Background literature. Introductory chemistry courses are often delivered lecture-style and assessed with multiple-choice exams in classes of hundreds of students, often lacking opportunity for realistic scientific activity.[1] Students often develop the notion that scientific knowledge may be acquired from external authorities rather than viewing science as a sense-making endeavor[2] and as such they may default to rote learning, as material seems removed from everyday experiences.[3] Often, students' understandings of the nature of scientific knowledge, that is, their **epistemological understandings of science**, are not explicitly addressed in traditional curriculum, yielding students, some who complete STEM degrees, who do not understand how science progresses.[4] Evidence suggests that undergraduate chemistry students possess significantly less sophisticated epistemologies than practicing chemists but that sophistication of undergraduates' epistemologies are positively correlated with authentic experience. However, processes by which shifts in student epistemologies occur remain unclear.[5]

For instance, one authentic scientific activity identified by the National Research Council's *A Framework for K-12 Science Education*, is that of scientific modeling.[6] However, because students often perceive scientific claims as "proven," they may not consider the nature and purpose of scientific models or a models' associated assumptions, known as metamodeling knowledge.[7] Students may have different metamodeling beliefs in different contexts.[8] For example, students have demonstrated particular difficulty reasoning with mathematical models in meaningful ways.[9] In contrast, expert scientists create and use models purposefully, to explain and predict phenomena, and generally possess modeling epistemologies that are far more stable and contextually appropriate.[8] Evidence suggests that incorporating authentic modeling activities into introductory courses can support students' development of expert-like epistemological ideas.[10] Little is known about the mechanisms by which students' epistemologies shift in response to engagement with modeling activities, but understanding these mechanisms could inform practices for instruction on scientific modeling epistemology. **I intend to identify the moments in which students' epistemological ideas are challenged, how and why students' epistemological ideas change, and the factors that contribute to such realizations in a modeling-focused classroom setting.**

Research questions. **1)** How do students rationalize their epistemological decisions while engaging in collaborative modeling activities in introductory chemistry contexts? **2)** How do modeling activities and instructor facilitation contribute to shifts in epistemological ideas?

Methods. Because students are often unaware of their own epistemologies, it is not reasonable to ask students to describe their epistemological ideas.[11] Rather, it is logical to analyze student discourse to deduce the ways in which students think about the nature of scientific knowledge. Furthermore, as I am interested in the process of students' shifting epistemologies toward those appropriate in chemistry contexts rather than static knowledge states, microgenetic analysis, a detailed, moment-by-moment analysis of the processes which contribute to learning, is appropriate for developing a nuanced understanding of change processes and the factors which contribute to them, such as design features of classroom activities or instructor-student interaction.[12]

My current graduate research is aimed at developing and testing modeling-focused collaborative learning activities that support students' understanding of the nature and purpose of models. As part of this project, I plan to examine pre- and post-intervention survey data to gain a sense of the impact of the activities on students' metamodeling knowledge (see Personal Statement). Support from the GRFP would allow me to expand upon this work to conduct a microgenetic analysis of classroom discourse as collaborative modeling activities take place, which would provide a finer-grained understanding of the mechanisms by which students' epistemological ideas shift toward more expert-like conceptions. Such a fine-grained account of how collaborative learning activities support students' epistemologies of modeling would provide insight for educators on how to orchestrate learning environments conducive for student development of robust understanding of the nature of scientific inquiry. While common in the mathematics education research community, few discourse analysis studies and fewer still microgenetic studies in particular, exist in chemistry contexts that would provide the kind of detailed mechanistic understanding that would support instructor facilitation efforts.

For this study, I will collect multiple sources of data including video recordings of whole class discussion and small group work during collaborative modeling-focused activities, and written work generated during the modeling activities. The collaborative nature of the modeling activities will necessitate that students express their ideas about models to other group members, providing data about students' thought processes. Since students will complete three modeling activities over the course of a semester, these data will allow me to observe the changes in the ways students discuss epistemological ideas about models over time.

As an initial analytical framework for helping me to identify epistemological shifts in classroom discourse, I will adapt Grünkorn et al.'s developmental progression of epistemological views of modeling on five subscales (nature, purpose, and changeability of models, testing models and multiple models for a single phenomenon). Grünkorn et al.'s progression ranges from naïve-realistic interpretations of models as mere copies of phenomena, to constructivist views of models as the scientific products of developing explanations about the natural world, an idea which students should ideally develop as they mature into individuals capable of contributing to science. This framework would allow for the characterization of the sophistication of student modeling epistemologies and for determining whether engaging in modeling activities supports shifts toward more expert-like views of models.[13]

In completing this project, I will draw on my experience analyzing qualitative data. Additionally, my adviser has experience in classroom discourse analysis and will serve as a valuable resource during the analysis for this study.[14]

Summary of Intellectual Merit. The proposed research will provide insight about how students reason about the nature of models in chemistry. Since models are key tools used by scientists to communicate and explain the natural world, it is important that introductory courses can provide students with opportunities to develop scientifically appropriate understanding of models' nature and purpose. Additionally, microgenetic studies of chemistry learners are few; to my knowledge, this analytical technique has never been used in undergraduate chemistry contexts, but these methods are powerful for investigation of agents that contribute to shifts in student ideas.

Summary of Broader Impacts. The proposed research will inform instruction on science epistemologies. Students who understand the nature of scientific inquiry are more likely to engage meaningfully in subsequent coursework and experience academic success.[15] Evidence-based instruction on epistemologies can support student success. Furthermore, students will be able to apply knowledge of the nature of scientific knowledge beyond classroom chemistry contexts to understand how scientists model globally-relevant phenomena such as climate change.

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