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Unintended Consequences: Pre-Service Science Teachers' Immersion in Modeling-Based Inquiry in Tropical Ecology

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Abstract

Learning modeling-based scientific inquiry (MBI) can be a challenge for educators and students alike. Teacher educators have used various approaches, experiences, and tools to aid in preparing future science teachers to use MBI in the classroom. However, this ambitious vision of practice remains elusive for most science teachers. This qualitative case study investigates the following research questions: (1) What and how do participants learn from immersion in an authentic modeling-based ecology experience that is intended to be both a science experience and a science teaching experience? (2) What are the unintended consequences of learning that is situated in modeling-based inquiry for pre-service teachers? Findings from this study indicate that authentic inquiry experiences, if too far-removed from teachers' prior or future classroom practice, will not transfer easily to a teacher's practice. Furthermore, a short-term experience engaging with scientists might emphasize science content and obscure the instructor's focus on science teaching practices. Findings from this study can inform science teacher educators about the affordances and limitations of situating learning in a modeling-based inquiry community of practice.

Keywords: modeling-based inquiry, pre-service teachers, science teacher education, ecology education

1. Introduction

While modeling-based science curricula and modeling-based inquiry instructional approaches show promise for providing effective learning experiences for students, most science teachers have not experienced this type of inquiry as students in middle school and high school, in their teacher preparation courses, or as a professional development opportunity (Schwartz, Lederman, & Crawford, 2004; Windschitl, Thompson, & Braaten, 2008). Specifically, during undergraduate science coursework teachers often experienced "'doing science' only through highly scripted laboratory activities and lectures where instructors rarely discuss in explicit terms how science is done" (Windschitl, Thompson, & Braaten, 2008, p. 311). Although some pre-service teacher methods courses and in-service teacher professional development programs attempt to inform participants about modeling-based inquiry, intervention courses that teach about such inquiry have so far been only partially successful (Windschitl, et al., 2008). Not all teachers who learn about modeling-based inquiry will effectively implement this pedagogy in their classrooms. Windschitl et al. (2008) contend that preparing educators to teach with modeling is not as straightforward as it may seem. Because of a more traditional science background, many science teachers are ill prepared to incorporate modeling into their pedagogy; and successful models of how to teach modeling-based inquiry are needed (Harlow, 2010; Windschitl, Thompson & Braaten, 2008).

This study reports on a course that was specifically designed for participants to engage in modeling-based inquiry under the guidance of a science teacher educator and a biologist who collaborated in the development and instruction of the course. Over three weeks, course participants engaged in first-hand modeling-based inquiry experiences focused on central questions in tropical ecology. The course began with four days of coursework in the U.S. followed by an immersion experience in Costa Rica with participants working alongside research scientists. Taking this promising immersion experience as a case study, we examine the following questions: (a) What and how do participants learn from immersion in an authentic modeling-based ecology experience that is intended to be both a science experience and a science teaching experience? (b) What are the unintended consequences of learning that is situated in modeling-based inquiry for pre-service teachers? Findings emerging from this study may help other science teacher educators problematize modeling-based inquiry experiences for pre-service and in-service teachers prompting further consideration of how these contexts do (or do not) situate teacher learning in a community of modeling-based inquiry practice.

Windschitl, Thompson and Braaten (2008) call for a way for learners to engage with content and practices of more "authentic science…[through] forms of inquiry based on the generation, testing, and revision of scientific models—i.e., modeling-based inquiry" (p. 942). Modeling-based inquiry is a specific form of inquiry that aims "to test an idea—represented as a system of related processes, events or structures—against observations in the real world and to assess the adequacy of the representation (i.e., model) against certain standards" (Windschitl, et al., 2008, p. 313). This study is based on a guided form of inquiry that asks participants, as part of their course projects, to develop learning goals that require a deep understanding of key disciplinary models and cultivation of defendable explanations of the natural world.

Instruction in modeling is now being used in science teacher education courses to help prepare a new generation of science educators. Additionally, cross-communication and collaboration between university educators in the science disciplines and in teacher education programs holds promise for changing the status quo in science education. Successful interdisciplinary collaborations can advance education reform by fostering greater understanding of practices within a single discipline and assist in generating solutions for factors that are inadequately addressed by individuals working autonomously in their specific discipline.

To examine features of pre-service teacher learning for this study, we draw on Lave & Wenger's conceptualization of learning as *legitimate peripheral participation*. Learning is more than accumulating information and skills; it is not internalized solely in the individual, but occurs through interactions and conversations within a community (Lave & Wenger, 1991). In other words, learning is a combination of experiences and social practice—it involves negotiating new meanings, boundaries, identity transformation, and participation.

