is more precise than any single measure via factor analysis (Jöreskog and Sörbom 2004).

In this analysis, there are simultaneous, multiple outcomes. Multiple outcomes can have differences in variances across equations (cross-equation heteroskedasticity) and contemporaneous, correlated residuals that underestimate standard errors (Kennedy 2008). To model multiple outcomes properly, we use systems of equations (Kennedy 2008).

Explanatory variable issues include omitted variables, potential false positives, and mediation effects. Omitted variable bias can yield biased and inconsistent regression estimates (Angrist and Krueger 1999). We use differences-in-differences to control for unspecified student-specific variables, which reduces omitted variable bias (Angrist and Krueger 1999). Meanwhile, testing many hypotheses increases the likelihood of a false positive. To control for the false discovery rate (FDR), we will use the two-stage linear step-up procedure, which outperformed 13 other methods in computer simulations (Benjamini, Krieger, and Yekutieli 2006). Lastly, we test for indirect effects with mediation tests (Kennedy 2008).

Analysis

Factor analyses

We tested the internal validity of the survey items for each construct, minimized their measurement errors with confirmatory factor analyses, and its Bartlett

factor scores yielded unbiased estimates of factor score parameters (Jöreskog and Sörbom 2004). Using Monte Carlo simulation studies, Hu and Bentler (1999) showed that using a combination of the standardized root mean residual (SRMR) and one of the following indices tends to minimize Type I and Type II errors under many conditions for both factor analyses and SEMs: Tucker–Lewis index (TLI), incremental fit index (IFI), and root mean square error of approximation (RMSEA). The following threshold values separate good, moderate, and poor fits for each measure: SRMR ($<.08$; $<.10$; good fit if less than .08; moderate fit if between .08 and .10; poor fit if greater than .10), RMSEA ($<.06$; $<.10$), TLI ($>.96$; $>.90$), and IFI ($>.96$; $>.90$).

Differences in pre- and post-survey responses

First, we tested whether student post-survey responses differed from their pre-survey responses with paired *t*-tests. Then, we modeled differences (post-minus pre-) in self-efficacies, differences in intrinsic and extrinsic motivation, and differences in frequency of engagement in activities representing the CLAs with systems of equations (Kennedy 2008) with *EViews* software.

Differences in frequencies of student engagement in Globaloria *activities designed to cultivate the CLAs*

We modeled students' differences in frequency of engagement in activities representing the 6-CLAs with a system of equations (Kennedy 2008). We entered the variables according to expected causal relationships and likely importance

$$\mathbf{CLA}_{iy} = \beta_{0y} + \mathbf{e}_{iy}. \tag{1}$$

β_{0y} are the grand mean intercepts of $\mathbf{CLA}_{iy}$, a vector of *y* outcome variables (post-survey minutes pre-survey differences) in each of the frequency of engagement in activities the following activities, for student *i*:

CLA 1 'Idea' [developing original project ideas at home, at school]
CLA 2 'Create Project' [creating digital projects and engaging in project management at home, at school],
CLA 3 'Wiki' [publishing artifacts on the wiki at home, at school],
CLA 4 'Social' [engagement in online communication and socializing at home, at school],
CLA 5 'Search' [searching for resources from home, from class], and
CLA 6, 'Surf' [internet surfing at home, at school],

The residuals are $\mathbf{e}_{iy}$. First, we entered the student demographic variables: Gender, Race (Asian, Black/African-American, Hispanic/Latino, White vs. other races), and parent education (**Demographics**). All non-significant

variables were removed immediately.

$$\mathbf{CLA}_{iy} = \beta_{0y} + \mathbf{e}_{iy} + \beta_{xy}\mathbf{Demographics}_{iy} + \beta_{1y}\mathrm{Informal}_{iy}$$
$$+ \beta_{2y}\mathrm{School\_1}_{iy} + \beta_{zy}\mathbf{Motivation}_{iy}. \qquad (2)$$

A nested hypothesis test (χ^2 log likelihood) indicated whether each set of explanatory variables was significant (Kennedy 2008).

