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Promoting students' science literacy skills through a simulation of international negotiations: The GlobalEd 2 Project

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ABSTRACT

Problem-based learning (PBL) is an instructional design approach for promoting student learning in context-rich settings. GlobalEd 2 (GE2) is PBL intervention that combines face-to-face and online environments into a 12-week simulation of international negotiations of science delegates on global science issues. Although GE2 focuses on science, it is implemented in a social studies classroom. This manuscript describes the GE2 environment and evaluates its impact on middle school students' scientific literacy compared to a comparison group receiving normal educational practice. Hierarchical Linear Modeling (HLM) analyses on GE2 and comparison groups demonstrates the significant positive impact of GE2 on two measures of scientific literacy (Socio-scientific Literacy and Scientific Inquiry), among middle-grade students from two states. Implications regarding instructional practice and future research are discussed.

1. Introduction

Many have argued, that in order to develop the next generation of citizens who are scientifically literate and capable of making both local and global decisions about science related-topics, science education needs to be grounded in current and meaningful socio-scientific contexts that emanate from the real world (Anderson, 2002; Sadler, 2009). Socio-scientific issues are complex, dynamic and ill-structured by nature, often without a single clear-cut solution for all the parties involved. Employing contextual issues confronting students with situations where they formulate their own data-based opinions, leverage their personal experience and values, and engage in collaborative decision-making, can have a major impact on the students' development of knowledge, attitudes and skills (Schrader & Lawless, 2004).

Socio-scientific issues have been regarded as real-world problems affording students the opportunity to participate in the negotiation and development of meaning through scientific argumentation (Chinn & Malhotra, 2002; Osborne, Erduran, & Simon, 2004; Schwarz, Neuman, Gil, & Ilya, 2003). Argumentation includes dialog that addresses "the coordination of evidence and theory to support or refute an explanatory conclusion, model, or prediction" (Osborne et al., 2004, p. 995). Research has demonstrated that when students engage in meaningful scientific argumentation, they not only learn how to develop and understand arguments, but also learn the science content and skills associated with the topic they are discussing (e.g., Osborne, Erduran, Simon, & Monk, 2001; Jiménez & Pereiro-Muńos, 2002; Schwarz et al., 2003; Erduran, Simon, & Osborne, 2004).

Unfortunately, it has been reported that all too often, that inquiry-based approaches to teaching and learning about science involving socio-scientific topics have not been employed within typical classrooms, particularly those that engage students in argumentation (Chinn & Malhotra, 2002; Driver, Leach, Millar, & Scott, 1996; Taber, 2008; Turner, 2008). While state and national standards have shifted towards the use of inquiry-based approaches and argumentation in science, and the inclusion of socio-scientific topics, there has not been a commensurate modification of the curricular space devoted to the teaching of science (Sadler, Barab, & Scott, 2007). Inquiry-based curricula, especially programs that immerse learners in active investigations of contemporary issues, can consume significant chunks of limited class time. Furthermore, research on science teachers has found that they report feeling under-prepared and often lack the efficacy necessary

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to implement and manage socio-scientific inquiry within their own science classes (Alozie, Moje, & Kracik, 2010; Bartholomew, Osborne, & Ratcliffe, 2004; Bennett, Lubben, Hogarth, & Campbell, 2005; Levinson, & Turner, 2001).

One way to solve the curricular compression issue is to look beyond the instructional time devoted to science, and identify interdisciplinary contexts that can be leveraged to expand when and where students engage in science inquiry. Problem-based learning (PBL) researchers have illustrated for decades that using interdisciplinary contexts, like social studies, as a context to engage in real-world problem solving can have a profound and positive impact on learning by deepening students' understanding and yielding flexibility in application and transfer of knowledge/skills (Jonassen, 2009; Koschmann, Kelson, Feltovich, & Barrows, 1996; Mergendoller, Bellisimo, & Maxwell, 2000; Strobel & van Barneveld, 2009). Because PBL consists of a presentation of authentic problems as the launch point for learning, it has also been shown to improve students' motivation and integration of knowledge across multiple contexts (Bednar et al., 1995). Further, when working cooperatively within a PBL environment, students also learn how to plan and determine what they need to solve problems, pose questions, and decide where they can get answers, as they make sense of the world around them (Brown et al., 2008; Brown, Lawless, Rhoads, Newton, & Lynn, 2016; Lawless & Brown, 2015; Lawless, Brown, & Boyer, 2016; Lawless et al., 2012). As such, social studies can be used as a space where students can ground the learning of science in real world contexts, apply their science knowledge and become a forum for engaging in socio-scientific inquiry and argumentation.

