Using Digital Interrupted Case Studies for Whole Class Inquiry in Life Sciences

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Abstract: This short paper describes BioScann, a high school *STEM* inquiry curriculum that uses a CSCL environment to support an interrupted case studies (ICS) method. This technology-enhanced curriculum supports autonomous, sustained student engagement, scientific argumentation, conceptual understanding, and the development of student self-efficacy and career awareness. The BioScann technology platform scaffolds student activities, collects student artifacts, and helps the teacher advance the curriculum through various stages. We discuss how our designs were improved across multiple pilot studies, including two major versions of the curriculum and technology. Each new pilot allowed us to improve the materials and technology environment, as well as student engagement, career awareness, and collaborative data-based decision-making.

Major issues addressed

Scholars, visionaries, and policymakers have called for education that prepares students to face the complex challenges of an increasingly technology-driven "knowledge society" (OECD, 2016; Pellegrino, & Hilton, 2013). In response to such calls for change, STEM education has generally shifted away from the memorization of facts toward engaging students in authentic science inquiry and scientific argumentation.

Researchers have advanced problem-based learning (PBL) as a pedagogical framework to develop 21st century competencies and to increase student understanding of science (Slotta, 2010; Bell, 2010). Our work is concerned with one such approach, called case-based learning (e.g. Riesbeck, & Shank, 1989; Foran, 2001) first developed for students in medical education. In case-based learning, students are engaged within peer groups to deliberate on carefully constructed "cases" (e.g., cases of medical scenarios) that provide opportunities for analytical thinking and application of concepts to real-world scenarios. Case-based learning can also integrate the evaluation of evidence and data-based arguments – skills that are critical for 21st-century health literacy. Our team (Jacque et al., 2015) has advanced a more structured model of case-based learning called interrupted case studies (ICS). By structuring cases into a clear progression, ICS provides "interruption points" that (1) allow teams of students to stay in sync and (2) give teachers an opportunity for planned or spontaneous whole-class discussions.

ICS can be challenging for teachers who must keep track of student progress, monitor their ideas, and ensure that the case itself remains at the center of attention. To support teachers and students, we combined ICS and CSCL methods to build on the advantages of technology-enhanced learning environments (Slotta, 2010) to help track student ideas, scaffold their learning activities, and prompt them for reflection. The ICS method also advances CSCL methods by opening the door for the design of CSCL "scripts" (Dillenbourg & Jermain, 2010) that provide teachers with strategic opportunities to pose questions, review student responses, and to use those responses to address student misconceptions and model answering questions appropriately (Herreid, 2005). In this way, the combination of ICS and CSCL methods has a synergistic effect, allowing for more control over the technology environment and more support for both students and teachers. To support the use of ICS in high school settings, we have developed a technology environment called BioScann that engages students in collaborative STEM inquiry explorations. Students document their thinking and work in BioScann's collective knowledge base/shared workspace and teachers use the digital records to lead discussions and help students debate issues.

With CSCL environments – even those enhanced by ICS like BioScann – there is a substantial risk that the teacher will spend inordinate time ensuring the technology is functioning smoothly and keeping students "on task". We are finding that teachers are challenged to coordinate such complex forms of interaction and that the technology environment, while critical (e.g., in providing materials and collecting student responses), is an additional source of complexity and strain on the teacher's capacity to guide meaningful student inquiry. This paper reports on our efforts to improve the BioScann environment based on early classroom pilots and teacher interviews. At the time of paper submissions, we have completed multiple rounds of pilots and revisions, with a major iteration of the technology to be completed by the time of the conference in June 2019. Sections below

describe the theoretical perspective and specific approach and materials supported by BioScann, as well as our iterative designs of the technology environment, together with findings about teacher orchestration and student experience.

Potential significance of the work

We recognize the fit of our work to this year's conference theme: *A wide lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings*. Preparing students with vital 21st century competencies (Scardmalia et al., 2015) will necessitate a wide range of interactions for learning, including collaborative forms of inquiry. To accomplish this, CSCL environments and materials must be able to support complex forms of inquiry that transform the nature of learning and teaching.

To achieve this goal, we produced a suite of innovative technology-enhanced curricula and tools that can be integrated into existing science courses offered in high schools. The robust and flexible web-based platform and ICS authoring toolkit, BioScann.org, enables classrooms to scaffold scientific inquiry in the form of ICS pedagogy. Our objective was to develop a learning environment and curricula capable of engaging underserved high school students' in scientific inquiry, addressing the challenges of a learning community approach, as well as increasing STEM career interest and awareness and retention in science. Such an environment will work best when it supports the teacher in orchestrating the curriculum.