Next, we entered *Informal* (vs. formal). Then, we entered *SJSV1* or *School_1* (vs. other schools) due to descriptive statistics indicating a possible difference for this school. Lastly, we entered a vector of motivation variables: intrinsic motivation and extrinsic motivation (**Motivation**).

An alpha level of .05 was used for all analyses. Testing many hypotheses increases the likelihood that at least one of them incorrectly rejects a null hypothesis (a false significant result). To control for the FDR, we used the two-stage linear step-up procedure, which outperformed 13 other methods in computer simulations (Benjamini, Krieger, and Yekutieli 2006).

We used mediation tests across the above vectors (Kennedy 2008). For significant mediators, the proportional change was $1 - (b'/b)$, where b' and b were the regression coefficients of the explanatory variable, with and without the mediator, respectively. For a sample of 93, statistical power was .97 for an effect size of .4 (Cohen et al. 2003).

Differences in self-efficacies
We modeled students' differences in self-efficacies with a system of equations (Kennedy 2008). Except for the variables, the statistical procedure was the same as that of *differences in frequencies of engagement in activities supporting cultivation of the 6-CLAs*. β_{0y} are the grand mean intercepts of $\mathbf{SE}_{iy}$, a vector of y outcome variables (self-efficacy differences in individual items for student i,

> Online research for game project
> Developing game storyline
> Playing games online
> Using software for project creation
> Graphic design
> Designing for an audience
> Posting artifacts online
> Organizing the wiki
> Blogging
> Engaging in teamwork
> Organizing my time
> Concentration
> Finding answers to design problems online
> Using online tutorials for game design
> Programming in actionscript
> Giving other students help and

Meeting deadlines).
The residuals are $\mathbf{e}_{iy}$. **Motivation** was not entered in this model.

$$\mathbf{SE}_{iy} = \beta_{0y} + \beta_{xy}\mathbf{Background}_{iy} + \beta_{1y}\text{Informal}_{iy} + \beta_{2y}\text{School\_1}_{iy} + \mathbf{e}_{iy}. \quad (3)$$

Results

Factor analysis

The confirmatory factor analyses showed good fits for each of the above CLA, self-efficacy, and motivation constructs (ranges of all goodness-of-fit measures were acceptable; SRMR: .00−.06; RMSEA: .00−.09; CFI: 1.00; IFI: 1.00; and TLI: .99−1.00). The reliability coefficients ranged from .93 to .99. Space limitations prevent detailed discussion of the results, but the complete factor analyses are available from the authors.

Summary statistics

Content analysis evaluation of team games

A list of team names and game titles are provided in Table 2. The game titles at SJSV1 reflect their class focus on ancient Rome. The game titles at SJSV2 reflect their class focus on math. The second game of SJSV3 reflects the group focus on social issue themes. Table 3 presents mean game evaluation outcomes for each location. We observe that the formal locations (SJSV1 and SJSV2) had a much higher percentage of students who completed a game. Among the formal locations we observe that while students at SJSV1 appear to score higher on average in programming, those in SJSV2 appear to score higher in the three design categories.

Surveys

The 93 students who completed pre-surveys were 41% female, 59% male, 13% Asian, 11% Black or African-American, 59% Hispanic or Latino, and 15% White. Of these students, 68% participated in formal *Globaloria* activities in class and 32% participated in informal *Globaloria* activities. The education of their parents varied widely, as 40% of their parents did not complete college (including 15% who did not complete high school) while 37% attended some graduate school.

Students in the formal vs. informal conditions differed on a few variables prior to participating (see Table A2). More students in the formal condition were white (21%) than in the informal condition (3%). On the other hand, prior to participating, students in the *informal* condition reported significantly higher frequency of engagement *at home*, in CLA 2 (Create Project), CLA 3 (*Wiki*), and CLA 4 (Social).

Table 2.   Team names and game titles.

