CHAPTER 4

Educating Students for STEM Literacy: GlobalEd 2

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Abstract GlobalEd 2 (GE2) engages classrooms of students online, and simulates negotiations of international agreements on issues of global concern such as water scarcity and climate change. GE2 is an interdisciplinary problem-based curriculum targeting students' global awareness, scientific literacies, and twenty-first century workforce skills. For the past 15 years, various iterations of GE2 have been implemented in classrooms, ranging from middle schools through college. Results have demonstrated the positive impact of GE2 along a number of dimensions including writing, argumentation, science knowledge, and social perspective taking. This chapter provides an overview of GE2, its design principles and discusses data from a recent implementation with college freshmen, specifically focusing on gains with respect to self-efficacy across multiple domains.

Keywords Global education • Problem-based learning • Science education • Simulation • STEM education • Writing skills

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Today's college graduates are entering an interconnected world in which globalization and science, technology, engineering, and mathematics (STEM) literacy will affect nearly every facet of their lives. Yet, as current and future citizens, our students' global awareness and STEM literacy remain strikingly limited—if anything, they appear to be in a state of decline. According to Derek Bok, the USA bears "the dubious distinction of being one of only two countries in which young adults were less informed about world affairs than their fellow citizens from older age groups."[1] Compounding the problem is the complexity of global learning itself: a balance of knowledge (such as science, geography, politics, and economics), skills (the ability to find and evaluate information sources and communicate their meaning to others), and attitudes (interest, efficacy, appreciating the value of other cultures, and having a sense of responsibility for our shared planet). Helping students to acquire such a diverse array of knowledge, skills, and attitudes cannot be accomplished through a single discipline. Nor can it be taught with traditional expectations of disciplinary mastery, since its subject is constantly changing and is as vast as the globe itself.

Concomitant with the need to develop global citizens, colleges are also responsible for preparing students for the twenty-first century work force, which is also rapidly evolving. Across several independent surveys of businesses and potential employers, the most commonly cited skills that industries require in newly graduated college students include the following: the abilities to solve complex, multidisciplinary problems; to work successfully in teams; effective oral and written communication skills; and good interpersonal skills. Yet in report after report, employers reported that universities are failing to prepare graduates for the current expectations of the workforce.

Preparing students for the globalized world and the twenty-first century workforce requires that both application and relevance be present. John Morley suggested that students should "know how rather than simply knowing that,"[2] and John Heldrich stated in 2005, "higher education can be improved by making it more relevant to what happens in the workforce."[3] According to Derek Bok, this is best accomplished through intentional educational practices that are integrative in nature, provide experiences that challenge students' own embedded worldviews, encourage application of knowledge to contemporary problems, and integrate knowledge across a wide array of disciplines. Creating and implementing educational experiences with these characteristics in higher education will not only develop critical thinking skills among our students, but will also equip them as citizens with the drive, values, capacity to question, and ability to develop solutions that will help them advance both commercial and social interests.

While it is clear that these preparation gaps of today's college students exist and have existed for some time, most universities have made little progress toward resolving these deficits. Institutions of higher education continue to operate using programmatic approaches that exacerbate the siloed, decontextualized nature of academic content and skill sets—an approach that is counter-productive to facilitating twenty-first century skills. The genesis of this emanates from a number of structural and financial issues regarding how universities operate. Universities are organized in departments based on content areas. This departmental structure provides structure and a shared discipline, but it also fosters the isolated nature of the disciplines, limiting the interdisciplinary opportunities students experience as they prepare for a twenty-first century workforce that has been transformed from the factory model to innovative multidisciplinary models.

