Productive Disciplinary Engagement in Three-Dimensional Agriscience Instruction

Subject & Problem

One of the primary goals of recent reforms in science education is to enable more informed decision-making in personal and professional contexts (NRC, 2012; NGSS Lead States, 2013), especially for topics that affect public interest (Rudolph & Horibe, 2016). Decision-making in agriculture is particularly pertinent, as over 70% of the contiguous US is used for agriculture and private forestry (Merrill & Leatherby, 2018). While agricultural landscapes contain much of the nation’s wildlife habitat (NRCS, 2020), conventional agricultural systems in the US generally have unsustainably high consumption rates of natural resources and exacerbate stresses to natural systems (Lengnick, 2015). The extent to which rural students are prepared to make informed decisions as potential future agriculturalists has significant consequences for the public interest.

Agricultural education may provide both unique affordances and challenges with regard to strengthening student outcomes related to three-dimensional science learning. The US has over 8000 secondary agricultural education programs (Jackman & Schescke, 2014) which could potentially bolster rural science instruction while also attending to important social needs of rural communities (Hains, Hansen, & Hustedde, 2017). Agricultural education is primarily scientific in nature, and *agriscience* courses (consisting of a combination of science and agricultural content) are frequently offered for science credit in many rural schools (Barrick, et. al., 2018).

This paper addresses empirical findings that emerged from case study data in two secondary agriscience programs during the enactment of an experimental agro-ecology curriculum. This curriculum consists of NGSS-aligned instruction intended for use in high school agricultural classrooms. With support from a NSF Graduate Research Fellowship, I designed this curriculum to enable more informed decision-making among future agriculturalists through three-dimensional engagement with phenomena in a manner relevant to rural agricultural contexts, particularly with regard to ecological sustainability. Currently this experimental curriculum consists of two courses: *Natural Resources*, an agroecology course that emphasizes habitat management decisions in rural agricultural landscapes; and *Horticulture*, which addresses the sustainable management of fields for crop productivity.

Theoretical Framework. The manner in which student engagement is scaffolded within a particular discipline is an important consideration for supporting three-dimensional learning (Berland, *et al.*, 2016). Engle & Conant (2002; Engle, 2012) provide clear criteria for distinguishing engagement from other forms of classroom performance, specifying that active student participation does not necessarily equate to genuine engagement. In addition to *disengagement* (where student attention and participation is largely lacking), students can act *procedurally* (Bloome, Puro, & Theodorou, 1989), accurately providing one-dimensional responses that are personally irrelevant. Additionally, student participation can be merely “*doing school*” (Windschitl, 2019), where student participation is primarily due to an emphasis on teacher control, grades, and completion of a curriculum versus meaningful student engagement.

Engle and Conant (2002) also describe a progression of three levels of meaningful student engagement that are desirable but difficult to achieve. The most basic level (*engagement*) occurs when students display an active interest in classroom discourse and respond with their own ideas. The next level (*disciplinary engagement*) entails genuine expressions of student interest in a manner consistent with a particular discipline’s norms, vocabulary, patterns of thinking, and other forms of discourse. The highest form of engagement described by Engle and

Conant (2002) is *productive disciplinary engagement*. This is a discipline-specific level of student intellectual progress that enables increasingly sophisticated claims over time. As a result, students are able to raise new questions, identify previously-unseen connections between concepts, and design solutions to satisfy a goal.

Environments that foster PDE also support stronger student engagement with particular disciplinary ideas in a manner that can enable more robust three-dimensional performances (Berland, et al., 2016; NRC, 2015) in accordance with the Next Generation Science Standards (Stroupe, 2014). However, K12 science instruction traditionally has been disconnected from students' lived experiences in a manner that can inhibit student engagement (Engles, *et al.*, 2019). The instructional model for agricultural education consists a unique combination of classroom science learning and situated community-based learning which may have support greater student engagement across disciplines. As such, this proposal addresses the following research question: *What resources and practices inside and outside agriscience classrooms are valuable for fostering productive disciplinary engagement as a means for enabling more informed and more sustainable decision-making among future agriculturalists?*

Design & Procedure

Study Context. This bounded double case study involved two high school agricultural education programs in two states. Two agriculture teachers and 83 students took part in this work during the 2019-20 school year. Both teachers were recruited through the National Association of Agricultural Educators and teach in rural districts in agricultural areas. Mrs. E taught at Lanesville in the Midwestern US and had five years of teaching experience with teaching licenses in agriculture and biology. Mrs. B teaches in Shoehaven in the northeastern US and had less than 5 years of teaching experience with a teaching license in agriculture. Each case study teacher was also asked to choose four students representing a range of backgrounds and abilities for monthly focus group interviews. Data were collected between September 2019 and February 2020 from a pre- and post-assessment of sustainable knowledge and practice, teacher interviews, student focus group interviews, and written assessments. The findings described in this paper are primarily drawn from teacher and student interviews, while other sources of data provided a source of triangulation. This investigation is part of a larger design-based research (DBR) study with the primary objective of applying principles of instructional design to develop a curriculum that responds to the special challenges of NGSS-aligned agriscience instruction.