SJSV1		SJSV2		SJSV3	
Team name	Game title	Team name	Game title	Team name	Game title
Awesome Dalek Battlers	Escape The Pyramid	Barcelona	MATH SPORTS	Team Salad	Team Robots
Bamboo straw hat Madness	Labyrinth	Sharks	Time Telling Ball	Bertha's BIG Adventure!	Bully
Bored	Greek Survival	Strikers	Pac Rat		
Digital Romans	The Roman games	T.G.I. Flash	Multiplying Integers Math Racing		
Ford Chevy Cessna	Aztecs Weapons	Task Force Flash	Stickman Vs. Wild		
Greek God and Goddess	War of Mount Olympus	The IDK'S	Math Blocks		
Killer Robots	Spartans vs. Athens	YMCMB	Race Around the USA		
NOR-CAL	ESCAPING ROME!				
Roman Numerals	Journey of Gladius				
Team Name	Save The Princess				
The Awsome Romans	A Day In Rome				

Students' aggregate frequency of engagement in CLA activities all appear to increase during *Globaloria*, but only CLA 2 (Create Project) at school was significant from pre- to post-program (see Table 4 for details). Likewise, only self-efficacy in graphic design significantly increased during *Globaloria*. Other measures of self-efficacy and motivation did not show significant differences in this sample.

Explanatory models

The system of equations in the explanatory models adds insight on some of the observed and measured differences in the overall grouped sample for frequency of engagement in CLA activities, self-efficacies, and intrinsic and extrinsic motivation.

Table 3. Mean game evaluation score, by location.

	No. of games	No. of students who created games	Programming	SD	Visual and sound design	SD	Game-play/ mechanics	SD	Concept	SD	Total sum	SD
SJSV1	11	33 (all)	7.45	1.57	12.45	2.21	12.64	1.91	17.55	2.11	50.09	6.28
SJSV2	7	32 out of 34	6.57	1.52	13.00	1.47	14.29	0.84	19.71	0.52	53.57	3.49
SJSV3	2	4 out of 30	3.00	2.83	8.00	4.24	8.50	3.54	14.50	3.54	34.00	14.14
SJSV4	0	0 out of 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.   Summary statistics ($N = 92$).

Variable	Mean	SD	Min	Median	Max	Significant?
Differences in ... (post- minus pre-)						
CLA 1 'Idea' at home	0.29	1.89	−4.90	0	4.88	
CLA 1 'Idea' at school	0.39	2.16	−5	.01	4.99	
CLA 2 'Create Project' at home	0.43	1.66	−5	0	5	
CLA 2 'Create Project' at school	1.19	1.93	−5	.85	5	**
CLA 3 'Wiki' at home	0.21	1.45	−5	0	5	
CLA 3 'Wiki' at school	0.87	2.04	−5	0	5	
CLA 4 'Soc' at home	0.16	1.55	−4	0	4.52	
CLA 4 'Soc' at school	0.26	1.66	−5	0	5	
CLA 5 'Search' at home	0.52	1.70	−3.94	.25	4.42	
CLA 5 'Search' at school	0.66	1.84	−4.68	.14	5	
CLA 6 'Surf' at home	0.15	1.86	−4.85	.01	4.53	
CLA 6 'Surf' at school	0.28	1.86	−4.95	0	4.95	
Self-efficacy (confidence in ...), online research for game project	0.02	1.60	−3	0	4	
Developing game storyline	0.13	1.60	−4	0	4	
Playing games online	0.20	1.71	−4	0	4	
Using software for project creation	0.22	1.73	−4	0	4	
Graphic design	0.42	1.95	−4	0	4	*
Designing for an audience	0.08	1.85	−4	0	4	
Posting artifacts online	0.01	1.83	−4	0	4	
Organizing the *wiki*	−0.02	1.94	−4	0	4	
Blogging	0.09	1.90	−4	0	4	
Engaging in teamwork	−0.48	1.82	−4	0	4	
Organizing my time	−0.57	1.63	−4	0	3	
Concentration	−0.26	1.84	−4	0	4	
Finding answers to design problems online	−0.27	1.78	−4	0	4	
Using online tutorials for game design	−0.22	1.76	−4	0	4	
Programming in ActionScript	−0.57	1.61	−4	0	3	
Giving other students help	−0.10	1.64	−3	0	4	
Meeting deadlines	−0.26	1.81	−4	0	4	
Intrinsic motivation	−0.30	1.73	−4	−.11	3.73	
Extrinsic motivation	0.33	1.40	−3.75	.24	3.13	
Female	0.41	0.50	0	0	1	
Asian	0.13	0.34	0	0	1	