The GlobalEd 2 Project

GlobalEd2 (GE2) is a set of interdisciplinary, problem-based simulations, and curricular supports intended to provide a venue for students to apply their developing knowledge and skills in an authentic, real-world activity. It is designed for ground teaching and learning in meaningful socio-scientific contexts related to the world in which students currently live, representing an innovative approach to improving outcomes, particularly for high need, underrepresented students. Its targeted learning outcomes include increased engagement and knowledge across several disciplines, heighten positive affect around these domains, the development of STEM literacy, and improved college and career readiness skills (e.g., collaboration, problem solving, and written communication). Moreover, it is an evidenced-based curricular experience that has shown promise across multiple academic levels and a diverse array of students.[4]

GE2 evolved from the earlier model, GlobalEd, which was situated in the social sciences.[5] The current version has been developed through funding provided by the Institute of Educational Science in the US Department of Education to become an interdisciplinary learning environment centered on STEM literacy.[6] GlobalEd and GlobalEd 2 have serviced over

8000 middle grade through college students, and research studies across multiple implementations has demonstrated this approach to learning has high impact on a variety of important student outcomes, including writing argumentation and quality, science knowledge, interest in science, writing self-efficacy on STEM topics, problem solving, leadership, negotiation, academic motivation, and taking social perspective. Results have further demonstrated that these gains occur across diverse student groups, including Black, Latino, and female students. Finally, observations of implementations indicate changes in instructors' pedagogy consistent with problem-based learning (PBL). While GE2 has predominantly been implemented in middle school classrooms, it has also been successfully implemented in both high school and college level courses with similarly positive student outcomes.

GE2 is a technology-mediated curricular intervention, provided via a suite of web-based applications, including professional development (PD) and implementation support for instructors, resources, learning scaffolds for students, and a communications platform to enable collaborative interactions among students. The underlying technology provides consistency across implementations and scalability of the program to large number of students across multiple settings. A single simulation of GE2 can accommodate up to 20 classes of students (n ~ 400–500), and may be provided for a single institution or collaboratively across multiple institutions. Moreover, the technology infrastructure can handle multiple simultaneous simulations, affording delivery to an exponential number of students.

Previously, we have presented research data demonstrating GE2's specific impact on student writing, one of our strongest and most consistent outcomes across student settings (middle grade through college) and scenario topics (Water Resources and Climate Change).[7] In this chapter, we focus on our discussion on the impact of GE2 on students' self-efficacy, a belief in the self that is key to achieving educational goals. According to Albert Bandura and his research, a person's self-efficacy is very specific and tied to specific tasks and/or knowledge. It influences behavior by determining what the person attempts to achieve and the amount of effort applied to his/her performance. The psychological research literature of Bandura et al. has firmly established that self-efficacy is an important variable in predicting student engagement, motivation, task commitment, and learning outcomes. This research has demonstrated that self-efficacy is affected by cognitive, emotional, and behavioral variables which are tied to encouragement, challenge, previous success, and emotional arousal. If students' STEM experiences are successful, then their self-efficacy, and, in return their attitudes related to STEM, are augmented, increasing the likelihood of future engagement in the discipline. In contrast, when students' have unsuccessful STEM experiences, their associated attitudes are decreased, as they develop low self-efficacy for related content and tasks, and they are less likely to engage in STEM topics.

The following discussion will focus on how students' experiences in the GE2 simulations has positively affected their STEM self-efficacy.

STEM Literacy

The science and academic communities have been sounding the warning alarm about the crisis in science education for years: Our schools are just not producing the STEM professionals necessary for the USA to maintain its scientific and technological prominence, thereby putting our current and future global economic standing at risk. Beyond the need for more highly trained professionals within STEM fields, however, we also face a much larger secondary societal crisis: The need to establish a scientifically literate citizenry that can make informed decisions at the local, regional, and national levels. Recent standardized test results indicate that only 21% of twelfth-graders performed at or above the proficient level in science, and our ranking internationally on the scientific literacy of our students, measured on tests like PISA, has rapidly fallen.[8] In order to engage with the many social, cultural, political, and ethical issues that arise from advances in knowledge, our population, not just our STEM professionals, needs to be sufficiently informed and efficacious with the principles of STEM. 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. Moreover, STEM literacy involves much more than just content knowledge; it also require an understanding of the representation and interpretation of scientific data, scientific explanations and projections, and the process of science. Further, STEM literacy involves cognitive and metacognitive abilities, collaborative teamwork, effective use of technology, and the abilities to engage in scientific discourse around global issues, synthesize disparate concepts, and persuade others to take informed action based on scientific evidence. These skills, the National Science Board has argued, may be even more important than knowing particular scientific facts.

