How a Learning Community Model Can Improve Student Collaboration, Understanding of the Nature of Science, and Student STEM Identity Development in a High-School Biology Class

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Abstract

This paper describes the objectives, theoretical framework, design, preliminary results and outcome of a study which used a scientific learning community approach and was carried out in a Grade 11 Biology classroom in Ontario, Canada. Students' development of collaboration, communication, scientific argumentation, critical thinking about primary and secondary sources, and understanding of scientific concepts was supported through carefully designed curriculum. During the study, students were engaged in a whole-class dialogue and collaborative knowledge construction. Students' work was supported by existing Internet technology. It has been found that students' collective inquiry supports students' collaboration, critical scientific literacies, including scientific argumentation, and the competency of critical thinking about primary and secondary resources, and has a positive impact on students' epistemological beliefs about the value of collaboration, sources of knowledge and nature of argumentation. Additionally, students' STEM identities have been explored in this study.

Keywords: *scientific argumentation, learning community, collaboration, Nature of Science, STEM identity.*

Objectives

Each subject in the Ontario science curriculum is represented by five units, or strands. Grade 11 Biology course includes Biodiversity, Evolution, Genetics, Plants, and Animal Systems. We designed a curriculum that integrated those units by adding a cross-cutting theme of diet and nutrition. For each unit, we provided students with interesting evidence cases and inquiry activities that were designed to engage students around ideas, connections to real-world issues, and data analysis.

This study explores the potential of a learning community approach [1], [2] for supporting students' development of scientific literacies and understanding of the Nature of Science (NOS). It has been suggested that students' understanding of scientific concepts can be improved through inquiry-based learning and engaging in activities and thinking processes similar to those of real scientists [3]. Several scholars have suggested that a learning community approach can support students' engagement in such activities, adding a layer of authenticity and participation in the practices of science [4], [5]. Described below, the Knowledge Community and Inquiry (KCI) model was developed as a formal model of learning communities, in order to make this pedagogical approach more practicable for secondary science.

Theoretical Framework

In the KCI model, students participate in the interactions and scientific argumentation reflecting some practices characteristic of the real scientific community. Students make connections within and across instructional units and connect to real-world situations. Along with a deeper understanding of scientific practices and scientific processes, students also build their understanding of the NOS and explore their STEM identities and possible careers in STEM. It has been shown that students often struggle when they are required to evaluate the conclusions and arguments of others in the science classroom, may not see the value in discussing other students' ideas or do not argue from the evidence they are offered or they collect [3]. In the KCI Model, students work collectively as a knowledge community, creating a knowledge base which is further used as a resource for students' ongoing inquiry. Inquiry activities engage students with a knowledge base as a resource and students can add new ideas and elements to the knowledge base, can edit and improve it [2, 6].

The 21st Century Competencies

Along with cognitive competencies in critical thinking, analysis and problem solving which have long been considered as keystones of success in science, new forms of interpersonal and intrapersonal competencies have now been recognized as central to success [7]. *Collaboration*, which is part of the interpersonal domain, "requires students to develop collective intelligence and to co-construct meaning, becoming creators of content as well as consumers" [7, p. 13]. *Communication* – also part of interpersonal skills – often centers around the use of technology, information and digital literacy [7]. Another important scientific competency is the ability to *work with data* where data sharing becomes an essential element of research [8]. *Intrapersonal competencies* have been shown to correlate with career outcomes, and life and career skills [9]. *Career readiness* has been associated with "21st Century Competencies" and includes cognitive and non-cognitive skills, knowledge, and attitudes [7]. The development of the 21st Century Competencies is supported in our project using the KCI model.

Understanding the Nature of Science

NOS refers to our understanding of science, science as a way of knowing and the characteristics of scientific knowledge [10]. Scientific epistemology concerns the following fundamental questions: what is knowledge and what is meant by 'knowing', what are the sources of knowledge and how to verify their reliability, and what is the scope of knowledge and what are its limitations [11]. Along with distinction between observations and inferences, scientific laws and theories, NOS also concerns with exploration of scientists' mindset, cultural and background factors, scientists' imagination and creativity, and tentativeness of scientific knowledge [10].