Table 4.   Continued.

Variable	Mean	SD	Min	Median	Max	Significant?
Black/African-American	0.11	0.31	0	0	1	
Hispanic/Latino	0.59	0.50	0	1	1	
White	0.15	0.36	0	0	1	
Parent education	2.29	1.64	1	1	6	
Informal (vs. formal)	0.32	0.47	0	0	1	
School #1	0.33	0.47	0	0	1	

$^*p < .05.$
$^{**}p < .01.$

Changes in frequency of engagement in activities designed to cultivate the CLAs

Globaloria formality and motivation were two variables that were related to changes in students' frequency of engagement in some of the CLA activities. Specifically, students participating in *formal Globaloria* activities increased in frequency of engagement in CLA 2 (Create Project) at school more so than students in *informal Globaloria* activities (Before participating in the formal or informal *Globaloria* activities, the two groups of students did not differ in CLA 2 [Create Project] at school.) (see Table 5).

Notably, students whose intrinsic and extrinsic motivation increased during *Globaloria* activities also showed greater increases in their frequency of engagement in several of the CLA activities. Specifically, students whose intrinsic motivation increased showed greater increases in their frequency of engagement in the following: frequency of engagement in CLA 1 (Idea) both at home and at school; CLA 2 (Create Project) at school; CLA 4 (Social) at home; CLA 5 (Search) both at home and at school; and CLA 6 (Surf) both at home and at school. The same was true for extrinsic motivation, for CLA 6 (Surf) at school only.

Self-efficacies

Self-efficacies were measured using single items. Parent education, race, and the context of *Globaloria* implementation (formal = 0; informal = 1) were linked to students' self-efficacies (see Table 6). Specifically, the online research self-efficacy for students whose parents had less education *increased more so* than those of students whose parents had more education. Before the *Globaloria* activity, the online research self-efficacy of students did not differ across parent education. Gains in online research self-efficacy were lower for the black/African-American students than for other students. Meanwhile, Asian students had greater gains in self-efficacy toward both designing for an audience and programming, compared to other students.

Table 5. System of equations predicting pre- and post-survey differences in CLA 1 'Idea' at home and at school; CLA 2 'Create Project' at school; CLA 4 'Social learning' at home; CLA 5 'Search' at home and at school; CLA 6 'Surf' at home and at school.

	Outcome variable		
Explanatory variable	Model 1	Model 2	
Difference in CLA 1 'Idea' at home			
Constant	0.288 (0.196)	0.389 (0.186)	**
Difference in intrinsic motivation		.342 (.101)	***
R^2	.000	.123	
Difference in CLA 1 'Idea' at school			
Constant	0.387 (0.223)	0.501 (0.213)	**
Difference in intrinsic motivation		.383 (.118)	***
R^2	.000	.115	
Difference in CLA 2 'Create Project' at school			
Constant	1.438 (0.212) **	1.501 (0.208)	***
Informal	−.787 (.290) **	−.775 (.292)	**
Difference in intrinsic motivation		.225 (.103)	**
R^2	.076	.132	
Difference in CLA 4 'social learning' at home			
Constant	0.155 (0.161)	0.220 (0.157)	
Difference in intrinsic motivation		.217 (.087)	**
R^2	.000	.075	
Difference in CLA 5 'Search' at home			
Constant	0.515 (0.176) **	0.597 (0.169)	***
Difference in intrinsic motivation		.278 (.092)	***
R^2	.000	.102	
Difference in CLA 5 'Search' at school			
Constant	0.662 (0.191) **	0.732 (0.186)	***
Difference in intrinsic motivation		.238 (.099)	**
R^2	.000	.071	
Difference in CLA 6, 'Surf' at home			
Constant	0.148 (0.193)	0.285 (0.173)	
Difference in intrinsic motivation		.462 (.096)	***
R^2	.000	.210	
Difference in CLA 6, 'Surf' at school			
Constant	0.282 (0.193)	0.132 (0.184)	
Difference in extrinsic motivation		.450 (.116)	***
R^2	.000	.127	