Twenty-First Century Workforce Skills

STEM literacy skills parallel those employed in the authentic, socio-scientific work of twenty-first century scientists. Contemporary scientists need to be able to bring their knowledge, insights, and analytical skills to bear on matters of public importance. Often they can help the public and its representatives understand the likely causes of events (such as the potential for natural and technological disasters) and to estimate the potential effects of projected policies (such as the ecological impacts of various water conservation methods, as we are currently seeing in parts of the American West). In playing this advisory role, scientists are expected to be especially careful in distinguishing fact from interpretation and research findings from speculation and opinion in order to develop valid arguments, as are the citizens who are consuming this information to develop their own positions—the essence of a scientifically literate citizen.[9]

As such, argumentation is a central process necessary for the development of a scientifically literate citizenry. Argumentation includes any dialog that addresses "the coordination of evidence and theory to support or refute an explanatory conclusion, model, or prediction."[10] Research has demonstrated that when students engage in scientific argumentation, they not only learn to develop valid arguments but also learn science content while doing so. Further, there is convergent evidence that demonstrates that both instruction and authentic opportunities to write have been shown to improve writing skill.[11] While there has been strong advocacy for argumentation and writing in science, opportunities for students to learn how to engage in productive scientific argumentation in the current context of school-based science have been rare. This has been a driving force behind the emergence of college general education requirements of discipline-based writing experiences.

Through the work of O'Brien et al. research has also established a link between interest in science and science self-efficacy beliefs. It stands to reason, then, that if we can develop settings where students have the opportunity to experience success and illustrate the personal relevance of STEM topics in the world in which students live, we can positively impact their STEM self-efficacy and interest. As a result, we may better be able to affect student engagement and enrollment in the sciences with the outcomes of further developing their STEM literacies, thereby increasing the pool of viable candidates in the STEM workforce.

Many have argued that using the social sciences (i.e., psychology, anthropology, political science, economics, education, sociology) as a forum for integrating and applying science has the potential to develop a scientifically literate citizenry capable of bringing a scientific approach to bear on the practical, social, economic, and political issues of modern life. Furthermore, researchers, such as John Bransford et al. and David Jonassen, have illustrated for decades that leveraging interdisciplinary contexts, like the social sciences, provide opportunities for students to engage in real-world problem solving that can deepen students' understanding, their flexibility in the application of knowledge, and the transfer of knowledge to novel situations, while also reducing the likelihood of inert knowledge.

Socio-scientific contexts afford students the opportunity to ground their STEM learning in the world in which students currently live, making science personally relevant. Socio-scientific issues are complex and often do not have a single, clear-cut solution. Such issues confront students with situations in which they have to engage in formulating stances based on data, their own experiences and values, and collaborative decision-making. They are regarded as real-world problems that afford the opportunity for students to participate in the negotiation and development of meaning through scientific argumentation and promoting epistemic, cognitive, and social goals, as well as enhancing students' understanding of science.

To sustain our competitive edge in today's global economy, we must provide accessible and supportive pathways for *all* students to enroll in postsecondary education and complete their degrees in a timely fashion. Postsecondary education is the primary conduit for strengthening our workforce and ensuring a better quality of life for our citizens. Better educated people clearly have a greater chance than those who are less educated of obtaining secure jobs that provide opportunities for advancement, higher wages, greater health and retirement benefits, and greater opportunities in general.