Recognizing this, the GlobalEd 2 Project (GE2) expands the curricular space afforded to the teaching of science by building upon the interdisciplinary nature of social studies classes while also enhancing the social studies curriculum. GE2 is designed to cultivate a scientifically literate citizenry by grounding science education in meaningful socio-scientific contexts related to the world in which students currently inhabit (Anderson, 2002; NRC, 1996; Sadler, 2009). GE2 is an interactive, online simulation that links classrooms of students across multiple locations that are otherwise isolated from one another by physical distance and socio-economic boundaries, implemented by social studies teachers in middle school social studies classrooms. Further, GE2 is linked with the Common Core (2017), Next Generation Science Standards (NGSS, 2013) and the C3 framework for social studies (NCSS, 2013). In the following sections, we describe the GE2 experience as it is currently implemented, followed by results of our large-scale efficacy study conducted over the two years.

2. How GE2 works

One implementation of GE2 lasts 14 weeks (although this timeframe can be modified to fit different needs of participating classrooms), and engages 16–20 classrooms of students. Each participating classroom is assigned to represent the interests of a different country. Countries are pre-selected and assigned by the GE2 staff in order to ensure a diverse set of perspectives across governments, culture, geography, economics, environment and health concerns within each simulation. While international negotiations of the scale and scope posed in GE2 problem scenarios would not be authentic if the United Stated were not involved, it is important to note that one of the intents of GE2 is to expand students' social perspective to be more global. As such, while the United States is played in every scenario, it is never assigned to a participating classroom. Instead, two trained undergraduate students play the role of the USA, a fact that is unknown by the teachers or GE2 student delegates. This design feature of GE2 forces students to learn to adopt the perspective of an "outside" international actor. Further, this affords the opportunity for the USA team to model negotiations, particularly written format and socio-scientific content, for participating students.

Students within each country opt to participate in one of four, smaller working groups, called issue areas (Economics, Human Rights, Environment and Health). These issue areas are consistent across each of the participating classrooms, affording students in one issue area to communicate with their corresponding issue area in another classroom (See Fig. 1). Although interaction takes place between the specific issue groups *across* countries in the simulation, it is important to note that *within* a country the four issue groups must also communicate to ensure a unified policy stance of the entire country in the simulation.

At the outset of a GE2 implementation, each participating classroom (country) is provided with a problem scenario. The problem scenario provides background information about a current issue somewhere in the world with specific scientific details that would lead the participating countries in the simulation to have to take timely action. It sets the common context for the countries in the simulation, anchoring interactions among students. Current scenario topics include Water Resources, Climate Change, Food Security and Alternative Energies.

There are three phases of a single implementation of GE2 (see Fig. 2). The first phase, the Research Phase, is six weeks and requires the students to use the online Student Research and Tools Database to learn about the issues presented in the problem scenario. Students must identify the key scientific issues of concern, as well as how their assigned country's culture, political system, geography and economy influence their science perspectives. Additionally, students must also become familiar with the policies of the other countries included in the simulation in order to develop initial arguments and plan for potential collaborations. For example, in the water resources scenario, students use the Student Research and Tools Database to learn about water consumption, pollution, irrigation, and access to fresh, clean water as well as other related issues currently facing each of the countries involved. As the outcome of the Research Phase, students in each classroom work collaboratively to develop opening policy statements (written socio-scientific arguments), containing their national position for each of the four issue areas and how they wish to start addressing the international problem presented in the scenario with other countries who will also be negotiating within the simulation. These opening statements range in length from 200 to 500 words, though some detailed statements are longer. Statements are then shared as documents through a proprietary Online Communications Platform. The sharing of the opening statements serves as the launch activity for Phase 2 of the simulation, the interactive negotiations among countries.

