Group-Based Cloud Computing for STEM Education

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Abstract

This project will advance efforts of the Innovative Technology Experiences for Students and Teachers (ITEST) program to better understand and promote practices that increase students' motivations and capacities to pursue careers in fields of science, technology, engineering, or mathematics (STEM). The Group-based Cloud Computing (GbCC) for STEM Education Project investigates pre-service teacher designing, developing, implementing, and enacting a socio-technological system for group-centered STEM teaching and learning consistent with a nationally recognized pre-service program. The project takes a design-based research approach to creating and studying technologies and materials that support generative teaching and learning in STEM. Computational thinking, including agent-based modeling, and simulation across STEM domains as well as geo-spatial reasoning about personally meaningful learner-collected data will provides an important scientific foundation for the project. This will be achieved by developing a highly-interactive and group-optimized, browser- and cloud-based, device-independent and open-source architecture and by integrating and extending leading computational tools including the NSF-funded NetLogo Web agent-based modeling language and environment.

Keywords

Group-based Cloud Computing, Project Based Instruction, Traffic Simulation, UTeach

Introduction

The Group-based Cloud Computing (GbCC) for STEM Education project will foster the growth of educational infrastructures to enable the dissemination and effective adoption of generative teaching and learning in STEM particularly in high school engineering. The project is intended to advance efforts of the Innovative Technology Experiences for Students and Teachers (ITEST) program of the National Science Foundation to better understand and promote practices that increase students' motivations and capacities to pursue careers in fields of science, technology, engineering, or mathematics (STEM).

Three prior and continuing frameworks are to be integrated in this ITEST project are (1) the NetLogo (Wilensky, 1999) agent-based and aggregate modeling and participatory simulation (HubNet, Wilensky & Stroup, 1999) capabilities, (2) the completely open-standards based, group-situated, device independent, and database mediated cloud-in-a-bottle (CiB) network architecture (Remmler & Stroup, 2012) and (3) the use of socially-mediated generative activity design for supporting STEM focused learning and teaching in classrooms (c.f. Stroup, 2007, Ares, 2009, Brady, 2014). Our approach extends to group-level interactivity in classrooms a longstanding commitment in the learning sciences to develop "shared environments that permit sustained exploration by students and teachers" in a manner that mirrors the kinds of problems, opportunities, and tools engaged by experts (LTC, 1992 p. 78).

The project takes a design-based research approach to creating and improving the technologies and related project materials. Key to this design effort is a focus on supporting and advancing the ability of pre-service and in-service teachers to pursue participatory and more-fully socially mediated approaches to classroom-based learning. This STEM-specific focus on teaching and learning in classrooms is framed by what we consider a vitally important design consideration: The most consistent and conspicuous feature of school-based learning is that it takes place in a group setting. Indeed, schools-based formal education around the world is all but defined by the shared practice of a teacher and a collection of students gathering in a physically contiguous location with the intent of advancing meaningful domain-related insight and learning outcomes.

More often than not, however, the potential of these group-based settings for pursuing highly interactive and immersive forms of content-specific learning is underutilized. Instead most of the activity that typically takes place in classrooms centers on relatively isolated forms of individual activity and, particularly at the secondary level, most of the interactions between the teacher and students follow a Initiation (teacher) – Response (student) – Evaluation (teacher) sequence (c.f., Wells, 1993). Student-student interactions or other forms of teacher-student interaction occur much less frequently and are rarely sustained even within a single teaching episode, much less over the multiple class periods typically associated with presenting a topic from standard STEM curricula.

Our work, then, is framed by a conjecture that if we can iteratively develop a low-cost, research-based, device independent, user-authorable, highly-interactive architecture that supports authentic group-based STEM learning and teaching in classrooms then we can dramatically increase students on-going development and motivation to participate in STEM-focused coursework and careers.

To help ensure the activities supported by this group-based cloud computing architecture mirrors the kinds of problems, opportunities, and tools engaged by experts we draw upon the Legacy Cycle as situated within a Project Based Instruction framework. Next we discuss how the Legacy Cycle with a PBI framework can be integrated with group-based network-mediated simulations. We will use an example from our prior work using a group-based network-mediated simulation where students control a light in simulated city's traffic grid and attempt to improve traffic flow. Extensions to prior work are discussed next. Then we are in a position to highlight how our implementation of the immersive and participatory nature of GbCC-supported activities is meant to address the equity commitments of the ITEST program to significantly improve persistence in STEM courses and STEM-related professions.