Method

Our KCI curriculum for 11th Grade Biology class included a series of lessons co-designed with the classroom teacher and used a variety of technology environments and materials to support the curriculum and assessments. In a whole-year study, students worked in groups and as a whole class across various contexts. We added a cross-cutting *diet and nutrition* theme to the five units. Students learned as a community of young scientists, by building a common knowledge base supported by technology, working with interesting evidence cases and datasets, evaluating the credibility of online and published primary and secondary resources (i.e., scientific journal papers), developing scientific argumentation, participating in debates and reflecting in their response journals.
The KCI research method includes collaborative knowledge construction, scaffolded inquiry activities, and accessible learning outcomes. A co-constructed curriculum included activities developed by the teacher and researchers, along with case studies offered by *The Great Diseases,* Tufts University. A C.R.A.A.P. rubric (by California State University) was used by students to evaluate primary and secondary resources. A pre-post tests of students' epistemological ideas on the NOS, Learning Communities and Career Exploration were developed to measure the impact of our curriculum.
Exploration of the NOS and student epistemology in our study was effectuated through students' scientific argumentation, exploration of their beliefs about the NOS, and critical interpretation of evidence. Students worked in groups to address the distinction between observation and inference, scientific laws, theories, hypotheses, principles and facts. Students also explored scientific controversies (e.g., "obesity is not inheritable", "there is no connection between obesity and infection", or "people with gluten intolerance are sensitive to all sources of gluten"), and reflected on healthy food and lifestyle choices for themselves, their family and their community.
Additionally, during the school year, students became familiar with the roles of many professionals, including researchers, lab technicians, and doctors. Exploration of the STEM identities included students' identities in STEM learning and epistemology, and exploration of various careers in STEM. In each unit, students contributed to the Class Career folder where they recorded about careers they had come across in their readings or discussions.

Data Sources

The data collected during this study include student replies on pre- and post-questionnaires, tables, documents and journals created by students individually, in groups and as a class (on Google Docs, Google Forms, and Padlet). Co-constructed tables and student contributions represent a community knowledge base built during school year and used by all students for their final projects and debates. In scientific argumentation activities, information was collected as claims, arguments, counterclaims and counterarguments. In their exploration of the scientific datasets and case studies, students explored available evidence and made predictions (Fig. 1). Table 1 illustrates an example of an activity that explicitly explored the NOS: students worked in groups to sort statements describing scientific theory, hypothesis, scientific law, scientific principle or fact, and provided an explanation for their choice. Each group created their own table and discussed their answers as a class at the end of the activity.

A Class Career folder built progressively on Google Drive, individually and in groups, served as a platform for further discussions and exploration of each career (Fig. 2). Students researched on and added career title, its description, connection to other professions, university/college program leading to the career, and interesting videos and articles about that career. They also explained how that career was connected to each unit of the curriculum.

Fig. 1. Examples of students' predictions about two different diets (students worked in groups)