Across several independent surveys of businesses and potential employers, the most commonly cited skills that industry requires in newly graduated college students include the abilities to solve complex, multidisciplinary problems, work successfully in teams, exhibit effective oral and written communication skills, and practice good interpersonal skills. However, industry leaders point out that many students who obtain their postsecondary degrees do not possess these skills and, as such, are not fully prepared to successfully participate in the twenty-first century workforce.[12] It seems that our education systems need to change—quickly!

The GE2 Project Design Principles

Current instructional practice, predominantly based within the cognitive perspective of learning, is at odds with research findings about how people learn with understanding. As stated in the 2012 report from the National Research Council, "Typical classroom activities convey either a passive and narrow view of learning or an activity oriented approach devoid of question-probing and only loosely related to conceptual learning goals."[13] Such instructional practices limit the teaching of high order thinking skills that are critical components of college and career readiness. Moreover, the transfer of learning resulting from course activities enacted in this way is also hindered, as there is little understanding of the contexts in which the acquired knowledge and skills are useful.

In light of the shortcomings of cognitive-based approaches to teaching, our theory of change is rooted within the sociocultural perspective on learning. The sociocultural perspective emerged in response to the perception that research and theory within the cognitive perspective was too narrowly focused on individual thinking and learning. In the sociocultural model, learning takes place as individuals participate in the practices of a community, using the tools, language, and other cultural artifacts of the community. From this perspective, learning is "situated" within and emerges from the practices in different settings and communities.

Problem-Based Learning

Problem-based learning is an enactment of sociocultural theory aimed at addressing the need for deep learning, the transfer of skills and knowledge, and situating learning. In contrast to more traditional teaching methods that use problems after theory has been introduced, PBL uses a problem scenario to initiate, focus, and motivate the learning of new concepts. PBL research has illustrated that knowledge needs to be *conditionalized*, that is, people should understand when and why knowledge is useful.[14] Further, the empirical evidence base examining PBL has illustrated that learning should be *contextualized*, or the learning environment should mirror the context in which the outcomes are expected to be utilized. Such conditionalization and contextualization demand that students interact with authentic, ill-structured problems—those where there is no one correct way to solve the problem and which require knowledge and skills from multiple topic areas or disciplines. PBL also includes a collaborative component; students often work in groups where collective decisions are made about task distribution, and in which group members investigate different aspects of the problem that together contribute to the total solution.

There is an extensive literature base examining the positive impact of PBL as a pedagogical approach for teaching across a large variety of domains and with a highly diverse array of students. Gains on important learning outcomes, including knowledge, affect, and the use of high order thinking skills, have been well chronicled. However, less well documented is the impact of PBL on more distant learning outcomes, such as academic progress and retention in college students. We identified only one study meeting the What Works Clearinghouse Evidence Standards, with reservations, examining this. Sabine Severiens and Henk Schmidt conducted a quasi-experimental study with 305 first-year Psychology students, examining academic progress/retention in terms of credit accrual. Comparing a fully implemented PBL approach to a conventional lecture-based approach and a mixed approach that integrated various forms of "active learning," results indicated that students who experienced the PBL pedagogy outpaced students in the other conditions with respect to persistence and the rate of credit accrual. Further, levels of social and academic integration were also higher among students in the PBL curriculum. While the research of Severiens and Schmidt provides initial evidence showing the promise of PBL to promote college success, larger scale work must be conducted to further explore PBL's full potential.

GlobalEd 2 and Problem-Based Learning Principles

GE2 is designed to meet the criteria outlined by Nick Zepkey and Linda Leach, as well as the high impact practices (HIPs) espoused by the AACU and George Kuh as requisite for engaging students at the postsecondary level. Moreover, GE2 is grounded in PBL principles and design components. These principles and their alignment in the GE2 design are presented in Table 1.