Finally, we have developed and tested innovative professional development approaches for high school teachers to support implementation. At present, we are engaged in a substantive trial with 25 classrooms with over 600 students, with whom we hope to develop knowledge of and interest in bioscience careers.

Theoretical and methodological approaches pursued

From a theoretical perspective, BioScann employs a multi-role ICS approach set within a web-based, interactive environment to integrate conceptual learning with competency building and the development of awareness about STEM careers. The BioScann curriculum was guided by design principles from problem-based learning (PBL) and CSCL. PBL offers a pedagogical perspective that is well suited to students' development of critical 21st century competencies, long-term retention of content and improved critical thinking skills (Bell, 2010; Kolodner et al., 2003; Strobel & Van Barneveld, 2009). CSCL complements this view, allowing the design of environments and activities that foster critical scientific inquiry and work-life skills, such as collaborative problem-solving with shared decision-making (Scardamalia & Bereiter, 1994; Means et al., 2015). By combining these perspectives with the ICS approach, BioScann cases reveal new information (data) that is critical for solving the problem facing the class at defined interruption points. In this way, BioScann models the processes of scientific discovery while simulating participation in STEM careers, as students become a workforce team collaborating to solve authentic inquiry-based problems.

BioScann was created using a design-based research (DBR) approach, in which the designed innovation is itself one of the outcomes to be analyzed as a source of findings relating to the research questions (The Design-Based Research Collective, 2003). A co-design model was applied, involving education researchers, biomedical scientist and teachers (e.g., Roschelle & Penuel, 2006). This ensured that teachers have been deeply involved in the design process, that their values of pedagogy and practice are incorporated within the design, and that they emerge from the process with a full sense of ownership and familiarity with all aspects of the innovation. This method has been shown to improve the viability of designs in diverse school settings and ultimately leads to increased adoptability and adaptability (Voogt et al. 2016; Jacque et al., 2013, 2015).

The Bioscann curriculum and technology were designed and developed in parallel by a team that included six high school biology teachers, researchers, content experts, and technologists over a period of two years (Roschelle & Penuel, 2006). They went through multiple cycles of 'design, enactment, analysis, and redesign' (Collins et al., 2004) to assess the quality as well as the effectiveness of both the design and its theoretical underpinnings. This included: (1) initial testing by co-designers in laboratory and classroom settings; (2) refinement of any features, functions or interfaces; (3) testing in settings with a second cohort of classrooms by teachers who are <u>not</u> members of the co-design team; (4) further refinements. In this way, we tried to rigorously address any emerging problems with implementation. From a research perspective, the design-based process also uncovered new areas of research.

Materials, findings, and discussion

The original goal of BioScann was to create a technology platform that could be used independently by students to work through interrupted case studies allowing the teacher to lead extemporaneous interactions. Version One (v1.0) of BioScann.org contained all the content needed to participate, guiding each student team through the activity. BioScann v1.0 was a four-day curriculum that placed students into teams of 3-4 students and each team

in the class worked independently to design a new drug to combat HIV – a scenario that provides real-life context and is highly engaging at the high school level. On Day One, students learned about the HIV life cycle and worked as a team to consider the pros and cons of four drug candidates with the goal of selecting the best one to test. On Day Two each team learned about cell culture and animal models to test their drug for efficacy and toxicity. On Days Three and Four students learned about Phase I-III Clinical Trials for testing efficacy and safety of drugs in humans. Each day of the curriculum required that students understand experimental designs and utilize results in the form of graphs to make decisions that would set the stage for the next step of the ICS. Based on the group decisions, teachers would manually release the next step of the ICS on bioscann.org. Students received career information through infographics.

In our initial pilot testing of BioScann v1.0 with 19 public school students, we documented the need for improving the usability of the technology to a) allow for more student interaction within groups and as a class and b) to simplify teacher facilitation. Students felt the overall BioScann experience was positive, commenting: "It was fun to have a first hand on how being a scientist works." "If all tech problems are fixed, this program can be used without a problem and people can learn something new." "Program was great and a lovely experience." Analyzing observation and interview data, we identified five key challenges to consider in the re-design: One, running the case required more teacher facilitation than expected. Two, using the technology to regulate individual group workflow required more support than expected. Three, students requested additional time for small group and class discussions. They wanted to review and debate each other's work as a class in addition to within their individual teams. Four, students wanted to do more work off-line using paper rather than the computer. Five, although a pre-post survey indicated that student's knowledge and awareness of bioscience careers increased (paired t test, $p = <.001$), student feedback indicated that they needed more context to understand and assess the careers.