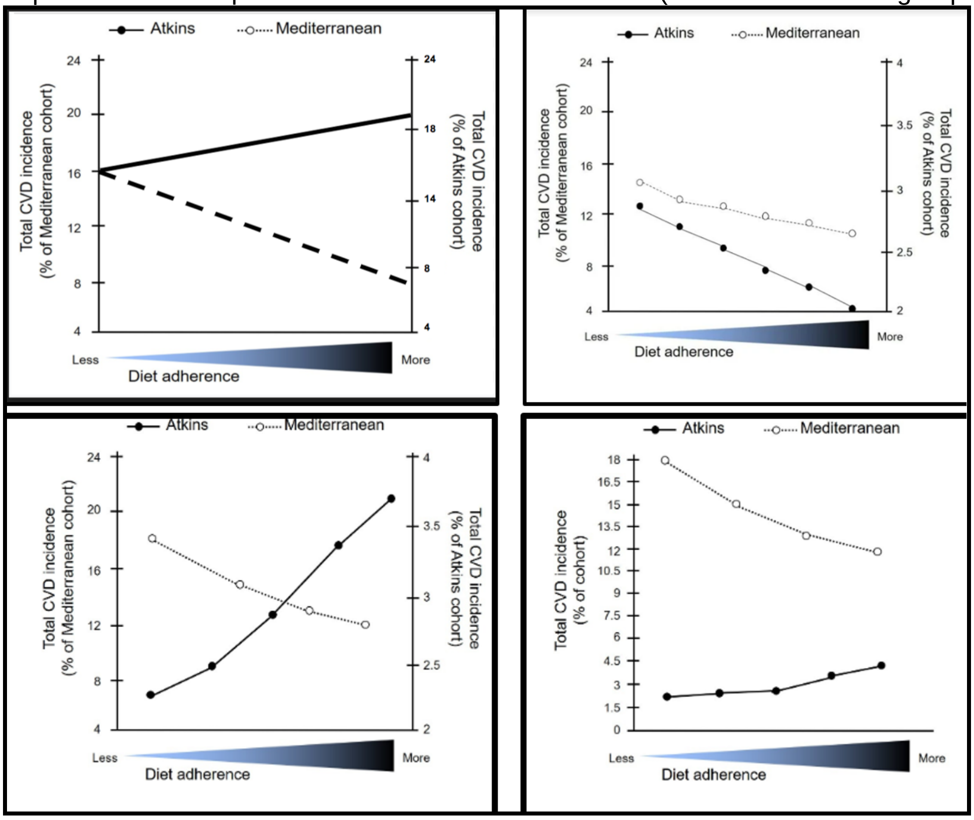
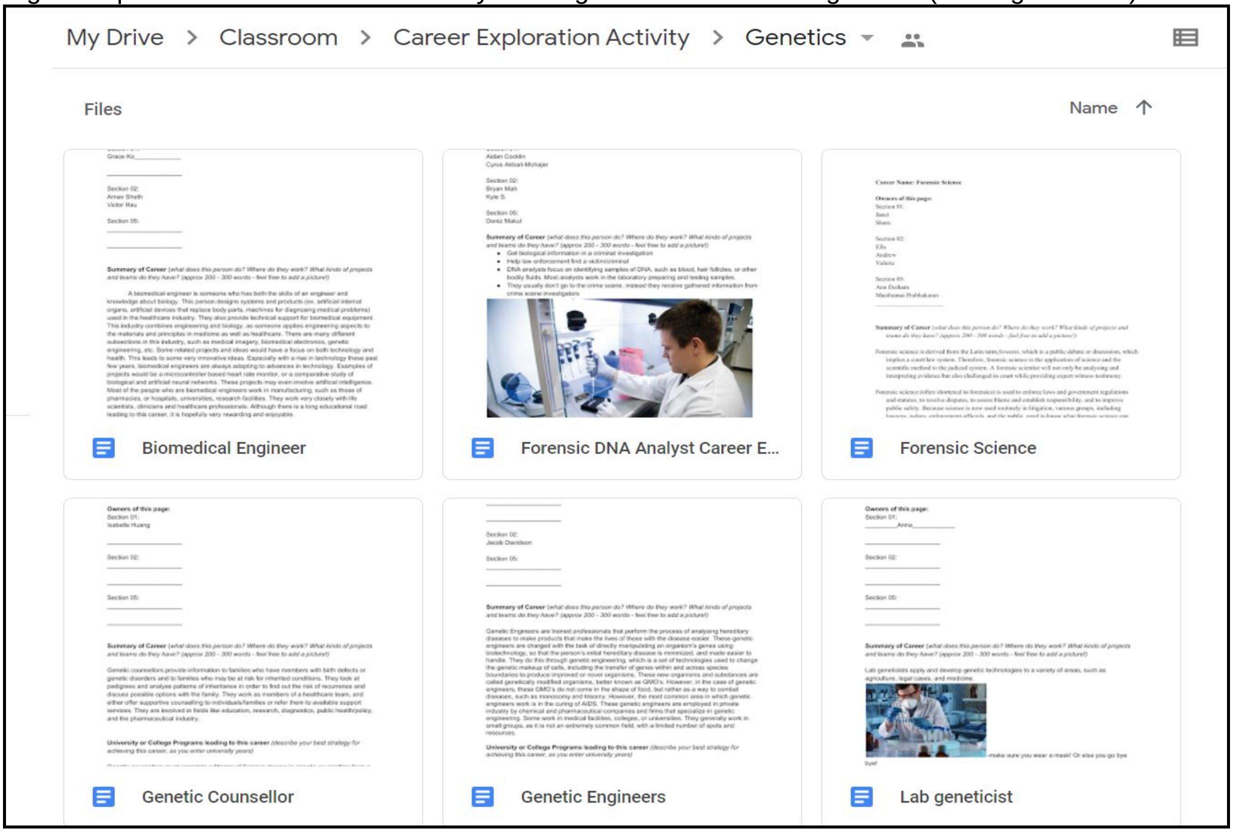


