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INCREASING STUDENTS' SCIENCE WRITING SKILLS THROUGH A PBL SIMULATION

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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 advisors on global water resource issues. The GE2 environment is described examining the impact it has had on middle school students' written scientific argumentation during the intervention. Analyses using HLM on treatment and comparison groups demonstrated a significant positive impact on the written scientific argumentation scores of 1818 middle-grade students from two states with an effect size of 0.257 ($p<.001$).

KEYWORDS

Problem-based Learning; Simulation; Writing Skills

1. INTRODUCTION

It has been broadly contended, that to develop a scientifically literate citizenry who can make local and global decisions about science related-topics, that science education needs to be grounded in meaningful socio-scientific contexts related to the world in which current students inhabit (Anderson, 2002; Sadler, 2009). Socio-scientific issues are both complex and ill-structured by nature, often not having a single clear-cut solution for all the parties involved. Such contextual issues confront students with situations in which they have to engage in formulating their own opinions based on data, their own experiences, attitudes and values, and collaborative decision-making. Further, they also require students to communicate these issues to other in a clear and precise manner.

Socio-scientific issues are regarded as real-world problems that afford students the opportunity to participate in the negotiation and development of meaning through scientific argumentation (Chinn & Malhotra, 2002; Osborne, et al., 2004; Schwarz, et al., 2003). Argumentation includes any 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 to develop valid arguments but also learn science concepts associated with the topic while they are arguing (e.g., Osborne, et al, 2001; Jiménez & Pereiro-Muńos, 2002;Schwarz, et al., 2003; Erduran, et al, 2004).

Unfortunately, all too often inquiry-based approaches to teaching and learning about science that involve socio-scientific issues are not employed within typical classrooms (Chinn & Malhotra, 2002; Driver, et al., 1996; Taber, 2008; Turner, 2008). This lack of socio-scientific inquiry tasks in science classrooms likely results from fact that there has been a national and state shift in the science standards towards scientific literacy and related pedagogical reform set forth without commensurate alteration of the curricular space devoted to the teaching of science in American schools (Sadler, et al., 2007). Inquiry-based curricula, especially programs that immerse learners in active investigations of contemporary issues, can consume significant chunks of class time. Additionally, the standardized test-driven culture of today's American educational system, the allocation of limited instructional time and resources, are a major concern for both teachers and school administrators (Sadler, et al., 2006). Furthermore, research on science teachers has found that they report feeling under-prepared and often lack the efficacy necessary to implement and manage socio-scientific inquiry within their science class (Alozie, et al., 2010; Bartholomew, et al., 2004; Bennett, et al., 2005; Levinson, & Turner, 2001). So, while it appears that we know what to do in order to develop a scientifically literate citizenry and address dwindling science interest and participation among our students in STEM, we are simply not doing it as much as we should or could.

Rather than compete for the already overburdened curricular space devoted to science instruction, 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. As problem-based learning (PBL) researchers have illustrated, leveraging interdisciplinary contexts, like social studies, as a venue to engage in real world problem solving can have a profound and positive impact by deepening students' understanding, flexibility in application and transfer of knowledge (Jonassen, 2009; Koschmann, et al., 1996; Mergendoller, et al., 2000; Strobel & van Barneveld, 2009). Because PBL consists of a presentation of authentic problems as a starting point for learning, it can increase student motivation and their integration of knowledge (Bednar, et al., 1992). When working cooperatively in groups within a PBL environment, students learn how to plan and determine what they need to solve problems, pose questions, and decide where they can get these answers as they make sense of the world around them (Brown, et al., 2008; Lawless & Brown, 2015).

There can be no doubt that recent USA policy initiatives across local, state and national levels have placed increased pressure on schools to improve student performance in the domains of literacy, mathematics and science. PBL researchers have illustrated for decades that leveraging interdisciplinary contexts as a venue to engage in real world problem solving can deepen students' understanding, flexibility in application and transfer of knowledge (Bereiter & Scardamalia, 1987; Hayes, 2000; Jonassen, 2009; Koschmann, et al., 1996). Recognizing this, GE2 was created as an educational multi-team simulation that employs educational technologies currently available in most schools to build upon the interdisciplinary nature of social studies as an expanded curricular application aimed at increasing instructional time devoted to science and persuasive writing in a virtual environment (Hayes, 2000) while simultaneously enhancing the social studies curriculum.