Throughout the six weeks of the Interactive Phase (Phase 2), students work to negotiate international agreements with the other "countries," sharpening their arguments through usage of the Student Research and Tools Database a sharing them through the Online Communications Platform, in an asynchronous format similar to email. Based on prior implementations, the number of communications exchanged during the Interactive Phase can exceed 5000 (though length varies from a single sentence to longer multi-paragraph exchanges). Participating students also engage in real-time conferences (i.e., instant messaging-like) at various points throughout the Interactive Phase. These real-time conferences are important for students to clarify understandings among participating countries and push negotiations forward more quickly than might be attainable through asynchronous communications alone. Both the content and negotiations among the countries participating within the Interactive Phase are student-

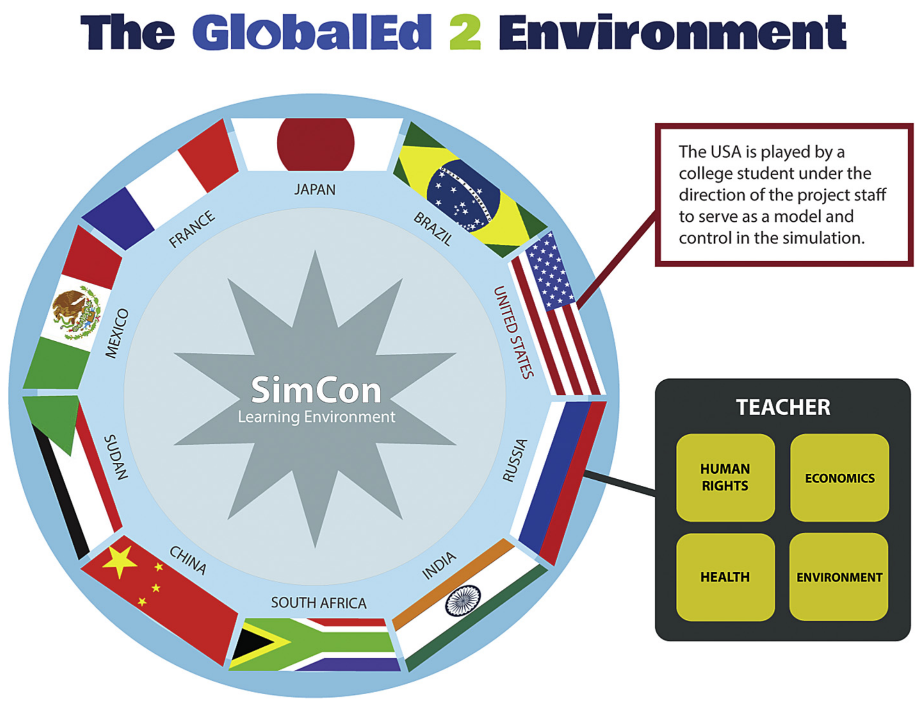

Fig. 1. The GlobalEd 2 simulation environment.