Methods. I began by identifying and cataloging interview transcript excerpts that provided evidence of student performances as they pertained to levels of engagement (or lack thereof) as well as observations among teachers and students of perceived challenges and successes while taking part in the course. I also noted incidences in which participants' responses were particularly relevant to key design considerations. I identified significant statements from these sources that provided particularly valuable insights and used these to establish the narratives within and across cases in accordance with recommendations from Creswell (2014) and Merriam (2009). It should be noted that this work is ongoing and that the results presented here are still preliminary. This paper primarily serves as an opportunity to reflect on the motivation for specific design considerations inherent in the work of developing a NGSS-aligned agriscience curriculum.

Findings & Analysis

Evidence of Productive Disciplinary Engagement. Both teachers and students provided evidence of a progression among students toward productive disciplinary engagement as the experimental curriculum was implemented.

Evidence of Student Engagement: Initially, both teacher and focus group responses suggest that students struggled to achieve even a basic level of engagement in the experimental course. Mrs. E acknowledged some students initially felt it was "biology and chemistry all over again and they hated those classes." In their first interviews, Mrs. B's focus students noted that this experimental course was "definitely different from [other] agriculture classes".

However, as the semester progressed both teachers and students provided evidence of improved student engagement. In later interviews, students provided unprompted expressions of engagement (e.g. "I'm so interested in this stuff" and "I wish there was a full-year course"). Improvements to engagement were also evidenced by incidences in which students completed each other's sentences, competed to respond to questions, and had explicit displays of emotion. Teachers also observed that most of their students began to enjoy the course more as they became accustomed to the structure and gained proficiency in scientific disciplinary norms.

Evidence of Disciplinary Engagement: In their first interviews, students' descriptions of perceived threats to food production and subsequent solutions initially reflected a very limited understanding of ecological disciplines. However, in later interviews students frequently outlined detailed relationships between biodiversity, ecosystem services, and agricultural production. Mrs. B observed that students were increasingly comprehending that maximizing a specific ecosystem service like food production came at the expense of other services. Mrs. E noted the improved precision in their descriptions of ecological relationships, and the gains to systems-level knowledge that enabled most students to effectively address novel scenarios and problems.

Evidence of Productive Disciplinary Engagement: Students' arguments generally became increasingly sophisticated, entailing greater use of evidence and explanatory models to address agro-ecological problems. Students with personal connections to agriculture stated that they now understood why they "can't do just whatever we want as a farmer." Focus group students in the Horticulture course improved in their capacity to choose production options that balanced the need for profitable agricultural production with ecological constraints. They also recognized specific tradeoffs and barriers inherent in these decisions (e.g. initial transition costs). While some students with identities more closely tied to conventional production systems demonstrated reluctance to fully acknowledge the "line of thinking" inherent in the curriculum, they also increasingly acknowledged the legitimacy of differing viewpoints on these topics.

Curricular Aspects that Fostered PDE. The primary purpose of this work was to investigate which aspects of the experimental curriculum were valuable for fostering productive disciplinary engagement as a means for enabling more informed and more sustainable decision-making. Case study teachers and students alluded to three particular design considerations of the curriculum that they found to be particularly valuable for this purpose: case study data, an emphasis on reasoning across systems and scales, and situated learning opportunities.

Case Study Data: Each unit in these courses begins with a "data dive" where students consider data and evidence from specific experiments or case studies that are representative of specific natural phenomena. Both teachers felt that this strategy was particularly useful for supporting student discourse in a manner that provided students with agency and authority. For example, Mrs. E stated that this let students "hear different areas," adding "if somebody left something out, somebody would remember … they could add on [to each other's contributions].” Mrs. B made similar statements, arguing that these materials engaged students in more robust three-dimensional performances, particularly in respect to developing observations, hypotheses, and explanations from data.

Focus group students alluded to the value of case study data for engagement as well. When asked how their thinking and reasoning about ecology changed over the fall semester, the Shoehaven case study students argued that they were not only “more aware” of the problems but also felt that they “wanted to do something about it” and “know how we can help” because they had encountered evidence from actual examples as opposed to hypothetical scenarios.

Reasoning Across Systems & Scale: Mrs. B felt that the emphasis on systems-level analysis in each unit was a “big change” from how agricultural education has been traditionally taught, and that as a result, students would “make better decisions than they would if they just went through and just got to learn about wildlife.” She argued that “the systems-based approach and having them look at how do these concepts actually relate to what [they’re] going to be doing ... made light bulbs go off.” Mrs. E alluded to this well, stating that her students “started thinking as a whole and saw humans being part of that ecosystem.” This better enabled students to recognize the dependence of human activity on biodiversity and ecosystem services.