2. GLOBALED 2 AS A SIMULATION: HOW IT WORKS

The current GE2 simulation operates within a middle school social studies class, focusing on an international science crisis created by the simulation staff. GE2 capitalizes on the interdisciplinary nature of social studies in order to expand the curricular space for additional opportunities to learn about science on a global scale and the use of educational technology, without sacrificing the curricular goals of the social studies curriculum, to address the crisis. It works as a simulation environment in which classrooms of students work across teams with the goal of reaching an agreement on a critical global science issue, while representing their specific assigned country, over a period of 12 weeks.

The GE2 simulation is implemented by trained teachers within middle-school social studies classes, focusing on a specific international science-based crisis. It works as a 12-week, interactive multiplayer simulation environment in which classrooms play the role of a specific country with the goal of reaching an agreement on a critical global science issue with at least one other of the country-teams in the simulation. The scenario developed for the current simulation focused on Global Water Resources (other science-based GE2 scenarios include Global Climate Change; International Food Resources and Alternative Energy Sources). There are three phases of the 12-week GE2 Simulation: Research, Interactive and Debriefing. The simulation is coordinated across multiple classrooms, as each country-team experiences the activities associated with each of the three phases (see Lawless and Brown, 2015 for further descriptions of the GE2 phases) (see figure 1).