Project-Based Instruction Extended to Group-Based Interactivity

In this section we illustrate to how a Project Based Instruction (PBI) framework can be used to address the learning design potential of the highly interactive, group-based functionality we are developing. We choose one example from the core set of activities we will release with the GbCC architecture to illustrate the integration with an extended PBI framework. Managing and optimizing traffic flow is an engaging area of research in civil engineering with practical personal implications for many of us, including school-aged students who are, or may soon be, drivers themselves. By providing a highly interactive cloud-based environment for having students in a classroom control individual lights in a simulated traffic grid (cf., Wilensky & Stroup, 2000) we look to provide a way of integrating a developing understanding of the kinds of optimization issues that characterize many areas of engineering with a group-based activity design and infrastructure.

In Project Based Instruction (PBI), students experience a process of inquiry in response to challenges or driving questions. While allowing for some student autonomy, projects are carefully planned, managed, and assessed to ensure students learn key academic content, practice 21st Century Skills, and create authentic products (Markham, Larmer, & Ravitz, 2003). The Legacy Cycle also helps to organize learning activities into an inquiry cycle. It begins with a challenging problem so learners discover information about the problem as the need arises, provides opportunities for continual formative assessment throughout the process, and allows learners to progress by presenting a variety of methods to think about the topic (Schwartz, Lin, Brophy, & Bransford, 1999).

The Legacy Cycle uses challenges as anchors for learning. The challenge of improving traffic flow in a simulated city is an example of anchor for classroom-based learning using group-level interactivity. Challenges within the legacy cycle are designed to create an increasing depth of knowledge in a specific subject, with each challenge presented as one cycle of the Legacy shell. The combination of well-designed challenges and meaningful learning activities provides a rich environment for both the students and the instructor.

The challenge of improving traffic flow in their own city or town, as supported by the use of the simulation environment, is to engage students in ways that mirror how scientists or engineers approach and solve problems and are also to have qualities that lead to extended inquiry. Ideally the students have some familiarity with the challenge, but need to research more or try out possibilities to better comprehend the problem, identify potential solutions, and then generate and execute a plan to solve it. Within a traffic simulation where each student controls one light in a simulated city, students may start off using hit-or-miss or highly localized strategies for controlling traffic ((Wilensky & Stroup, 2000, Stroup & Wilensky 2014).

As they extend their inquiry and reflect on the overall outcomes for traffic flow, the comprehension of the issues and of the possible responses (e.g., coordinating the changing of the lights) improves. Support for this process comes through the other phases in the legacy cycle.

Students are to generate ideas allowing them to explore, within a group setting, their initial thoughts and conjectures about the challenge at hand. Next, they compare their ideas with multiple perspectives provided by others. In controlling traffic students often generate distinct strategies that they share with their peers. This gives the students opportunities both to listen to each other and to be able to engage experts in the field as they describe their own hypotheses and approaches to the same problem. In addition to describing traffic control strategies, the simulation environment allows students to develop and explore the use of various metrics for describing traffic flow (e.g., wait time, average speed, number of cars stopped, or number of blocked intersections). These, too, provide a bridge to the kinds of metrics that practicing civil engineers deploy professionally in their analyses.

The combination of these three phases provide students with the conditions so that they can apply their knowledge, generate questions they would like answered and provides an opportunity to self assess what they know compared with others. Legacy cycle based lessons include a research and revise phase where students test their own hypotheses concerning a challenge. For example, the class might implement an agreed-to strategy for controlling traffic or use a version of the simulation where a student implement rules for controlling the lights by altering the existing simulation code,

As part of their research students will need to move to a test your mettle phase where formative assessment strategies are deployed to allow participants to reflect on what they have learned thus far, and to identify any weaknesses or misconceptions they still may be holding onto about their challenge.

With what they have learned they will need to revise their thinking and then act on this new knowledge to test their understanding. These two phases outlined above are the heart of the instructional process of acquiring new knowledge and will take the most time and instructional guidance by the instructional team.

Finally, learners will take what they have learned to Go Public. This final phase requires the learners to synthesize what they have learned to either provide a solution to the initial challenge, or to a similar challenge but in a different context, or both. Optimally, students will present their syntheses to the class and/or to experts from the STEM fields that situated the anchoring challenge they are addressing.