Description of the GlobalEd 2 Implementation

As described previously by Lawless et al. GE2 is a set of problem-based, online curricular activities that engages classes of students across multiple locations in simulated, multinational negotiations around a socio-scientific issue currently facing the world.[15] Within a single implementation of GE2,

Table 1 Principles of PBL related to the GE2 design

PBL principles	*GlobalEd 2 implementation of the PBL principles*
Anchoring learning to Problem Scenario	Problem Scenario provided in a global and multidisciplinary setting; Includes 4 issue areas in each team
Support learners in developing ownership and control over problem	Web-based application enables customization and learner-directed interactions; online informational resources provided; SimCon interactions to guide and prompt learners
Be based on ill-structured authentic, problems	Problem scenario based in real-world, global socio-scientific issues, e.g., water resources, climate change, food security
Be collaborative	Learners are required to collaborate within and across country teams with the goal of negotiating a multi-team agreement to address the problem
Provide alternative views and solutions	Social-perspective taking supported by issue areas, social, and cultural perspectives; international focus with SimCon monitoring and support
Require the students to reflect on both the content and the process	Debriefing phase is designed to promote reflection on the experience and to facilitate near and far transfer

16 to 18 classes participate, each assigned to represent the interests of a different country for the entire simulation. Students within each country are further broken down into four collaborative groups, called issue areas (e.g., Economics, Human Rights, Environment, and Health). These issue areas are consistent across all the classes in a simulation, enabling the students from one issue area to communicate with their counterparts in another class. Although negotiations may take place between the specific issue groups across countries, it is necessary that these four issue groups also negotiate within their class/country to reach a consensus to represent a unified policy stance.

At the beginning of a GE2 implementation, each participating class is presented with a problem scenario and the collective goal to reach an agreement with at least one other country. The scenario provides background information about a current issue in the world that requires the participating countries in the simulation to take timely action. It sets the common context for the countries in the simulation, anchoring interactions among students. Sample scenario topics include water resources, climate change, and food security. In addition, GE2 participants (students

& instructors) are supported by a set of three separate web applications: (1) the Student Research and Tools Database; (2) the Communications Platform, which hosts the online communications among students; and (3) the Instructor Portal for instructional support, scaffolding, and PD.

There are three phases of GE2. The first phase, the Research Phase, 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 perspectives. Additionally, students 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. Per the outcome of the Research Phase, students in each classroom work collaboratively to develop opening policy statements (written 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 that they will also be negotiating within the simulation. These opening statements generally range in length from 400 to 900 words, though some detailed statements are longer. Opening statements are then shared as documents through the online *Communication Platform* and serve to launch Phase 2, the interactive negotiations among countries (student-to-student communications across teams).

Throughout the Interactive Phase, students work within their class to refine their arguments and negotiate international agreements with the other "countries," sharpening their arguments through the use of the *Student Research and Tools Database* and sharing them through the *Communication Platform*, in an asynchronous format similar to email. Based on prior implementations, the number of communications exchanged during the Interactive Phase can exceed 5000 (although length varies from a single sentence to multiparagraph exchanges). Students are also afforded the ability to engage in moderated synchronous conferences (i.e., like instant messaging) at various scheduled points throughout the Interactive Phase. These synchronous conferences are important for students to clarify understandings and push negotiations forward more quickly than is attainable through asynchronous communications.

In order to provide control and flow during the Interactive Phase, a trained simulation coordinator, “SimCon,” monitors all e-messages among teams and facilitates the synchronous conferences. SimCon’s role is similar to that of a virtual teacher/facilitator in an active learning class, in which SimCon oversees all aspects of the learning process and coaches students to think critically about the complex issues central to their written arguments. Further, SimCon monitors and provides feedback to students regarding the content (scientific and political), writing quality, and tone of their communications as a means of formative evaluation. SimCon’s ability to moderate the dialogue and interactions among participating students is facilitated through a back-end control function in the *Communication Platform*.