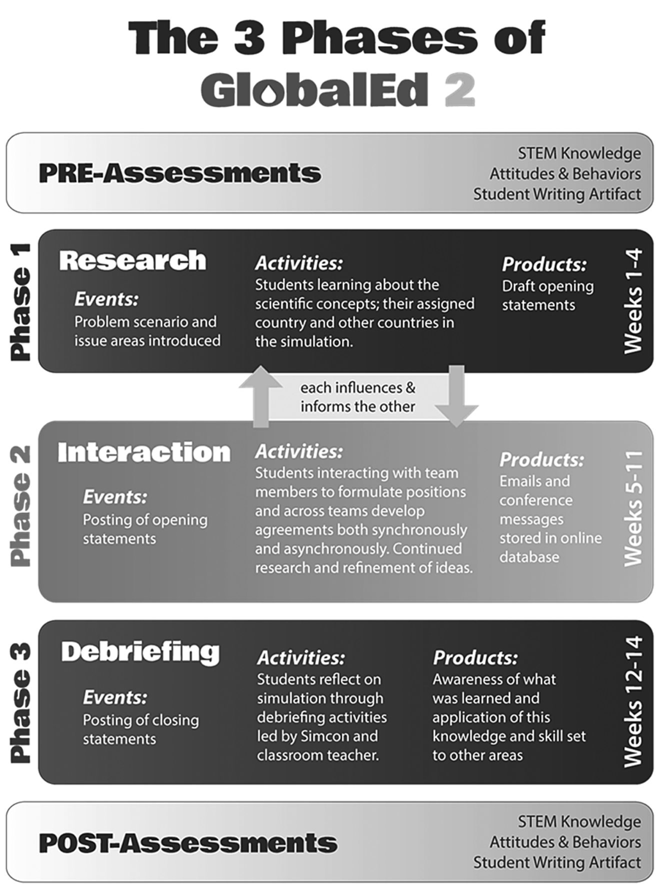

Fig. 2. The three phases of the GlobalEd 2 simulation.

driven and dynamic, as GE2 is designed to engage participants in ill-structured and dynamic problem solving. As such, while the problem scenario sets the larger context for the simulation, what and how students negotiate emerges from their interactions with one another.

A trained simulation coordinator, "SimCon," monitors all online communications and facilitates the real-time conferences. SimCon's role is similar to that of a virtual teacher/facilitator in an active learning classroom, in which SimCon oversees all aspects of the learning process and coaches students to think critically about the complex issues central to their scientific arguments. Further, SimCon monitors and provides feedback to students regarding the content (scientific and political), argument structure and tone of their communications with other countries as a means of formative evaluation on a weekly basis. SimCon's ability to moderate the dialog and interactions among participating students is facilitated through a back-end control function in the Online Communications Platform.

The culminating event of the Interactive Phase is the posting of each country's closing statement, reflecting the final position of each country-team on the four issue areas. Students work collaboratively within their country-team issue area to construct these closing arguments, articulating points of agreement and topics where continued work is necessary among the participating countries. The posting of the closing arguments in the Online Communications Platform marks the start of the third phase of the GE2 experience, Debriefing.

The Debriefing Phase lasts two weeks and is designed to activate metacognitive processes in students as they review what they learned and how they can apply this new science content knowledge and associated skills in other contexts and domains. SimCon facilitates a scheduled on-line debriefing with all participants, exploring issues related to learning outcomes, simulation processes, transfer, and feedback. Teachers are also trained to perform multiple debriefing activities within their classrooms to promote metacognition, learning and transfer. These include educational activities, such as analyzing the "behind-the-scenes" negotiations available to students after the simulation ends, writing final essays about the experience, examining local water resource issues or completing other tasks aimed at relating the experience back to the educational context and the real world of environmental sustainability in both local and global affairs.

It is extremely important to note, all interactions in GE2 are text-based – a purposive design decision for two reasons. First, the written artifacts the students produce (e.g., opening/closing statements and online negotiations) are a means of making students' thinking visible on a consistent basis, providing an avenue for teachers and researchers to formatively assess student's engagement, scientific thinking, writing, leadership and problem solving. GE2 teachers are trained in the use of these written interactions as an evaluative tool during their professional development (intensive online training for 5 days prior to the start of the simulation and ongoing on a weekly basis during the simulation proper) and are provided assessment rubrics in the GE2 curricular materials to facilitate this process. Secondly, the use of this anonymous written communication mode allows educators to hold some factors in the educational context neutral (e.g., personal appearance, gender, race, verbal communication abilities and accents). Students only identify themselves within GE as country, issue and initials; for example, "ChinaEnvSWB" (China's environmental negotiator SWB), blinding their actual identities to students outside their classroom. As a result, typical stereotypes, associated with gender, race or socioeconomic class are minimized as factors influencing the interactions among participants.

Classroom teachers implementing GE2 are supported by both front end and on-going professional development provided through an online Teacher Portal. Prior to their first time implementing GE2, teachers participate in a three-day online course in which they learn about GE2, the theory behind it, how teaching and assessment occurs within GE2, content related to the scenario and how the technology works. In addition, weekly podcasts are provided using a "just in time" training model, providing content and process suggestions to instructors as demanded by the trajectory of the students' interactions in the simulation. Finally, an online learning community for GE2 supports information exchange, questions and queries and the sharing of pedagogical tips and lessons among cadres of GE2 teachers.