$*p < .05.$
$**p < .01.$
$***p < .001.$

Table 6.   System of equations predicting pre- and post-survey self-efficacy differences in graphic design, designing for an audience, programming in ActionScript and online research for game project.

Explanatory variable	Outcome variable	
	Self-efficacy differences in online research for game project	
Constant	.561 (.206)	**
Black	−1.259 (.315)	***
Parent education	−.176 (.060)	**
R^2	.128	
	Self-efficacy differences in designing for an audience	
Constant	−0.034 (0.194)	
Asian	.842 (.360)	**
R^2	.036	
	Self-efficacy differences in programming in ActionScript	
Constant	−0.650 (0.169)	***
Asian	.651 (.290)	**
R^2	.024	
	Self-efficacy differences in graphic design	
Constant	.587 (.210)	**
Informal	−.516 (.235)	**
R^2	.042	

** $p < .01$.
*** $p < .001$.

Lastly, the gains in graphic design self-efficacy of students in the formal *Globaloria* setting significantly exceeded those of students in the informal setting. [Note, before participating in the *Globaloria* activities, these self-efficacies did not differ significantly across school, race, or the context of *Globaloria* implementation (formal = 0; informal = 1).]

Other explanatory variables were not significant. Also, all mediation tests were not significant.

Discussion

As the aggregate findings in Table A2 indicate, students in our California sample reported limited experience with most program activities prior to their participation. Changes in frequency of engagement at home for CLA 2 (Create Project) are an indicator of students' transfer of activities from the school to the home environment, indicating perhaps a heightened level of motivation toward these specific activities. This category represents the primary activity of *Globaloria* (developing a game) and reflects particularly

'Constructionist' creative and production-based work. Building a game in Flash creates a 'need to know' among students. Their transfer of engagement to the home environment may signal a growing disposition toward the Constructionist practices.

Increases in self-efficacy for graphic design indicate that students feel a growing level of confidence in their productivity with design software. While the other apparent mean changes for self-efficacy were not significant in this smaller California student sample, we note the opposition in directionality for a contrasting set of activities. Specifically, apparent (non-significant) self-efficacy *decreases* result for activities representing *less-structured* aspects of the *Globaloria* instructional design (e.g., *wiki* use), whereas the findings indicate apparent *increases* in student self-efficacy toward central *creative game design activities*. While student affect toward the central game-making activities seems to be enhanced, they may find the discovery-based approaches for learning difficult. This finding appears related to results of a recent interview study (Reynolds et al. 2013), which indicate that while the *Globaloria wiki* offers some coordinating affordances for students (such as aiding in tasks such as syllabus assignment completion and offering tutorial resources for game design), students struggle to successfully use some of the tutorial and informational resources provided. Students also appeared to underutilize the *wiki* platform for active project management and version control (Reynolds et al. 2013). More understanding is needed of students' use of the e-learning environment. On site observation and *Google Analytics* page read data made available from 2012/2013 forward will help.

Explanatory models

This study presented six research questions. Research questions 1 and 2 addressed the contribution of context formality to students' frequency of engagement and self-efficacy toward CLA activities. Students in the formal context reported greater increases than those in the informal context in time on task at school for the main program activities of game creation; greater increases in self-efficacy for graphic design; and they ultimately had more success completing final games that could be evaluated as measured in the content analysis. The frequency results are parsimonious given that the more formal environment reflected a greater amount of daily time on task at school, grades for work, course credit, consistent implementation, and little lag time between course sessions. Overall, changes in student attitudes were not notably different as a result of formality context differences.