Version Two (v2.0) allowed more flexibility to a) increase student interaction within groups and as a class and b) to simplify teacher facilitation. Specifically, we developed a new script whereby students are placed into five "expert" groups, each of which is given a distinct role as a member of a drug discovery team with career relevant information and role-specific data to contribute to a team decision. Mirroring how interdisciplinary teams solve complex scientific challenges, students then work in "jigsaw" teams, integrating information (data) from the five career-focused perspectives. To support data-based discourse and class-based decision-making, we added a "results page" to the BioScann platform. Expert group data and discussion posts are shared via the results page and students use their posts to contribute their expert perspective in the jigsaw groups, informing the ICS progression. Throughout this iterative workflow (Figure 1), students practice data interpretation, data-based decision-making, and group communication - critical STEM mastery skills. As well, we created a student workbook to support student accountability. Finally, we developed a teacher power point to help them guide students through the lesson and enable adaptability to support different student populations. This re-design reduced teacher facilitation of asynchronous group work, creating a single point of regulation to release the next step in the ICS in bioscann.org, rather than multiple steps for each group during class. It also brought the whole class together for critical decisions and it further integrates career roles and encourages collaboration between groups. Together, these changes have resulted in a *multi-role ICS authoring tool* (Figure 1).

BioScann responds to the challenges of enacting ICS by: (1) allowing for multidirectional decision making – in which students can choose their own path of inquiry; (2) providing distinct content to each group to encourage classroom discourse; (3) utilizing interactive technologies for group decision-making and reporting to
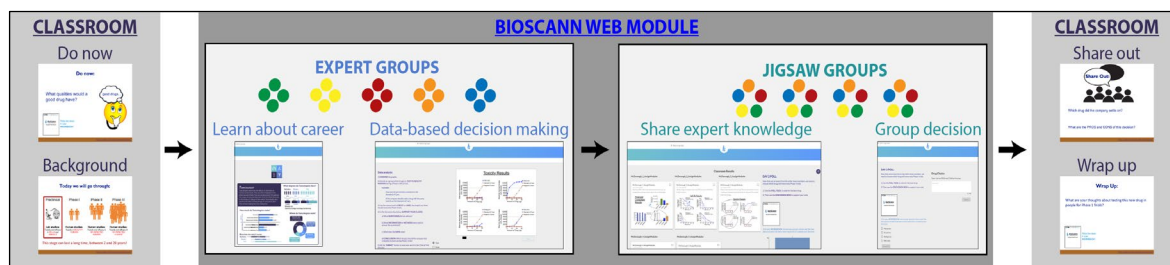

Figure 1. BioScann v2.0 - multi-role ICS approach.

the class; (4) creating a common data and results workspace that supports teacher-led discourse. The platform affords scaffolding that emulates scientific discovery and practices, while providing instructors with opportunities to manage discussions by posing questions, reviewing student responses, and using those responses to address student misconceptions. Preliminary analysis of classroom observations and interviews revealed that BioScann v2.0 is usable and adaptable across a range of classroom settings – from advanced classes in exam schools to

special education classes. However, the use of the results page varies across implementations and the depth of data-driven decision making differs greatly across teachers and students. Preliminary data from pre-post testing indicates that student's data interpretation skills (paired t test, p < 0.017) and awareness of bioscience careers increases (paired t test, *p* < 0.0001). That said, we are not yet able to relate aspects of the curriculum, technology or implementation to student-level outcomes.

Conclusions and implications

The iterative design process has enabled us to refine BioScann into a flexible technology-enhanced curriculum that fosters career awareness and engagement in authentic scientific inquiry as students make collaborative, data-driven decisions using multidisciplinary perspectives. When looking at the impact of the BioScann intervention, we identified several important design implications. The addition of a "results page" was critical to scaffolding discussions and data-based decision-making as it made student artifacts the centerpiece of discourse. The design of a new workflow that moves students from an expert group to a multi-role jigsaw group deepened the quality of the data-informed decision-making. Finally, integrated career-based role playing significantly improved career awareness and interest.

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