Participants in this course were situated in two learning environments simultaneously (a) a tropical ecology learning environment where they were immersed in modeling-based inquiry as "newcomers" to this particular set of science practices and science concepts, and (b) a new-pedagogy learning environment where they were asked to examine and envision the use of modeling-based inquiry as an approach to science teaching. The goal of the course under study was to follow newcomer participants as they navigated their entry into this modeling-based community and to see how they engaged in participation. Thus, this study examined the ways that pre-service teachers participated in the activities, goals, and norms of the group by looking at how newcomers' participation compared with the participation of the "old-timers" – the instructors and scientists who played leadership roles while working with course participants. This study informs educators concerned with preparing aspiring science teachers about the methods and pedagogy needed for inquiry-based science teaching in general, and teaching with modeling-based inquiry specifically. It investigates the challenges and consequences of an authentic modeling-based inquiry experience with pre-service teachers.

2. Materials and Methods

This instrumental case study analyzes the participation of five pre-service teachers as they engaged in course activities first in a university setting in the U.S. and then in a field ecology setting in Costa Rica. Two instructors co-developed and taught the course.

2.1 Course Goals

The course curriculum focused on evolutionary ecology using guided modeling-based inquiry experiences within a community that included practicing scientists, a teacher educator, and student peers in both classroom and field environments. Course goals broadly were to better prepare committed and aspiring educators to teach science through modeling-based inquiry and to assist participants in strengthening their ecology knowledge. Participants traveled to various settings in Costa Rica where they met with scientists, researchers, and educators as they learned about the history of the country, its commitment to environmental conservation, and the research that is being conducted on populations of plants and animals.

2.2 Participants

All the participants for this study were from the same public university in the Midwest United States and were involved in the summer course *Science and Pedagogy: Exploring the Nature of Science Through Tropical Ecology* described above. The course was taught by a science education professor who had experience in teaching with modeling-based inquiry, and an entomologist who taught introductory biology, had extensive experience with field research in various countries, and was newer to modeling-based inquiry in science education.

2.3 Data Collection

To address our two research questions about participants' learning in an authentic ecology setting and the unintended consequences of such situated learning, we conducted pre- and post-course interviews, made daily observations, administered a post-course questionnaire, and collected final projects.

2.4 Data Analysis

There were five questions that were the same between the pre- and post- course interviews: What do you think are the central features of what it means to "do science"? What kinds of understandings or skills do you think students can get out of doing science? What does teaching science through inquiry mean to you? What do you think students learn about science while involved in inquiry-based activities? Can you give an example of a scientific model? / If you had to describe what scientific models are to someone else, what would you tell them? In the first phase of data analysis, we looked across all participants and their paired pre and post responses to the

five questions listed above and used a set of codes derived from previous research (e.g., Windschitl and Thompson, 2006) to trace participants' ideas about inquiry-based teaching, "doing science," and modeling. We identified some initial trends from comparisons across time within each participant's data then looked across participants to see how trends compared amongst individuals. From this comparison, a small number of commonalities emerged and exceptions surfaced.

3. Results

Two themes emerged that centered on participants holding on to their beliefs about what is involved in doing science and teaching with inquiry. The first is that most participants made only a nominal change in their talk about scientific practices (i.e., what science consists of). In most cases, they altered some of their words but not their underlying conceptions of teaching and learning science in the classroom. A second theme is that the course content and pedagogy did not seem to prompt participants to think differently about how to create the types of engaged experiences in their classrooms that they experienced in their field work in Costa Rica. Rather than taking up the idea that first-hand experience with science is valuable in the classroom, most participants looked forward to teaching their future students *about* their time in Costa Rica. These findings stand in stark contrast with the instructors' conceptualizations for the course and highlight the disparity between pedagogical intentions and enactments.

3.1 Persistence of Initial Ideas about Science and Science Teaching

Both before and after the course, participants largely described science as a straightforward method of observing, questioning, designing and carrying out experiments, gathering and interpreting data, and analyzing information. They spoke of science inquiry in classrooms as letting students be in charge of their learning, as opposed to "giving students information." Participants recognized they wanted students to be "doing" things, and their underlying vision of science teaching differed from the instructors' visions of the course. While participants often appropriated new language from this course experience, such new language was used to re-name pre-existing ideas about science dominated by an unproblematic scientific method devoid of theorizing and modeling.