Research questions 3–6 address relationships among intrinsic and extrinsic motivation, parent education, and the dependent variables. Results indicated that *prior to participating*, the higher the students' parent education level, the higher was their level of confidence across most *Globaloria* activities (before participating in *Globaloria*, mean of correlations of parent education with self-

efficacy measures = .32). This finding may indicate prior self-esteem differences due to SES, and/or differences in students' prior experiences with technology due to greater technology affordances for higher SES students. For online research, it appears that *Globaloria* may offer particular advantages to students whose parents have lower levels of education, in terms of feelings of self-efficacy. Inquiry is an autonomous and agential activity. This result holds digital divide implications that invite greater investigation. It may be that *Globaloria* is effective in introducing lower-income students to inquiry-type activities, which have potential to contribute to their feelings of agency with technology. We are investigating these phenomena further with a larger *N* data set, especially in light of their apparent contrast to the Kirschner, Sweller, and Clark (2006) critique of discovery-based search activity during learning.

The explanatory model results for intrinsic and extrinsic motivation are also notable. Ryan and Deci (2000) argue that intrinsic and extrinsic motivation are neither traits nor state concepts or characteristics of individuals; they are mutable, but are more stable than typical fluctuating state characteristics, which change as a function of time and place. The environment in which one is operating can be autonomy-supportive to greater or lesser extents and thus more or less conducive for self-determined action and creative fulfillment (Ryan and Deci 2000). Participation in the coordinated game design activities of *Globaloria* (i.e., increases in frequency of engagement at home and school) has now been linked to positive intrinsic motivational shifts in some students, which reflects motivational change at a more fundamental psychological level. We must investigate why these changes occur for some students in particular, whether these shifts are lasting, and how they may further influence ongoing student cognition, affect, and behavior trajectories outside of *Globaloria*. This result seems to further contradict arguments against discovery-based learning (Kirschner, Sweller, and Clark 2006). Findings for Black/African-American and Asian students also indicate that cultural factors may be influencing student experiences.

Conclusion

California was the only *Globaloria* site in this school year that offered variation in formality of instructional design context (in-school and after-school), thus it was the focus for this investigation. The findings on final game number and quality offer preliminary support that greater structure was beneficial to student game completion rates. Further, results invite greater investigation of SES and student inquiry activity, and, further investigation of the seemingly contrasting results for declining self-efficacy vs. the positive relationships between change in frequency of engagement and change in intrinsic motivation. The results will inform our hypotheses in future multi-level analysis models. Qualitative observational analysis (underway) will also inform student experiences and processes at varying stages of the curriculum sequence (e.g., early phase paper prototype decision-making, vs. late-phase 'crunchtime'), and, how specific

instructional design features encountered at varying sequential phases interplay with student decision-making and success trajectories. More research is needed to understand what specific program structures will support a fuller range of participants (e.g., those who may be more extrinsically oriented). Overall, this study shows that explication and statistical analysis of context factors, SES, and individual motivational differences can contribute to our understanding of student experiences, and can support instructional design iteration.

Given that this was the first year of implementation in California, changes being made in the after-school locations in 2012/2013 include firmer commitments on behalf of the educators and students to consistently be present for a greater number of days each week. Further, the *World Wide Workshop* recently hired a state program manager for California, who will more closely coordinate the implementation and serve as the educator point of contact. The gap in performance outcomes between the formal and informal locations may thereby narrow as the program continues. Iterative year-by-year improvements to the implementation and to teacher expertise must be investigated in our future models. As the program *N* grows, and our explication of key variables and their measurement is refined in our design-based research, we step closer to our primary research goal of creating a predictive multi-level social science model of the phenomena driving this social learning system. These efforts can inform development and implementation of more effective 'guided discovery-based' technology-supported learning experiences for students, as such programs and curricula become more readily utilized, which we expect they will.