The culminating event of the Interactive Phase is 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 statements in the *Communication Platform* marks the start of the third phase of the GE2 experience, Debriefing.

The Debriefing Phase is designed to activate metacognitive processes as students review what they learned and how they can apply this new knowledge and associated skills in other contexts and domains. SimCon facilitates a scheduled online debriefing conference through the *Communication Platform* with all participants, exploring issues related to learning outcomes, simulation processes, transfer, and feedback. Instructors are also trained to perform multiple debriefing activities to promote metacognition, learning, and transfer (e.g., examining local water issues or other tasks to relate the experience to the real world of environmental sustainability).

All interactions in GE2 are text-based—a purposive design for two reasons. First, the written artifacts students produce (e.g., opening/closing statements and negotiations) are a means of making students’ thinking visible, providing an avenue for instructors and researchers to formatively assess students’ engagement, scientific thinking, writing, leadership, and problem solving. Second, 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, and verbal accents). Students only identify themselves within GE2 as country, issue area, and their initials, for example, “ChinaEnvSWB,” concealing their actual identities to students outside their specific class. As a result, typical stereotypes, associated with gender, race, or socioeconomic class, are minimized as factors influencing the interactions among participants.

Although GE2 is a technology-mediated experience, participation in the simulations only requires a device that is Internet capable, including netbooks, iPads/tablets, and smartphones. The platform-independent nature of GE2 provides access to the simulation almost anywhere, any time.

The role of instructors changes dramatically within GE2. Rather than being the traditional "knowledge bank" that simply transfers what they know to students, within GE2, instructors take on the role of learning guide. The instructor's role is not to inform the students but to encourage and facilitate opportunities for them to learn for themselves by using the provided problem scenario, simulation experience, and student-learning scaffolds as a focus for the learning. Instructors implementing GE2 are supported by both front-end and on-going PD provided through an online *Instructor Portal*. Prior to their first time in the role of GE2, instructors will take approximately 24 hours of online course in which they learn about GE2, the theory behind it, how teaching and assessment occurs within it, how to support students to write effectively, and the science and social science content needed to successfully implement it with students. In addition, weekly podcasts will be provided using a "just in time" training model, providing content and process to suggestions to instructors as demanded by the trajectory of the students' interactions in the simulation. Finally, an online learning community of instructors and GE2 staff is used as a forum for instructors across GE2 sites to exchange information, ask questions of each other and GE2 staff, and collaboratively develop new knowledge and resources about teaching with GE2.

The *Instructor Portal* also provides access to an array of GE2 web-based lesson plans and learning supports. The lessons are aimed at helping students to identify and align important information across disciplines that are relevant to the problem. Understanding the world water crisis, for example, requires that students understand the Earth's water purification cycle (hydrologic cycle), the economic implications of water trade, water as a "virtual" commodity, access to water as a human right, health issues, and water reclamation technologies. In addition to content, instructional materials are provided to help shape the quality of students' writing using a research-based approach.[16] Finally, examples of completed assignments and evaluation rubrics are provided to support assessment of student learning both formatively and summatively.

GlobalEd 2 in College Courses

GE2 is not a core curriculum in and of itself. Rather, it is a set of extended curricular activities that provides a venue for students to build and apply their knowledge and skills in an authentic problem space *in concert with* standard curricular practice. It is intended to deepen and strengthen, not replace, the understanding and use of the knowledge and skills that students develop from middle grade classes through college.

In college, GE2 aligns best with First-Year Experience (FYE) classes and has been taught by FYE instructors across multiple disciplines (i.e., from engineering to business and public health) in both the USA and abroad. As outlined in their book, *Striving for Excellence*, John Szarlan et al., outline the typical FYE learning objectives, including information literacy, academic writing, study skills, campus knowledge, understanding academic expectations, collaboration work, service learning, and problem solving. By engaging students with the content, their peers, and their instructor in an early college experience, GE2 allows students to take ownership of their learning and use of learning skills at the beginning of their postsecondary trajectory with the goal that they will apply these skills in other courses and experiences.