A Legacy Cycle is a way of organizing lessons and activities in extended inquiry projects that make use of computer technology, Internet resources, and social networking to engage students in a variety of activities that imitate the way scientists approach and solve problems—reading articles, brainstorming with colleagues, designing and carrying out experiments to test hypotheses, conducting campaigns to collect measurements and make observations, interpreting data, and publishing their findings.

A Project-Based Instruction course is a core course in the UTeach STEM certification program (Petrosino, Walkington, and Ekberg, in preparation) and this is one of the reasons the UTeach program is emphasized in our design-based research and implementation efforts.

Learning from a Decade of Implementation Research

A key insight from more than a decade of implementation efforts related to the use of these capabilities is that in order for these capabilities to have a transformative effect on the lives of our students there needs to be explicit and on-going engagement with addressing the practical realities of teaching in STEM-specific domains. Accordingly the next-generation, cloud-base technological integration is to be integrated with the on-going efforts of the UTeach STEM certification program that, as a program, also developed from significant prior funding from the National Science Foundation. STEM-specific technology integration – as this includes agent-based modeling, simulations, the extensive use of digital probes, real-world data analysis and an inclusive approach to computational literacy – has been one of the "cross-cutting" themes of the UTeach STEM program from its inception.

Our approach to computational literacy includes the ways in which our building on open standards – e.g., moving from Java-based implementations to HTML5, JavaScript and open-standards for database utilization – supports not just the implementation of existing models and materials, but the extension and full authorabiity of such capabilities by students and teachers alike.

If, for example, a student doesn't think the rabbits in a GbCC supported predatory-prey simulation move in realistic ways, she or he has direct access to the code and can change the rules for the movement of the rabbits. Similarly, in the UTeach program the pre-service teachers are encourage to develop lessons that fit with their pedagogical vision. Whether by modifying existing models or by authoring their own environments, a key feature of the proposed GbCC architecture is that it would be fully extensible/authorable for students and teachers alike. Computational literacy and agency thereby would be supported as a built-in feature of the next-generation, cloud-based capabilities of the proposed GbCC architecture. We believe this kind of programmability will be important to the on-going needs of the UTeach program and then much more broadly in support of pre-service and in-service STEM educators.

Commitments to Equity

By leveraging the equity related commitments and the on-going lesson implementation infrastructure of the nationally recognized UTeach STEM pre-service program, a significant number of students in diverse, yet underserved, schools will gain direct access to: (1) next-generation, fully author-able/programmable, group-oriented, STEM-focused, cloud-based computing and (2) participatory approaches to STEM-focused computer modeling and classroom-based inquiry meant to advance the students' abilities in, and sense of on-going personal self-identification with, future participation in STEM-related coursework and careers. Our researching, iteratively developing, and implementing -- across many schools, subject-areas, and grade levels -- a scale-able and low-cost technological and pedagogical infrastructure is intended to directly address both the near term and longer term goals of the ITEST Program regarding students' future participation in the STEM workforce.

A broadened version of the core conjecture of the project that was introduced earlier is that by valuing and improving STEM-focused participation in classrooms we will directly support all students' sense of the value and importance of participation in STEM educational pathways and STEM careers. Increasing the connections between the students' sense of who they are and the highly interactive forms of STEM-related learning and teaching to be advanced by this project stand to improve the diverse, but underserved, students' ongoing personal identification with STEM-related educational pathways and careers.

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Dr. Stroup is the developer of generative design as an approach to support group-based, socially mediated, STEM focused classroom learning for grades three through university and of highly interactive network technologies to support group-situated learning and teaching including both the HubNet (Wilensky &Stroup, 1999) and the Cloud-in-a-Bottle architectures (Remmler & Stroup, 2012). He serves as Co-Director of the Kaput Center for Research and Innovation in STEM Education and Associate Professor of STEM Education and Teacher Development at the University of Massachusetts, Dartmouth. Funding for his research has come from the National Endowment for the Humanities (philosophy), the National Science Foundation (including a CAREER Award), Ministries of Education in Mexico, as well as from various private foundations and corporations. He is a Co-Founder of the UTeach STEM program is the Principal Investigator on the GbCC Project.