The Teacher Portal also provides access to a host of GE2 web-based lessons and learning supports. The lessons are aimed at helping students to identify and align important information across disciplines that impinge upon the problem space. Understanding the world water crisis, for example, requires that students understand the Earth's water purification cycle (hydrologic cycle), economic implications of water trade, water as a "virtual" commodity, access to water as a human right and health issue and water reclamation technologies – to name a few.

3. Research questions

While GE2 was specifically designed to leverage the interdisciplinary curricular space afforded by social studies and the use of socio-scientific inquiry as a means to increase students' exposure to and learning of important scientific literacy skills in an applied setting, what remains to be seen is if this approach yields demonstrable results. This study provides a quasi-experimental evaluation of the GE2 intervention examining the impact of participation in the curriculum on students' scientific inquiry and socio-scientific literacy compared to students receiving Normal Educational Practice (NEP). Specifically, this study addresses the following research questions:

1) Does exposure to the GE2 intervention lead to improved average scores on a measure of scientific inquiry?
2) Does exposure to the GE2 intervention lead to improved average scores on a measure of socio-scientific literacy?
3) Does exposure to the GE2 intervention lead to differential outcomes for males vs. females?

4. Methods and procedures

This study was conducted in the fall semesters of 2013 and 2014. The focal simulation scenario was the Water Resources scenario. Fifty-seven ($N_t = 57$) 7th and 8th grade social studies teachers were trained in the GE2 curriculum prior to participating in the study. Each teacher had at least three years of experience in middle-grade, social studies classrooms. In this study, teachers served as their own controls. As such, all participating teachers provided access to two social studies classes ($N = 114$), which were then randomly assigned to either the GE2 condition or the NEP condition. An external consultant, not affiliated with the development team, performed the randomization process.

A total of 2665 middle grade students participated in either the GE2 or NEP conditions. The GE2 students participated in a live GE2 simulation, and were provided across to all GE2 curricular components and resources. Students in the NEP condition received the social studies curriculum that the teacher would normally be provided as part of the school or district curriculum, and did not have access to any component of the GE2 simulation experience. All students in each class participated in the educational activities, but only those who had both parental permission and student assent participated (IRB) in the data collection and research components of the study.

The student sample was 50.9% female, and 46.3% male (2.8% missing gender information); with a nearly equal split between 7th and 8th graders. The students in the sample reported their race/ethnicity as 44.8% White, 13.4% Black, 26.3% Latino/a, 5.6% Asian/PI, and 7.7% *Other*, with the remaining not reporting race/ethnicity. A total of 51.8% were from urban settings and the remaining 48.2% were from suburban settings. There was a nearly equal split in the numbers of students between the GE2 and NEP conditions.

All consented/assented students, in both treatment conditions, completed a battery of pre-test assessments prior to treatment assignment and immediately after the end of the GE2 simulation. Within this assessment battery were individual measures of socio-scientific literacy and scientific inquiry. The Socio-scientific Literacy measure examined the consumption, evaluation, and communication of science information in everyday life. Inspired by previous theoretical and measurement work related to this construct (Bisnaz, 1995, Bisnaz et al., 1997; Norris and Phillips, 2003; Wheeler-Toppen, Wallace, Armstrong, & Jackson, 2005), this instrument measures socio-science literacy in context (similar to the approach used for the PISA science sub-test). It includes 16 items of varying item formats, including: multiple choice, fill-in-the blank, and open-ended, short answer questions. Five cross-site IRR checks indicated 89.94% absolute agreement and 91.73% averaged agreement across the three Socio-Scientific Literacy assessment scorers. The Science Inquiry measure also incorporates a variety of response formats for its 11 items, including multiple choice and open-ended, short answer questions. Integrating modified items from the Test of Integrated Process Skills (TIPS ii, Burns, Okey, & Wise, 1985) and TIMSS 2003 Special Initiative in Problem Solving and Inquiry (Mullis, Martin, Kennedy, Trong, & Sainsbury, 2009) the assessment focuses on the explanation of scientific/experimental processes, description of causal relationships in science, and examination of scientific evidence from multiple points of view. Six cross-site IRR checks suggest 76.21% absolute agreement and 80.53% averaged agreement across scorers. Students completed the battery using