In the spring of 2012, we conducted a study of GE2 implementation in First-Year Experience (FYE) courses at a large northeastern public university. A total of 252 FYE students and their FYE instructors participated in a GE2 simulation on international water resources for an entire semester. The FYE course was a 1-credit course and met weekly for 60 minutes in class sections of 19 or fewer students throughout the 14-week semester (weeks 1 and 14 were reserved for assessments). Instructors of the course completed a training seminar to prepare them for implementing the curriculum with their students.

This study received IRB approval, and therefore participants were given the choice of whether to consent and be included in the research component of the class, which involved pre- and post-assessments. All students participated in the educational component of GE2. Consenting students completed a battery of pre-test prior to being introduced to GE2. Within this battery were two self-efficacy subscales and a social perspective taking scale. The Cronbach alpha reliability estimates for each of the three scales have exceeded 0.80 on previous samples[17] and were similar on the current sample. Once the students completed the pre-test battery, they began participation in the GE2 simulation, after which they completed the same assessments as post-assessments.

Following the pre-testing, students were informed of their assigned country, the scenario, and the four issue groups (e.g., Human Rights, Economics, Environment, and Health), which instructors allowed the students to select with the goal of creating roughly equivalent group sizes and gender distribution. There were 12 countries in the simulation, plus the USA, which was played by two GE2 staff members (which was not known to the FYE students). A veteran SimCon experienced in water resources and international affairs monitored all the online communications and hosted the synchronous conferences.

The data extracted during this study was examined to assess the impact of GE2 on the STEM self-efficacy of these college students and provide feedback on current features of its college implementations. Three specific research questions were addressed: whether there were gains from GE2 on students' (1) self-efficacy for educational technology, (2) general academic skills self-efficacy, and (3) the social perspective-taking skills.

A total of 252 college students (54% White, 28% Black, and 18% "other" or missing) participated in GE2 during the spring 2012 semester; 173 providing informed consent, with 101 providing matched pre- and post-data on our battery of assessments. A series of three separate paired t-tests were conducted on the pre- and post-measures of *Technology Use Self-efficacy*, *General Academic Self-efficacy*, and *Social Perspective Taking*. The results displayed in Table 2 demonstrate statistically significant increases from pre to post on all three measures. The results speak

Table 2 FYE GE2 paired sample *t*-test results for pre- and post-testing

Variable	*T-statistic*	*Significance (p-value)*
Technology Self-Efficacy	–2.365	0.023
Social Perspective Taking	–5.252	0.001
Academic Skills Self-Efficacy	–2.192	0.035

to the potential of PBL, and specifically GE2, as a meaningful context within which college students can experience twenty-first century skills and STEM content, as well as developing skills positively affecting their skills and STEM self-efficacy. Specifically, each of the three self-efficacy skills (Technology, Social Perspective Taking, and Academic Skills) were found to increase significantly in a simulated game of international negotiations on a STEM topic, water resources.

GE2 for Instructors and Students

Over five years of research on GE2 have focused on two groups of end users: Instructors and their students. For instructors, GE2 promotes a shift of their pedagogical practices away from a traditional approach of being a content expert in a particular domain who controls the flow of the class, lectures, and/or transmits information.[18] In GE2, instructors are *guides* who facilitate a *student-centered* learning approach. Instructors are not content experts across the multiple domains represented, but serve as *model knowledgeable information seekers and evaluators.* GE2 not only creates a new innovative approach to teaching with PBL, but also trains and supports teachers on the enactment of PBL in their classes prior to, and through, the entirety of the simulation.

