Student Sensemaking in Inquiry-Based Physics Laboratories

Background: With the growing implementation of inquiry-based labs in physics, students are no longer following rote procedures and are expected to utilize complex experimental skills like measurement uncertainty, experimental modeling, and computation, which require students to engage in sensemaking [1]. We view sensemaking as "a dynamic process of building or revising an explanation in order to 'figure something out'—to ascertain the mechanism underlying a phenomenon in order to resolve a gap or inconsistency in one's understanding" [2]. Given that existing research on sensemaking has focused on textbook problem solving, research is needed to understand how sensemaking appears in inquiry-based labs, given their increasing prevalence [3]. Physics is often viewed by students as a confusing, unapproachable subject; understanding student sensemaking is an important step in developing labs that are more accessible to a range of students, beyond physics majors.

Preliminary Results: In response to the call for inquiry-based physics labs, as well as labs that serve as better preparation for pre-medical and other life science students, the PER group at the University of Utah has implemented Introductory Physics for Life Sciences (IPLS) labs, in which students investigate physical mechanisms in the context of biological systems. In my preliminary work with the group, I explored student sensemaking in IPLS labs, and I found that the instances of sensemaking led to students having a deeper understanding about the relationship between their data and the relevant physical systems. Furthermore, this initial analysis was instrumental in determining an appropriate theoretical framework for the proposed research. First, I noticed that students didn't often fully articulate their thinking and thus my data was limited. To ameliorate this problem, I aim to use a think-aloud protocol in which students are encouraged to share all their thoughts during the lab investigations, which will provide a more complete data set. However, a limitation of interviews is that they are not as authentic, so I find it is important to triangulate interview data with the lab observation data. Second, I observed that students were frequently comparing their model that was generated as a result of collecting and analyzing data to their existing mental model of the relevant system.

Theoretical Framework and Research Plan: For my research plan, I draw on two complementary theoretical frameworks. First, I will use the modeling framework for experimental physics, which was first developed for upper-division physics labs and functions on a recursive interaction between a student's physical system model and their measurement model [4]. Given that measurement models are less common in introductory physics, I focus on a data-based model, which captures the focus of these labs where students are predominately analyzing data; this is a similar adjustment to that which has been implemented elsewhere [5]. Second, I will utilize epistemic games, which are defined as the rules and strategies that guide inquiry; in PER, this framework has been used to study structured problem solving and knowledge development tasks [6-8]. Defining an epistemic game includes specifying the target epistemic form, constraints, entry conditions, moves within the game, and transfers to other games [9]. Based on my initial analysis, student sensemaking in labs has characteristics that parallel the form of an epistemic game, e.g., making moves toward an end goal of resolving inconsistencies. These two frameworks are complementary as the recursive elements of modeling translate to moves in a game. Each framework on its own has certain limits, but together they are more comprehensive and powerful; they will allow for a rigorous analysis of student sensemaking in inquiry-based labs. The steps of my research plan are as follows:

Step 1: I will identify all instances of sensemaking in the existing lab observation data, focusing on the classroom environment factors that contribute to the sensemaking.

Step 2: Based on identified classroom environment factors from Step 1, I will write a task-based interview protocol intended to prompt sensemaking, and I will conduct these interviews with a different population of undergraduate life-science students.
Step 3: I will first identify instances of sensemaking in the interview data. Then, using instances of sensemaking from both the observational data and interview data, I will code my data using a coding scheme developed for the different parts of the modeling process, based on the modeling framework (e.g., revision of the data-based model, comparison between models).
Step 4: With the modeling framework analysis done in Step 3, I will define sensemaking epistemic games that occur in the inquiry-based lab environment by coding the data with key features of epistemic games. Depending on the prior analysis, I will either define one epistemic game that describes general sensemaking or a number of games that each describe a different form of sensemaking.
The merger of these two datasets, as well as the combination of the modeling framework and the epistemic games framework will allow for an in-depth understanding of student sensemaking in inquiry-based physics labs.
Intellectual Merit: The inquiry-based physics labs are designed to better replicate genuine research environments, as well as encourage students' agency and scientific inquiry; as such, they are increasingly prevalent in undergraduate curricula. But yet, there is limited research on sensemaking in these labs. To address this hole in the literature, I will take a novel approach of combining two disparate theoretical frameworks, epistemic games and modeling, and two complementary data sets, to gain a holistic understanding of sensemaking in inquiry-based labs. Results will be new knowledge about sensemaking in these increasingly prevalent labs that can serve as a foundation for future lab research, along with an example of how to effectively combine disparate theoretical frameworks that can serve as a model for other scholars in the field.
Broader Impact: Understanding student sensemaking in inquiry-based labs through the epistemic game framework will have direct instructional implications. For instance, we can improve training so that TAs and instructors can recognize sensemaking epistemic games in labs and utilize them in instruction, asking questions that prompt sensemaking, rather than recollection of facts. Such instructional changes will improve undergraduate physics education, and specifically better prepare pre-medical students for medical school and other life science students for postgraduate studies and careers. Life science students often view physics as a foreign subject; supporting pre-medical students in productive sensemaking in these labs may encourage more students to continue in these labs and be successful in long term careers in the medical field [10]. While typically unintentional, physics can be a "weed-out" course for these students, so these changes intended to increase retention have the potential to improve equity and contribute toward diversifying the medical field. Beyond the effect on pre-medical students, encouraging sensemaking is a step toward teaching students that they have relevant experience that can be used in a physics setting, making physics a more accessible subject for all.
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