Acknowledgments

Notes

1. For programming, 12-item kappas were $>.92$. For visual/sound design, all 5-item kappas were $>.91$. For game-play experience, all 5-item kappas were $>.84$. For concept development, all 7-item kappas were $>.75$.
2. Only students whose parents signed consent forms and who individually assented and volunteered to participate in research are included in our surveys, hence the drop-off from participation to pre-survey completion. Drop-off from pre-survey to post-survey is due to a range of factors, including student voluntary opt-out, student absences at the end of the school year on the days the surveys were administered, the drop-in nature of the informal contexts, student discontinuations in the program for instance due to the changing of schools. The *N* of students who completed the pre- but not the post- is so small that statistical differences between them and those who did complete it are undetectable. Due to the drop-off rate at SJSV4 the bulk of the results for the informal context must attributed to SJSV3 center.

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Appendix 1. Ancillary tables and results

Table A1. Correlations, variances, and co-variances are along the lower left triangle, diagonal, and upper right triangle of the matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	**3.54**	3.10	1.51	1.29	1.26	1.62	1.51	2.05	1.55	0.86	1.60	1.64	1.34	1.14	0.47	0.11	0.07	0.14	−0.06
2	0.77	**4.59**	2.30	1.25	1.29	1.61	1.91	1.81	1.54	1.24	1.73	1.92	1.52	1.26	0.58	0.09	−0.03	−0.22	−0.09
3	0.42	0.56	**3.67**	1.11	1.10	1.25	2.23	1.03	1.75	0.72	1.51	1.62	1.40	0.88	0.65	0.08	−0.03	−0.14	−0.26
4	0.48	0.40	0.40	**2.08**	0.87	1.25	1.32	0.93	1.16	0.21	0.84	0.73	0.67	0.42	0.09	0.09	0.03	0.37	−0.07
5	0.43	0.39	0.37	0.39	**2.38**	1.03	1.11	1.26	0.97	0.53	1.09	1.04	0.77	0.73	0.12	0.03	0.05	0.14	−0.01
6	0.51	0.44	0.39	0.51	0.40	**2.85**	1.57	1.89	1.36	0.77	1.40	1.28	1.24	0.94	0.40	0.05	0.02	0.16	−0.07
7	0.44	0.49	0.64	0.50	0.39	0.51	**3.35**	1.32	1.83	0.56	1.29	1.40	1.12	0.85	0.69	−0.01	0.08	−0.12	−0.13
8	0.59	0.46	0.29	0.35	0.44	0.61	0.39	**3.42**	1.26	1.12	1.79	1.67	1.64	1.46	0.53	0.07	0.04	0.25	−0.07
9	0.45	0.39	0.49	0.44	0.34	0.44	0.54	0.37	**3.42**	0.64	1.47	1.52	1.07	1.06	0.92	−0.07	0.02	−0.24	−0.16
10	0.29	0.36	0.24	0.09	0.22	0.29	0.19	0.38	0.22	**2.52**	2.22	1.82	1.68	1.89	1.02	−0.04	−0.14	−0.66	−0.09
11	0.44	0.42	0.41	0.30	0.37	0.43	0.37	0.50	0.41	0.72	**3.74**	2.75	2.38	2.20	1.32	0.06	−0.06	−0.31	−0.21
12	0.47	0.49	0.46	0.28	0.37	0.41	0.42	0.49	0.45	0.62	0.77	**3.40**	2.18	2.13	1.30	0.12	−0.04	−0.28	−0.14
13	0.44	0.44	0.46	0.29	0.31	0.46	0.38	0.55	0.36	0.66	0.77	0.74	**2.57**	1.90	1.10	0.08	0.01	0.13	−0.07
14	0.35	0.34	0.27	0.17	0.28	0.32	0.27	0.46	0.33	0.69	0.66	0.67	0.69	**2.97**	1.66	0.01	−0.04	−0.28	−0.11
15	0.18	0.19	0.24	0.05	0.05	0.17	0.27	0.21	0.36	0.46	0.49	0.51	0.49	0.69	**1.95**	0.00	0.00	−0.21	−0.04
16	0.18	0.13	0.12	0.19	0.06	0.09	−0.01	0.11	−0.11	−0.07	0.10	0.19	0.16	0.01	0.01	**0.11**	−0.14	0.12	−0.01
17	0.11	−0.05	−0.06	0.07	0.10	0.05	0.14	0.07	0.03	−0.29	−0.09	−0.07	0.01	−0.07	0.01	−0.01	**0.10**	0.08	0.02
18	0.05	−0.06	−0.04	0.16	0.06	0.06	−0.04	0.08	−0.08	−0.25	−0.10	−0.09	0.05	−0.10	−0.09	0.23	0.15	**2.66**	−0.02
19	−0.06	−0.09	−0.29	−0.10	−0.01	−0.08	−0.15	−0.08	−0.18	−0.13	−0.23	−0.17	−0.10	−0.14	−0.06	−0.05	0.14	−0.02	**0.22**