Table 1a
GE2 vs. NEP HLM Results Using a Fixed Effects Model for Scientific Inquiry.[a]

Parameter	Estimate	Std. Error	df	t	SSig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	7.1315	0.1510	34.70	47.200	0.000	6.8247	7.4383
Treatment	0.4319	0.1385	68.97	3.118	0.003	0.1556	0.7083
cc_know_pro_pre	0.3986	0.0184	2212.56	21.627	0.000	0.3624	0.4347
tc_cm_know_pro_pre	0.4310	0.1219	73.10	3.533	0.001	0.1879	0.6741
gc_tm_know_pro_pre	-0.1279	0.3182	19.79	-0.402	. 692	-0.7922	0.5364
sem_1	0.3926	0.2439	77.52	1.609	0.112	-0.0930	0.8784

[a] AIC = 9410.5; Deviance = 9404.5.

paper/pencil. All raters scored the instruments blind to the testing time (pre & post) and treatment condition (GE2 or NEP). Sample items from each of the two instruments are presented in appendices B1 and B2. The Socio-scientific Literacy instrument was based on a score of 0–19 points and the Science Inquiry scale on 0–12 points.

5. Results

Missing data rates ranged from approximately 6%–9%. Differential attrition was below 3% for all measures. With differential attrition below 3% and overall attrition below 9% the GE2 efficacy study is well within What Works Clearinghouse standards to be considered “low potential for bias due to attrition” (What Works Clearinghouse, 2013). As a result of the low rate of missing data, complete case analysis was used. The resulting sample was comprised of 2375 students.

Data was analyzed using a hierarchical linear modeling approach. Specifically, models were fit using the linear mixed-effects models (MIXED) command in SPSS 22 (IBM, 2013). For each outcome variable of interest, a three level model was fit, with students, classrooms and teachers defining level 1, level 2 and level 3, respectively. In addition to the outcome and treatment variables, each model contained an indicator variable for the year of data collection (year 1 or year 2) and three variables created from the pretest data corresponding to the outcome in question: (i) a student level pretest variable, centered about classroom means, (ii) a classroom level average pretest score, centered about teacher means and (iii) a teacher level average pretest score, centered about the grand mean. Additionally, all models included dummy variables to account for school membership (school fixed effects). Due to difficulties getting model convergence for models that allowed treatment effects to vary across teachers, random intercept models were used.

Results examining Scientific Inquiry as the dependent variable from the above model fits are reported in Tables 1a–1c. To avoid an overly complex presentation, estimates for the school fixed effects are suppressed. In addition, “unconditional” three level models that included the treatment variable as the only independent variable were fit. These variance component estimates were used to standardize the impact estimator. Specifically, the coefficient associated with GE2 from the full model was divided by the square root of the sum of the three unconditional variance components. Effect size estimates are 0.20 for the Science Inquiry outcome. This estimate is statistically significant at the 0.01 level.

The process for analyzing Socio-Scientific Literacy mirrored the process described above. Results of these analyses are presented in Tables 2a–2c. These results indicate a significant positive effect of participation in GE2 on Socio-Scientific Literacy compared to the students in the NEP condition at the 0.01 level. The corresponding effect size estimate is 0.13.

Analyses were conducted to determine the potential moderating effects of gender. Gender was not found to be a strong moderator. The effect size for females about 0.06 units higher than for males, which is not indicative of statistical or practical significance.

6. Discussion and conclusions

In order to engage with the many social, cultural, political and ethical issues that arise from advances in knowledge, our population needs to be sufficiently informed and efficacious with the principles of science. Issues related to global climate change, sources of alternative energy, evolution, and environmental preservation all require careful and informed decision-making by both citizens and elected leaders. Such science literacies involve much more than just content knowledge, but also require an understanding of the representations and interpretation of scientific data, scientific explanations, projections, and the process of science. This study sought to ascertain if GE2, a carefully crafted, PBL simulation, could leverage the interdisciplinary space afforded by social studies as an expanded context for engaging students in learning these vital scientific literacy skills.