Table 1. An example of the explicit exploration of the Nature of Science by a group of students

	Scientific Theory	Hypothesis	Scientific Law	Scientific Principle	Fact
Statement	A hypothesis supported by a significant amount of empirical evidence	A tentative explanation of a phenomenon	A rule or mechanism by which specific scientific phenomena work	Is a description of the relationships among observable phenomena	Something known to have existed
Explanation	There is a significant amount of scientific evidence that supports the hypothesis	It is a tentative explanation and it is not confirmed or fully supported by sufficient scientific evidence.	It is a generalized rule that explaines a body of observation in the form of a verbal or mathematical statement, therefore this statement is part of the definition	Is a description of the relationships among observable phenomena	An obsevation that is known
Statement	Provides a most logical explanation about why things happen the way they do	A proposed explanation of relatively limited sets of observations	Often can be represented by a mathematical formula	Can be used to predict the behavior of the natural world, but describes only specific concepts	A confirmed empirical observation
Explanation	Explains why and how a process works	It is a proposed explanation and it is limited	A scientific law is something that can be expressed in a mathematical formula	It is a description of nature but only describes certain concepts	Facts are repeated observations that are confirmed

Fig. 2. Exploration of careers in STEM by building a common knowledge base (a Google Folder)



Findings

By making connections within and across curriculum units, working on activities connected to real-world situations, and building the common knowledge base, students in our study developed cognitive, interpersonal and intrapersonal competencies, built or improved their understanding of the NOS and explored their STEM learning/career identities. Our preliminary findings are below.

First, our study supported students' understanding of the role of a learning community in science learning and science research, and in communication of results. In students' replies to a post-test questionnaire, students provided high-level responses on the role of a community: among scientists (e.g., contributing to a total knowledge pool, improving the credibility and accuracy of the previous ideas) and in a classroom (e.g., sharing information to peers and learning from them, learning through explanations).

Second, our KCI curriculum design supported students' communication, collaboration, and critical thinking about primary and secondary resources – through discussing, evaluating and ranking resources. KCI activities enabled student engagement and connected to important learning goals in biology.

Third, students' understandings of the NOS were built progressively through all units. Students learned that scientific knowledge is subject to change as new evidence becomes available or old evidence becomes reinterpreted with the advances of technology and new discoveries in science. Finally, through exploring different careers and contributing to the class career folder, students built their understanding of many STEM careers.

The study demonstrates opportunities of collaborative learning and learning community approach, achieved through student work and discussions in groups and as a whole class, for helping students develop the competencies of critical thinking about resources, collaboration and scientific argumentation, and explore their STEM identities.

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