Notes: Bold numbers indicate variances. (1) Difference in CLA 1 'Idea' at home, (2) difference in CLA 1 'Idea' at school, (3) difference in CLA 2 'Create Project' at school, (4) difference in CLA 3 'Wiki' at home, (5) difference in CLA 4 'Soc' at home, (6) difference in CLA 5 'Search' at home, (7) difference in CLA 5 'Search' at school, (8) difference in CLA 6, 'Surf' at home, (9) difference in CLA 6, 'Surf' at school, (10) self-efficacy differences in Online research for game project, (11) self-efficacy differences in Graphic design, (12) self-efficacy differences in Designing for an audience, (13) self-efficacy differences in Programming in ActionScript, (14) difference in Intrinsic motivation, (15) difference in Extrinsic motivation, (16) Asian, (17) Black/African-American, (18) parent education, (19) informal (vs. formal).

Table A2. Means of initial values for students in the formal vs. informal conditions.

Variable	Formal	Informal	Significant difference?
Pre			
CLA 1 'Idea' at home	2.11	2.25	
CLA 1 'Idea' at school	2.24	1.96	
CLA 2 'Create Project' at home	1.27	1.79	*
CLA 2 'Create Project' at school	1.38	1.56	
CLA 3 'Wiki' at home	1.21	1.90	**
CLA 3 'Wiki' at school	1.48	1.66	
CLA 4 'Soc' at home	1.74	2.56	*
CLA 4 'Soc' at school	1.50	1.76	
CLA 5 'Search' at home	2.19	2.42	
CLA 5 'Search' at school	1.84	1.76	
CLA 6 'Surf' at home	2.78	2.96	
CLA 6 'Surf' at school	1.63	1.95	
Self-efficacy (confidence in…)			
Online research for game project	3.94	3.86	
Developing game storyline	3.37	3.17	
Playing games online	3.06	3.17	
Using software for project creation	3.16	3.07	
Graphic design	3.16	3.24	
Designing for an audience	3.21	3.21	
Posting artifacts online	3.35	3.38	
Organizing the *wiki*	3.32	3.10	
Blogging	3.32	3.24	
Engaging in teamwork	3.97	3.90	
Organizing my time	3.89	3.83	
Concentration	3.65	3.52	
Finding answers to design problems online	3.54	3.21	
Using online tutorials for game design	3.54	3.45	
Programming in ActionScript	3.87	3.69	
Giving other students help	3.84	3.62	
Meeting deadlines	3.56	3.48	
Intrinsic motivation	3.65	3.56	
Extrinsic motivation	2.45	2.16	
Female	0.38	0.48	
Asian	0.14	0.10	
Black/African-American	0.08	0.17	
Hispanic/Latino	0.56	0.66	
White	0.21	0.03	*
Parent education	2.32	2.24	

$^{*}p < .05.$
$^{**}p < .01.$