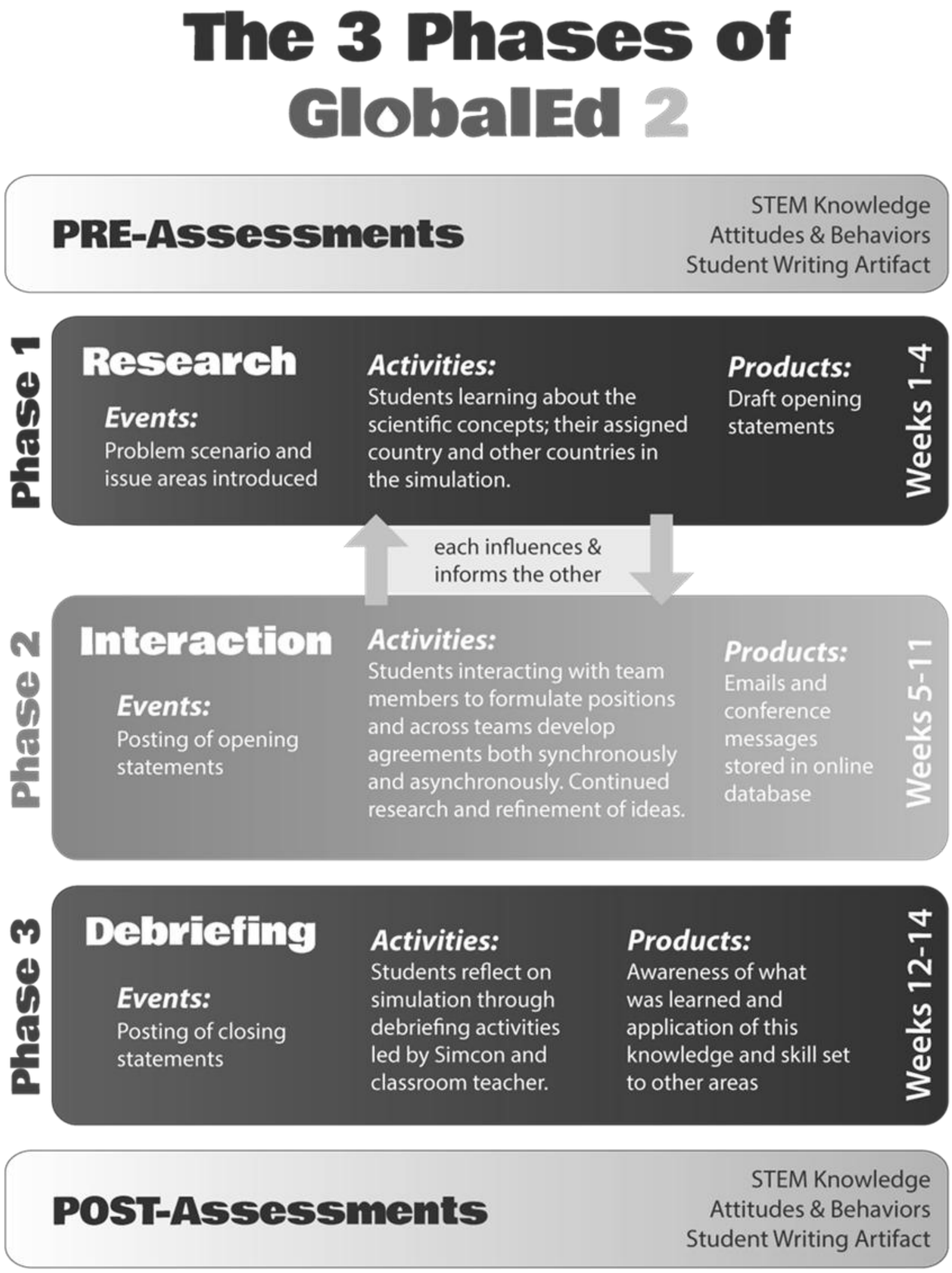

Figure 1. The Three Phases of the GlobalEd 2 Simulation

In the Research Phase, within each classroom-team, classrooms are randomly assigned to a country from our list of countries across the globe, representing diversity of region, development, size, and resource availability (Note: the USA is not randomly assigned to a class and is discussed further in the section below). Once the classes are assigned their countries, they are provided with the problem scenario, breaking into smaller issue area groups, and work on concrete analytical tasks related to four broad topical issue areas (i.e., Human Rights, International Economics, Global Health and The Environment; see figure 2). Students must use their research skills and GE2 provided resources to learn about the history, values and customs of their respective countries, as well as the other countries in the simulation, so that they are prepared to make appropriate “in character” posts as their assigned country during the negotiations in the Interactive Phase.

In the Interactive Phase, interactions between classrooms/countries are facilitated through the use of a secure, proprietary web-based platform that enables both asynchronous and synchronous written communication. Students are told that their country has to “stay in character” (e.g., remain consistent with the policy positions and core national and cultural value systems of their assigned country), while attempting to develop comprehensive policy responses to particular problems within the issue areas. The electronic interactions (asynchronous and synchronous) among the delegates are moderated by a Simulation Controller (Simcon), who is trained and knowledgeable of both international affairs and environmental science. The role of Simcon is to support/encourage and moderate the interactions so that delegates stay in character, use appropriate diplomatic language, and work towards agreements with other country-teams. During this phase there are also interactions within the classroom as delegates from the four issue areas discuss strategies of developing an agreement on water resources across the four issue areas. It is important to note that within each team the same four issue area groups exist and they must coordinate their negotiations such that one issue area group does not ignore the importance of another in trying to reach an agreement with another team. This is moderated by Simcon.

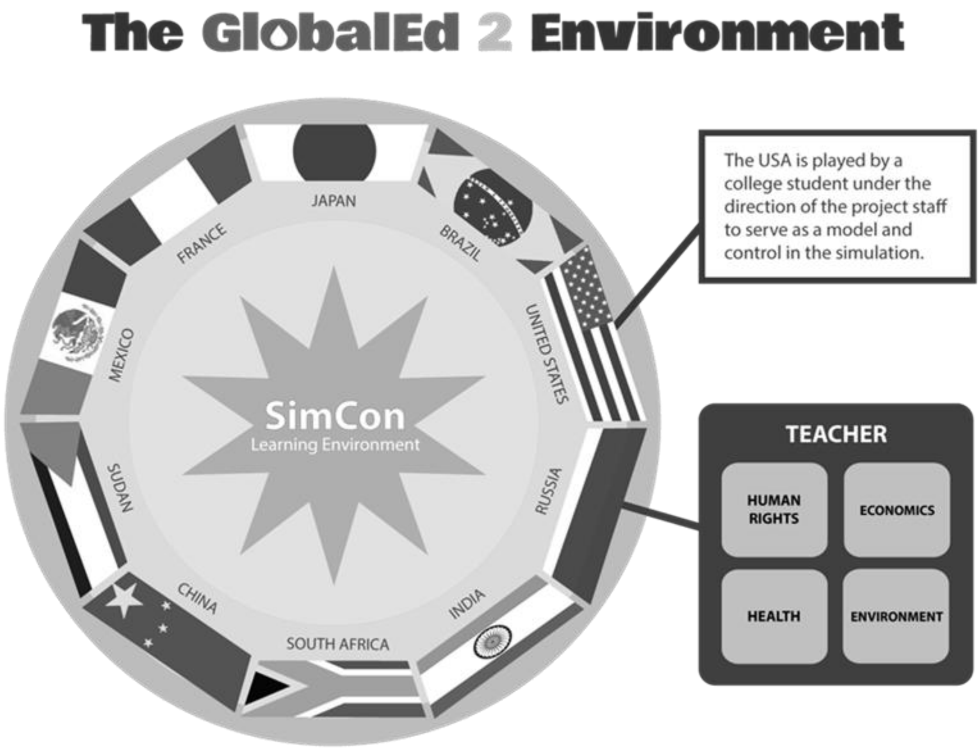

Figure 2. The GlobalEd 2 Simulation Environment

The USA team consists of two undergraduate students in the role of the USA, and is unknown by the teachers or GE2 student delegates. The role of the USA is to present a model for negotiations, through their diplomatic messages. Additionally, the USA can initiate international problems (e.g., calling for debt repayments, sending military to specific parts of the globe, or major policy changes that may affect participating countries differently) when the negotiations are unrealistically shallow or lack complexity. The USA enables the GE2 staff and Simcon to serve as a model or be disruptive, depending on the needs of the simulation during the Interactive Phase.