The teachers argued that as students became more proficient in reasoning across scales, they had an increased level of engagement in these ecological issues because they “feel like they’re armed with enough knowledge about our environment that they have a voice.” Students alluded to this as well, describing how they were now seeking out news stories related to course topics on social media platforms as a result of interest stemming from comprehension. For example, one student explained that he obtained most news through Snapchat accounts; prior to the class he “would have easily chosen the Sports Center one and never even considered looking at the boring one about science.” However, he felt that now that he had a capacity to understand ecosystems from a systems level, he was “much more inclined to read it and actually understand some of it” in a manner that compelled him to seek out even more information.

Situated Learning Opportunities: Mrs. E explicitly felt that the “outside the classroom stuff” (such as job shadowing, tours of area farms, and investigations in local habitats) was most important for improving informed decision-making. Mrs. E argued that these experiences helped students to “see both sides of things”, leading to a greater transfer of knowledge and practice to disciplinary considerations. Mrs. B observed that students were “now making those connections of land management options” only after working directly with agriculturalists to develop explanations and solutions during class time.

Both groups of focus students also explicitly acknowledged the increased engagement that was fostered by situated learning opportunities. The Lanesville students felt that their tours of nearby university’s agricultural research, their job shadowing opportunities, and their work in local habitats led to a level of motivation that exceeded what could occur in a classroom. “It was kind of cool to … actually see what was going on and not just reading about it or seeing pictures,” argued one student, adding, “I feel like being there actually was kind of cool and understanding what the process was.” Another added that the “real life” component made it more interesting. The Shoehaven focus group students stated that they “felt a connection to species” as result of their experiences in local habitats that was personally very moving and engaging to them. Similarly, students in Lanesville sought and obtained financial grants to purchase equipment to enact conservation agriculture practices in their school’s experimental field, which may suggest the potential for transfer from classrooms to more discipline-specific scenarios.

Engle and Conant's (2002) own work alludes to the potential value of situated learning with regard to student engagement. They note that resources connecting students to "community beyond the classroom wall" (p. 407) increased student accountability to others as well as to disciplinary norms in a manner that supported PDE. However, situated learning opportunities may be an under-attended component for enabling robust three-dimensional outcomes in K-12 science classrooms. In comparison to other key factors that were identified (evidence-based argumentation through case studies and an emphasis on reasoning across systems and scales), situated learning is less emphasized in both the Framework (NRC, 2012) and NGSS (NGSS Lead States, 2013). Traditionally, K-12 science content has been disconnected from students' lived experiences (Engles, *et al.*, 2019). Excerpts from both teacher and student interviews allude to the notion that situated learning experiences in combination with three-dimensional classroom learning experiences may better support outcomes like more informed decision-making, particularly for disciplinary considerations beyond the classroom.

Alternative Interpretations, Bias, Reliability, and Validity

As a former agricultural educator with ten years of classroom teaching experience, as well as a lifetime of experience in the agriculture industry, I have a strong interest in how classroom science instruction could be effective for enabling more informed practice among agriculturalists. As a result of overlapping personal identities with production agriculture, secondary educators, and the research community, it is unavoidable that my work is reflective of some level of bias and lack of objectiveness. I have sought to resolve this in a number of ways, but particularly by reaching out to individuals within each of those communities for feedback and critique of this work. While I position myself as having useful prior experience in developing NGSS-aligned sustainable agriscience curriculum, I also know that it is impossible for me to fully assess the effectiveness of this curriculum without being in the classroom on a daily basis. As such, I do not attempt to make broad assertions about the capacity of three-dimensional learning (as applied in these case study classrooms) to influence decision-making in agriculture. Rather, I am using this as an opportunity to reflect on insights gained from creating a "proof of concept" for secondary agricultural programs.

Contributions and General Interest

This work could have important implications for both rural and non-rural education. The goal of enabling students to make more informed decisions will likely require an expanded understanding of how NGSS practices such as evidence-based argumentation and constructing explanations are limited or enhanced by the structure of student learning systems inside and outside of the classroom. In particular, insights from this work suggest that enabling informed decision-making among students may be enhanced or even dependent on situated learning opportunities beyond the classroom walls. This work may help to push back against assumptions that three-dimensional science learning should be viewed as occurring exclusively in classrooms.

Since ecological sustainability is central to this work, it is being submitted in consideration for Strand 14 (Environmental Education). This paper will also be of value to members of NARST who have interest in community-based learning as a means of motivating students, who have an interest in situated learning that leads to more informed citizen decision making and action, and for those who have an interest in achieving goals specific to rural schools, including sociocultural responsiveness and the closing of achievement gaps between rural and non-rural students.

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