The results presented here speak to the potential of interdisciplinary simulations like GE2 as a mechanism to provide a meaningful learning context within which students can develop their knowledge of socio-scientific concepts as they enhance their skills about socio-scientific topics, such as water resources, for an authentic audience. GE2 students showed a significant increase in their Science Inquiry skills and Socio-Science Literacy compared to the NEP students while participating in a PBL simulation in a social studies class. Moreover, this positive increase in GE2 students' performance occurred across both female and male students. With recent national testing of middle school students indicating significant gaps between male and female students in the domain of science (Quinn & Cooc, 2015) finding curricula that yield positive and equivalent effects across genders is a critical mission for educators. We believe that the applied setting of social studies as a venue for teaching science provides a space for students to connect their understanding of natural systems to that of human systems. This creates relevance between the content and the lives of the students that may draw in students who are not currently inclined to enjoy learning science in through more traditional science instruction approaches. We also believe that these outcomes may be related to the ability of students to be anonymous in their identity as they negotiate online – a specific design feature of GE2; enabling students to take risks and safely explore options without the potential adverse impacts of negative feedback. Further, the GE2 simulation created a large and “authentic” audience to which students were communicating. Interacting within the simulated role-playing space of GE2 may have motivated students to engage in the educational activities in ways that more traditional mode of school based communication of science of science information does not.

Additional data gathered on this sample of student includes the

Table 1b
HLM Estimates of Covariance Parameters for GE2 vs. NEP Using a Random Effects Model for Scientific Inquiry.

Parameter		Estimate	Std. Error	Wald Z	SSig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Residual		3.0224	0.0909	33.224	0.000	2.8493	3.206115
Intercept [subject = TID]	Var,	0.4606	0.2727	1.689	0.091	0.1443	1.470360
CID [subject = TID]	Var.	0.4534	0.1097	4.133	0.000	0.2822	0.72854

Table 1c
HLM Estimates of Covariance Parameters for GE2 vs. NEP Using an Unconditional Effects Model for Scientific Inquiry.

Parameter		Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Residual		3.6585	0.1101	33.221	0.000	3.4489	3.8808
Intercept [subject = TID]	Var.	0.5122	0.1869	2.740	0.006	0.2505	1.0473
CID [subject = TID]	Var.	0.6944	0.1497	4.638	0.000	0.4550	1.0596

Table 2a
GE2 vs. NEP HLM Results Using a Fixed Effects Model for Socio-scientific Literacy.[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	8.2177	0.1582	30.112	51.926	0.000	7.8945	8.5408
Treatment	0.4635	0.1362	59.503	3.402	0.001	0.1909	0.7360
sem_1	1.0313	0.2435	60.804	4.235	0.000	0.5443	1.5183
cc_SSL_pre	0.5971	0.0178	2239.055	33.428	0.000	0.5621	0.6322
tc_cm_SSL_pre	0.6865	0.0623	56.956	11.014	0.000	0.5617	0.8114
gc_tm_SSL_pre	0.1711	0.2229	15.033	0.768	0.454	-0.3038	0.6461

[a] AIC = 11025.0; Deviance = 11019.0; Random Effects.

Table 2b
HLM Estimates of Covariance Parameters for GE2 vs. NEP Using a Random Effects Model for Socio-scientific Literacy.

Parameter		Estimate	Std. Error	Wald Z	SSig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Residual		5.9141	0.1769	33.420	0.000	5.5772	6.2713
Intercept [subject = TID]	Var.	0.5597	0.3236	1.729	0.084	0.1802	1.7386
CID [subject = TID]	Var.	0.2429	0.1073	2.263	0.024	0.1021	0.5774

Table 2c
HLM Estimates of Covariance Parameters for GE2 vs. NEP Using an Unconditional Effects Model for Socio-scientific Literacy.