In the third phase, Debriefing, classrooms are led by their teachers within the class and Simcon virtually, through a series of activities and discussions to reflect on their learning. Students also think about creating opportunities for the transfer of new knowledge and skills to other global issues facing the world today, as well as local science literacy topics. The goal of the debriefing is to bring the metacognitive skills gained through the simulation to the surface so that students can explore settings in which these new skills may be employed within formal and informal learning contexts.

In summary, GE2 places a pronounced emphasis on the development of students' understanding of science topics, interest in science pursuits, science self-efficacy, and most importantly, written argumentation on science topics. For more specific information about GE2 and how the larger context of the simulation operates across the three phases of implementation: Research, Interaction and Debriefing see Lawless and Brown (2015).

The core of GE2 is the problem scenario and the interactions across teams that occurs through a web-based system enabling email and real-time conferencing in a secure environment. Classrooms of students are assigned their country and provided a briefing on the scientific crisis 4-6 weeks prior to the launch of the simulation. Students are given analytical tasks related to broad topical issue areas (human rights, economics, environment, health) common to all country-teams, and presented in the scenario. Students are instructed that their country must "stay in character" (e.g., remain consistent in policy positions and value systems of their assigned country), while attempting to develop responses to problems within the four issue areas. The scenario developed for the current simulation reported here, focused on Global Water Resources. Students did not know the name, race, sex or location of the students on other teams, only the name of the country, issue area and student's initials; there were 17-18 countries in each of the four simulations that are reported here. Country-teams in the simulation reported here spanned two different states and across one time zone.

3. STATEMENT OF THE RESEARCH PROBLEM

GE2's extensive use of written communications creates an invaluable venue for students to learn and practice written scientific argumentation in a real world context and to a large and authentic audience. Research illustrates that both instruction and authentic opportunities to write have been shown in the literature to improve writing skill (Pajares, 1996; Midgette, et al., 2008). In addition, with more opportunities to experience success in writing there is a greater chance to positively impact their writing self-efficacy. Writing self-efficacy has been shown to mediate academic performance in writing within the GE2 simulation (Brown & Lawless, 2014). As such, GE2 has the potential to impact the quality of students' written work negotiating in the STEM field within the simulation, and may also have an impact on longer term performance.

The research question addressed here was, is there a significant increase in the quality of students' written scientific argumentation based on participating in a GE2 simulation? The dependent variable examined here was the writing quality score of the students in both the GE2 and NEP classes from the pre-and post- assessment of the students' written argumentation skills.

4. METHODS

A total of 1818 middle grade students (from grade 7 & 8) participated in the study conducted during the fall of 2014 (in either the GE2 simulation or the comparison group – Normal Educational Practice with no GE2 – NEP). The student sample was 50.9% female, and 46.3% male (2.8% missing gender information); with a nearly equal split between 7^{th} and 8^{th} 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 between the GE2 and NEP conditions.

Prior to the class assignment, each teacher received three days of online professional development (PD) on the purpose and implementation of the GE2 curriculum. Furthermore, the teachers also received weekly PD support and resource support for their students during the implementation of GE2 in the fall of 2014.

Each of the 51 teachers provided two "approximately" equivalent classrooms. The comparison class received the NEP curriculum that the teacher would provide as part of the school or district curriculum. An independent consultant blind to class characteristics and teacher/school identity, randomly assigned classrooms to either the GE2 or NEP condition. 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/research components of the study. In this way, each teacher taught both a treatment (GE2) and NEP class.

In order to obtain a measure of implementation fidelity in each classroom, observers were trained to record the teaching activities of each teacher in each condition weekly for the 12-weeks of the simulation process. Observers used the GE2 Teacher Observation Protocol to collect data on actual implementation of the GE2 curriculum and if there was any contamination, or spread of PBL into the NEP class. Initial results demonstrated that while there were different implementation practices across teachers, GE2 was implemented as a PBL environment in all the GE2 classrooms.