3.2 Teaching About Authentic Science Experiences

Participants experienced first-hand engagement in authentic scientific research in this Costa Rican tropical ecology course, but failed to see how they could replicate such an experience with students back in U.S. classrooms. The Costa Rica course was inquiry-based and drew on the expertise of local scientists and other community members to help participants experience research and issues around sustainability in the tropics. Yet instead of participants imagining how they might create authentic inquiry-based experiences in their own local communities by providing first-hand science research opportunities, they discussed how they wanted to *share* their Costa Rican experiences with students. Participants seemed to think their experience in Costa Rica was something they could transfer to their classrooms by telling students about it and having them engage in activities about Costa Rican ecology.

4. Discussion

Participants had particular goals for the course, such as experiencing ecology in a tropical setting, which were different from the instructors' envisioned goals. The instructors intended this course to be situated in authentic modeling-based immersion in the tropics. Participants saw it as an opportunity to experience Costa Rica and learn about tropical ecology rather than as a way to learn about inquiry pedagogy and how to recreate this type of an experience in their classrooms. Instead of this experience being both about learning ecology and learning how to teach modeling-based science, participants thought of their new ecology knowledge as something interesting to share with their students. This was more a science learning experience and not a science teacher learning experience.

One explanation for the lack of participants' uptake of inquiry pedagogy is that as a community of practice, the participants appealed to the scientists (and hence, their "science") as "experts" and failed to view the science educator as an expert contributor to the community. Thus, participants failed to incorporate the pedagogy the instructors infused throughout the course because they focused on learning the new science content and not on how to teach science in a new way. These findings are consistent with the analysis of Windschitl (2004) who notes although, "there have been calls to integrate more authentic inquiry experiences...into teacher education courses," just being involved in inquiry experiences such as this one may not be enough to convince teachers to change their ideas of inquiry and to use it in the classroom (p. 485).

Although course participants had an authentic tropical ecology learning experience, it may have been too far-removed from their teaching community to seem applicable in their classrooms. The urge to take this experience and share it with their students rather than develop the same type of experience was pervasive in participants'

thoughts and lesson plans. For example, one participant, Emily, looked forward to taking her course experiences and telling her students about them—failing to realize that in doing so, her students would be unable to experience the concepts and environment the way she experienced them. Instead, her students would only be listening to her account of Costa Rica, which is different than engaging in an authentic experience. Authentic experiences may have their place in teacher education, but teacher educators should proceed with caution because these experiences might not have the perceived intended outcomes—especially if they are not situated in both *learning* the science and *teaching* the science.

Along with the unintended consequence of participants missing the pedagogical implications of an authentic inquiry-based ecology experience is the lack of attention they gave to particular scientific language. Participants often appropriated new language learned during this course, but used this language to re-name pre-existing ideas about science dominated by an unproblematic scientific method devoid of theorizing and modeling. Although participants engaged in conversations with scientific "experts" who discussed their research and shared their findings, at no point did the scientists talk about using a "scientific method" or discovering "truths of science." However, course participants seemed wedded to phrases like "the scientific method" both before and after the course when they discussed what students learned through inquiry experiences. This finding remains perplexing because participants appealed to scientists as "experts" yet did not adopt a new way of talking about science in the classroom. As Windschitl (2004) contends, perhaps the experience these teachers had with the scientists was eclipsed by the "broader culturally reinforced models that maintain everyday ways of thinking about the disciplinary activities of scientists" (p. 508). Participants in this tropical ecology course seemed to verify Windschitl's (2004) notion that "investigative" activities such as those experienced by course participants might confirm the conception of a "one-dimensional Science Method" (p. 485).

5. Conclusion

The instructors envisioned this course as a way for participants to be immersed in learning tropical ecology through a modeling-based inquiry experience. At the end of the course, participants had stronger ecology content knowledge, but continued to struggle with how to design and implement novel inquiry learning experiences into their teaching practice. That is, instead of talking about how to recreate an environment in which students could explore the ecology of their region, participants instead envisioned sharing their first-hand experiences in Costa Rica with their students to get them excited about science. It appears the leap from this tropical ecology learning environment to the participants' U.S. classrooms is too far removed from the experience. There was not an unproblematic or inherent transfer of knowledge, skills, or pedagogy from one particular context (immersion in tropical ecology in Costa Rica) to another (U.S. classrooms).