Parameter		Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Residual		8.8503	0.2646	33.440	0.000	8.3465	9.3845
Intercept [subject = TID]	Var.	2.9371	0.7337	4.003	0.000	1.8000	4.7924
CID [subject = TID]	Var.	1.4014	0.3163	4.430	0.000	0.90032	2.1813

written communications shared during the back-and-forth messaging among students in the Interactive Phase of GE2, including both asynchronous communication as well as real-time messaging. This data enables the research team to track the quantity and quality of messages sent, as well as the date/time and recipient information. This large volume of data is still being coded and analyzed and may shed additional light onto the specific processes GE2 students engaged in that resulted in positive changes in their Science Inquiry and Socio-Scientific Literacy skills.

While we believe we still have much to learn about why this intervention produces these significant and positive effects for students, we can see that GE2 does indeed deliver on its promise to expand the curricular space afforded to the acquisition of important science related skills. Moreover, we believe that the results of this investigation also highlight the important role social studies can play as a context for implementing authentic, interdisciplinary simulations that ground learning an applied setting. It is important to note that the results reported in this study should be interpreted with some caution. Although this was a carefully designed and rigorous quasi-experimental study, it was limited to one science topic, Water Resources. Additional large-scale simulations should examine if these findings related to the impact of GE2 are equally as powerful across a variety of topics. In addition, these results do not address issues related to contextual and demographic differences in the sample as a whole, such as race or socio-economic status. As we move forward with our research examining the efficacy of GE2, we will be examining both content effects and differential impact across student variables beyond gender. Further, we intend to examine the optimal treatment duration, technology access and utilization, teacher training and support, and distal impacts of GE2 in future studies to better assess impacts of PBL environments on student learning.

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Appendix A

Typical Countries in the GE2 Simulation.

GlobalEd 2	
Countries	
1	Australia
2	Bangladesh
3	Brazil
4	China
5	Egypt
6	India
7	Indonesia
8	Iran
9	Japan
10	Mexico
11	Netherlands
12	Nigeria
13	Russia
14	Saudi Arabia
15	South Africa
16	Spain
17	Sudan
18	USA

Appendix B1

Sample Socio-scientific Literacy Item.

Genetically Modified Crops.

GM Corn Should be Banned.

Wildlife conservation groups are demanding that a new genetically modified (GM) corn be banned.

This GM corn is designed to be unaffected by a powerful new herbicide that kills conventional corn plants. This new herbicide will kill most of the weeds that grow in cornfields.

The conservationist say that because these weeds are feed for small animals, especially insects, the use of the new herbicide with the GM corn will be bad for the environment. Supporters of the use of the GM corn say that a scientific study has shown that this will not happen.

Here are details of the scientific study mentioned in the above article:

- Corn was planted in 200 fields across the country
- Each field was divided into two. The genetically modified (GM) corn treated with the powerful new herbicide was grown in one half, and the conventional corn treated with a conventional herbicide was grown in the other half.
- The number of insects found in the GM corn treated with the new herbicide was about the same as the number of insects found in the conventional corn treated with the conventional herbicide.

What factors were deliberately varied in the scientific study mentioned in the article? *Mark an X for either "Yes" or "No" for each of the following factors.*

Was this factor deliberately varied in the study?

9a. The number of insects in the environment?	____ Yes	____ No
9b. The type of herbicide used?	____ Yes	____ No

10. Corn was planted in 200 fields across the country. Why did the scientists use more than one site?

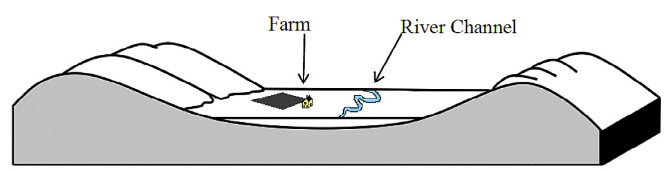
A. So that many farmers could try the new GM corn.
B. To see how much GM corn they could grow.
C. To cover as much land as possible with the GM.
D. To include various growth conditions for corn.

Appendix B2

Sample Science Inquiry Skills Item.

The diagram shows a river flowing through a wide plain.

The plain is covered with several layers of soil and sediment.



Write down one reason why this plain is a good place for farming.

____

____

Write down one reason why this plain is **NOT** a good place for farming.

____

____

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