All consented/assented students completed the battery of pre-test assessments prior to treatment assignment; GE2 classes received their country assignments, as well as the GE2 curriculum and resources. Within this battery was an open-ended essay prompt – *Is the world running out of fresh water? Agree or disagree and defend your position.* Students had a total of 30 minutes to complete the essay prompt each time (pre- and post-). The GE2 assessment battery was administered in a pre-post format to both the GE2 and NEP students for comparison purposes. All students completed the battery across multiple classes and using paper and pencil, so as not to advantage better resourced students. For the purposes of this discussion, only one part of the battery will be presented – Written Argumentation. A rubric developed and field tested prior to implementation was applied to the essays of all participating students. Each essay was read and scored focusing on Claim – Evidence – Reasoning, adapted from the model discussed by McNeill and Krajcik (2008), by two independent raters, who maintained over .89% inter-rater agreement. Discrepancies were resolved by a third rater. Raters scored essays blind to the pre-post and group of the student (GE2 or NEP).

5. RESULTS

After collating the data for IRB compliance and removing students with missing data, a final sample of 1818 students were subjected to HLM analyses examining the impact of the GE2 intervention compared to their NEP counterparts with a total of 51 teachers.

Reporting the results in effect sizes (Cohen's d) using the standard convention indicated that there was a significant effect of the GE2 treatment on the scores of written scientific argumentation (pre- to post) compared to the NEP students ($d=0.257$; $p<.001$) and further, that there was positive impact for <u>both</u> females and males. Further details of the treatment effects are presented in tables 1a-1c (AIC=6779.6; Deviance=6773.6).

Table 1a. GE2 vs. NEP HLM Results Using a Fixed Effects Model

						95% CI	
Parameter	**Estimate**	**S.E.**	**df**	**t**	**Sig.**	**Lower**	**Upper**
Intercept	4.544	.090	33.251	50.444	.000	4.361	4.727
Treatment	.445	.102	46.341	4.333	.000	.238	.651
cc_writepre	.256	.023	1712.838	10.750	.000	.210	.303
tc_cm_writepre	.674	.153	56.041	4.384	.000	.366	.982
gc_tm_writepre	.461	.207	17.631	2.223	.040	.024	.898

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

Parameter		Estimate	S.E.	Wald Z	Sig.	95% CI Lower	95% CI Upper
Residual		2.347	.080	29.255	.000	2.195	2.510
Intercept [subject = TID]	.062084	.070	.878	.380	.006	.578	57.790
CID [subject = TID]	.119491	.053	2.240	.025	.049	.286	.297

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

Parameter		Estimate	S.E.	Wald Z	Sig.	95% CI Lower	95% CI Upper
Residual		2.502	.085	29.270	.000	2.340	2.676062
Intercept [subject = TID]	.277523	.094	2.923	.003	.141	.542	.539721
CID [subject = TID]	.189243	.068	2.770	.006	.093	.383	.388718

6. CONCLUSIONS

The results presented here speak to the potential of PBL simulations such as GE2 to provide a meaningful learning context within which students can develop their knowledge of socio-scientific concepts as they enhance their skills in writing about scientific topics for an authentic audience. GE2 students showed a significant increase in their writing argumentation skills compared to the NEP students while participating in a PBL focused social studies class. We were also very pleased to see the positive impact for both females and males, as they develop the written argumentation skills on science related topics and no significant differences in impact based on race/ethnicity or location setting (urban and suburban) once pre-test scores were accounted for. We 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. Further, the large audience to which students are writing their international proposal to, in order to reach an agreement, may have motivated students to engage in the educational activities.

The data gathered on this sample of student includes additional pre- and post- scales focusing on science knowledge, self-efficacy related to technology, science and writing, as well as the message data shared during the interactive phase of the negotiations, enabling the research team to track the quantity and quality of messages sent, as well as the date/time and recipient information. Further analyses are underway examining the student data across urban and suburban settings, the sex of the student and the teacher implementation fidelity. These results will include an examination of sex, race/ethnicity, and school setting, as we examine potential differential effects of the GE2 intervention for various types of student groups.

These results must be interpreted with some caution because only one scenario was used in this study (Water Resources). Additional studies have been conducted since these data were analyzed enabling us to examine the impact of other scenario topics. Further, optimal treatment duration, technology access and utilization, teacher training and support, and distal impact are important foci for additional studies to better assess both proximal and distal impacts of PBL environments.

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 may afford students the opportunity to develop further scientific literacy through PBL simulations (Brown, Lawless & Boyer, 2015; Jonassen, 2009). Further analyses of this data set with the other dimensions of the assessment battery and additional data collection will enable a fuller investigation of the curricular implications regarding the utilization of interdisciplinary PBL educational simulations approaches, like GE2, in promoting STEM literacy among middle school students.

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