Perhaps there is too big a gap between these contexts for transfer to seem possible. Although this particular immersion-type experience did not seem to change participants' conceptions of inquiry teaching, we would not want teacher educators to completely abandon these types of immersion experiences. Rather, they should work to close the gap between the contexts in which the authentic learning experience and eventual teaching will take place. The question about how to close this gap remains. Would guidance during curriculum development in these types of settings help teachers make the leap toward how to create these experiences in their classrooms? Merely pointing out pedagogy as it is happening is not enough for participants to take it up and incorporate it unproblematically into their practice. Beyond this course, participants were not supported in inquiry curriculum development, teaching, or reflection. The schools in which three of the participants teach have a more traditional curricular and pedagogical focus. Thus compounding the limitations of this course is that these participants lack sustained modeling-based scaffolding and support from others in their teaching environments.

It would be interesting to incorporate into this ecology course some support tools and a way to sustain this support throughout the school year to see what effect a continued effort might have toward transformation in an inquiry community of practice. Future research into these questions may prove promising in further understanding the disconnect between having an authentic experience as a teacher-learner and incorporating it into one's science teaching pedagogy.

6. Epilogue

Although this course did not appear to have the specific effect on participants that the instructors envisioned, there is reason to be cautiously optimistic about these types of learning experiences. Despite the mixed results of this study, one participant attributed this course as the impetus for his commitment to pursuing his doctorate in sustainability while incorporating modeling-based inquiry from a STEM perspective. Although Alex seemed to have entered and left the Costa Rica course without changing much about the way he conceptualized inquiry and teaching, he was interviewed almost two years later to gain insight into any lasting effects the course had on him and his perspectives on education.

We found it notable that Alex now spoke differently about the course than he had in his initial post-course interview:

I can't say for certain, but I feel pretty confident in saying that the Costa Rica course definitely jumpstarted the sustainability interest just because it probably wasn't so much the aspects of the course as much as getting to see the culture in Costa Rica that revolves around sustainability. I guess there were certain ecological aspects of the course that contributed to it and for me as an educator and as a human, just seeing the culture in Costa Rica was really the best thing for jumpstarting that. The modeling aspects that I really picked up in the course are feeding into [sustainability ideas] now. (Alex, Interview, February, 4, 2012)

He particularly discussed the ways the Costa Rican culture of "wanting to be one with the environment" got him thinking about how "sustainability was something attainable and how it can even be successful economically." Although after the course Alex said that without the expertise of the Costa Rican scientists he "would not have been able to do anything" like what he did (Alex, Post-course interview), he now did not reference the Costa Rican scientists as contributing to the idea of sustainability. In fact, he thought of these Costa Rican scientists as "outsiders" who were already predisposed to sustainability and instead saw the native Costa Ricans as being the ones who "bought into and cultivated" sustainable ways of living.

In relation to the pedagogy of sustainability education, Alex discussed how he would prefer to take a modeling approach. He noted that while his graduate courses were not taught with sustainability in mind, he still thought about the content he learned in Costa Rica and:

How to turn some of this stuff into sustainability, particularity with modeling [since] modeling is a big thing and widely debated topic in sustainability. So just offering students possible ways of modeling things in sustainability ... is one way that I have thought of changing this [content]. (Alex, Interview, February, 4, 2012)

Alex preferred a cross-disciplinary approach to teaching—especially with sustainability, "There are just all kinds of ways where you could get cross-discipline unit plans going to not only teach future teachers *how* do I plan across disciplines but then also how [to] teach sustainability." He touted sustainability as "the best combination of STEM that I have seen in any topic. It encompasses everything in STEM and then it also encompasses lots of things outside of STEM. It's just such a far-reaching problem."

Upon reflecting on his initial Costa Rican experience, Alex noted that if he were to try and create an experience similar to what he had while in Costa Rica and for it to be as meaningful for his students as is was for him, he doubted that he "could replicate that by just teaching here in the U.S." He recalled that he "needed" his Costa Rican experience to:

Understand how consumer-driven our culture is and how much it doesn't have to be that way for personal happiness. We talk about that as Americans we are caught up in being consumers and we try to buy happiness, but while I had participated in all kinds of discussions on topics like [consumerism] in the past, I guess I really truly didn't understand the depth of that conversation and what it meant to me until I went to Costa Rica. There were philosophical awakenings that I had in Costa Rica. (Alex, Interview, February, 4, 2012)

Despite his reflection of how the Costa Rican course impacted his thinking, we are still puzzled by Alex's perception of his personal experiences in relation to what he envisions for his students. Perhaps he is thinking that as a course instructor and curriculum designer, he might be interested in and enhanced by first-hand experiences when designing a learning experience, but that to learn the content, his students do not necessarily have to engage in the same experiences in which he was involved. It seems as if he might be thinking that the instructor's experiences impact course design—while students can engage in course content in other ways to become knowledgeable about the topic.

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