With respect to students, GE2 engages learners, helping them to develop their STEM self-efficacy and STEM literacy (knowledge, skills, and attitudes that every citizen needs to know), as well as college and career readiness skills. GE2 also places a pronounced emphasis on the development of students' written communication, discussed in other forums, integrating a research-based instructional framework for writing to foster the development of written communication skills.[19] Beyond just learning written communication, there is also substantial evidence indicating that writing is also an effective tool for enhancing knowledge acquisition and cognitive skill development in the disciplines, student affect, and engagement.

The nature of the GE2 simulation also requires that teams work together, representing countries across issue areas and collaborating with other country teams across the large simulation space. Engaging students in these collaborative activities is the mechanism through which *team building* and *cooperation skills* are developed. Through the give and take of negotiations within the simulation, students engage in developing *problem solving skills* as they learn the complexity of the problem space, separate relevant from irrelevant information, and apply various tactics and heuristics to gain traction and progress toward their goal of agreement with at least one other country.

While each of the above student outcomes is important individually, in aggregate, GE2 fosters the much broader outcome of students' engagement with other students, their instructor, and the content, as well as intellectual development.

Conclusion

GE2 is grounded in empirical research findings drawn from multiple fields that influence STEM education, including the following:

- If students' STEM experiences are unsuccessful, then their STEM self-efficacy is diminished, decreasing the likelihood of future engagement in the discipline.
- The choice to enroll in STEM courses and pursue STEM-related occupations is mediated by a student's STEM-based self-efficacy. Low self-efficacy yields low engagement.
- Leveraging interdisciplinary contexts, like the social sciences, as a venue to engage in real-world problem solving can deepen students' understanding, flexibility in application, and transfer of knowledge.
- Embedding STEM curricula in global socio-scientific issues is a means for opening up science to females and excluded or disadvantaged ethnic and class groups.
- Scientific argumentation is a central STEM literacy. When students engage in scientific argumentation, they not only learn to develop valid arguments but also learn science content while they do so.
- Writing instruction and practice writing for authentic audiences improve writing skill.

A better understanding of how to maintain and cultivate middle school through college students' interest in STEM education and careers paths is vital to addressing the STEM pipeline issues and STEM literacy in the USA. The instructional approach proposed by GE2 not only addresses this need, but also broadens the focus on what, where, and how STEM literacy can be cultivated, enhanced, and assessed. Nearly 15 years of research and development, from the first iteration of GlobalEd to the current version of the STEM based GlobalEd 2 Project, has yielded consistently positive student (middle grades through college) learning results, including increased STEM self-efficacy, increased knowledge in both the social sciences and STEM fields, increased writing skills, and increased student engagement and motivation.

In transitioning GE2 from a successful research intervention to a viable educational curriculum designed to promote important student learning outcomes, we have determined that the human resources necessary to implement GE2 are modest. At scale, calculations indicate that GE2 can run at less than $25/student for veteran GE2 instructors and less than $40/student for novice/first time GE2 instructors (those requiring initial training) for the middle grades through college. This equates to a total of $500–$800 per class of 20 students—less than the average tuition postsecondary institutions charge for an individual student taking a three-credit course, even by conservative estimates, and less than the costs of classroom books in secondary schools. With our instructor training provided completely online for the last five years, it is very clear that GE2 can be brought to scale both effectively and efficiently for middle schools through colleges. Furthermore, the curriculum implementation may be adjusted to meet the needs of the educational environment, varying the implementations from 6 weeks to 14 weeks, while adapting the required amount of time per week for students, both in traditional settings, as well as virtually. Therefore, GE2 is both powerful and adaptable, adept at meeting the goals of educational institutions, their instructors, and their students.

While we are greatly encouraged by the results of studies of the GE2 approach, there remains much more to learn about its direct and long-term impact on student learning, as well as why PBL, and specifically GE2, enhances student knowledge, skills, and attitudes, so that we may advance student learning. Nevertheless, the evidence supports GE2 as an effective, cost-efficient approach to education that improves students' STEM competencies, resulting in more knowledgeable citizens who are ready to engage with the complexities and ramifications of science and the policies that shape it.

Notes

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