Using Classroom-Based Authentic Research Experiences to Foster Scientific Thinking and Representational Competence

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Abstract: In this preliminary mixed-method investigation, we explore how course-based research experiences using virtual supplements facilitate students' thinking and communicating like scientists. Our initial findings, from one institution (n=54 students), indicate that this experience has improved students' communication, representational competence, understanding about scientific processes, and professional identifies. We anticipate that these findings will be consistent across all five institutions we are targeting.

Issue Addressed

One of the best ways for students to understand how scientific knowledge is generated is through participating in the authentic practice of science through research. However, opportunities for research experiences are often limited and competitive. There is a need to provide more undergraduates with authentic interdisciplinary research experiences (AIRE) and assess their impact (AAAS, 2010). One way to provide research opportunities to more students is to integrate AIRE into the classroom. Ideally, classroom-based AIRE help students learn the process of science as they are guided to act and think like scientists while contributing to scientific discovery. Communication is an important aspect of science and advancements in technology have changed the way scientists communicated. Biological databases have grown significantly with the advent of genome sequencing technologies and the explosion of the internet has provided multiple options for sharing data and meeting virtually. Technology is integrated at multiple points during the process of scientific discovery as collection, analysis, and dissemination of data often relies on multiple virtual environments (VE) on the computer. Thus, AIRE for students should include the integration of technology. Technology (e.g., blogs, virtual worlds, and wiki spaces) can help create professional research communities and link students across institutions that are all participating in AIRE. Students can use this technology to communicate about problems, conceptual understandings, trouble shooting, and interesting findings (Clase and Halverson, 2013; Johnson et al., 2002; Kangassalo, 1994). The purpose of this investigation is to explore how course-based AIRE integrated with VE facilitate students' thinking and communicating like scientists.

Theoretical Framework

We used the Representational Competence framework (Halverson and Friedrichsen, 2013) to guide this study and we are testing its application for exploring changes in student thinking about annotated genomes and its relation to a biological system. Representational competence is the varying ability of an individual to understand and use representations when explaining complex phenomenon (e.g., a biological system). The seven levels identified range from no use to expert use of representations. Level 1: No use of representation; students are unable to create a representation. Level 2: Superficial use of representation; students create literal images to illustrate a scientific concept (e.g., drawing a scientists extracting DNA). Level 3: Simplified use of representation; students create representations with components of the concept, but these are not complete (e.g., drawing chromosomes only without annotation). Level 4: Symbolic use of representation; students' representations are based on a conceptual understanding of the phenomena; however their understanding is flawed. Level 5: Conceptual use of representation; students' are unable apply the information in their representations to their accurate conceptual understanding. Level 6: Scientific use of representation; students create accurate representations and descriptions, but demonstrate limitations justifying which representation is most appropriate within a given context. Level 7: Expert use of representations; students are able to generate multiple representations and use them to accurately explain a complex phenomenon.

Methodology

Our study explored the following research questions: 1) How can an AIRE influence students' levels of representational competence? 2) In what ways do students use representations to communicate their ideas like expert scientists? 2a) How does student thinking change after participating in an AIRE? 2b) How do students use representations to think about components within a biological system and across scales? 3) How do students react to using VE as part of AIRE classroom instruction? We are currently in the process of collecting and analyzing data for this mixed method investigation. Participants include students enrolled in AIRE introductory biology courses across five research universities in the US, about 15-40 students (all 18 years old or older) per course (or course series). Data comes from student responses on pre/post assessments measuring biological content knowledge, attitude about science, and representational competence for genomes, individual semistructured interviews with students after participating in course-based AIRE, and reflection prompts collected throughout the semester. Data for our preliminary findings come from one of the universities (n=54). We analyzed data using qualitative and quantitative methods. For the qualitative portion, we first used a deductive coding method to analyze student responses on the pre/posttest and individual interviews by grouping students' drawings and explanations into the levels of representational competence (Author, 2013). Then, we used an inductive approach to code students' responses from individual interviews to identify themes of students' reactions to using VE. These themes included scale perception, logistical aspects, communication, content visualization, and perceived purposes for integrating VE into AIRE. For the quantitative portion, we analyzed responses on pre/posttest using a Repeated Measures ANOVA to identify changes is attitudes toward science.

Preliminary Findings

According to our findings from the first university that offered a two semester course-based AIRE, students' showed gains in communicating like scientists and representational competence. Before instruction students demonstrated limited use of representations to communicate understandings, and much of this content was inaccurate. After instruction more students were able to conceptually understand and use representations in their explanation of an annotated genome. Overall, only 5% of participants achieved the highest level of representational competence. Even though not all students were skilled at using representations to communicate their scientific understandings, all students involved in the course were able to verbally describe what they were doing for their research project. They discussed how the act of doing science helped them better understand that scientists have to make choices about what they are finding. Furthermore, the students used the evidence they collected to make decisions, such as what constituted a gene, and also acknowledged that although their defined gene may not be right, it's their best guess based on the data they had examined thus far. The student drawings of an annotated genome resembled the genome visualizations from the VE used in the course. Although most students discussed a single computer image that influenced their representation, students who demonstrated the highest level of representational competence made comparisons among the multiple computer images. In addition, only students that completed the entire AIRE (both semesters) demonstrated an awareness of the genome from a biological systems perspective, making connections to proteins and biological function across organisms. We also found that VE helped facilitate a professional identity among the students. They reported the VE as helpful for recognizing the scale of their AIRE at a national level, beyond the work completed in the course. They reported value in being able to use a VE to "see" the concepts they had been investigating in the lab, such as a genome and they found VE useful for communicating their project to students at other institutions working toward similar goals. Students also engaged in using VE to help with problem solving when they experienced experimental difficulties.

Conclusions and Implications

While our current findings are only preliminary, they provide evidence that it is possible to offer AIRE in a classroom-based setting and allow more students the opportunity to have these experiences meeting the need identified by AAAS (2010). In these AIRE cases, students are afforded opportunities to develop insights into how scientific knowledge is really developed and provided with authentic ways to communicate understandings with others, particularly if paired up with VE supplements. This idea of communicating and collaborating with others was a key aspect to helping students feel like contributing scientists. We anticipate that the findings from this one university will be consistent with the other four institutions we have partnered with for this project.

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