The intention of this exploratory study is to describe and understand what factors impact how and where environmental science graduate students gain computational knowledge and the ability to reason through statistical and computational applications in their disciplines. Students who participated in the study described their experiences in acquiring computational skills and their ability to reason through statistical computing applications related to their field.

The findings of this study are summarized in a path diagram, depicting the resources students rely on when they are faced with computational expectations beyond their ability. With the emergent themes describing where students are acquiring computational skills, the path diagram in Figure 1 reflects these changes.

First, when a graduate student encounters a statistical computing problem they pull upon the knowledge they have acquired through their undergraduate background, graduate coursework and independent research. For these participants, the elements of background that proved to be of the most help were both undergraduate statistics courses and pre-graduate research. The programming understandings that these students attributed to their graduate coursework were primarily low-level concepts, such as logical statements, using built-in R functions, adding comments to their code, and trouble-shooting error messages. These concepts were found to ony be fully understood through the use of peer interaction, as they were being implemented in their own research.

Participants voiced the importance of their experiences performing independent research as a substantial influence on their abilities to reason through and perform statistical and computational problems. Through independent research, the participants were able to play with real-world data and applications outside of what they saw in the classroom. The programming understandings informed by a student's independent research, in conjunction with peer collaboration, were described to be largely high-level concepts, such as user-defined functions, conditional statements, and loop implementation. Students described their independent research as opening the door to experiencing the unease that comes when one is asked to perform computational tasks beyond one's knowledge. In these circumstances, students stated that they turn to external resources.

In a direct connection to the participants' discomfort in asking for help from an adviser, the theme of a singular consultant emerged. These singular consultants serve as an all-knowing individual, from whom the participants have either had the “best” experiences with, where the individual spends the necessary time to explain the concepts, or the consultant has always been capable of providing the participant with an answer to their problem. These figures serve as computational mentors, where participants were both able to seek computational help and acquire new computational skills and understandings through their interactions. If due to time or physical constraints, this consultant is unavailable to the graduate student, they then turn to their peers.

Peer support was initially discussed by the participants in their interviews as a mechanism they use when their "code doesn't run" or when they are asked (or need) to do something beyond their current computational understandings. However, this theme continued to emerge as the participants worked through the computational problems, often attributing their knowledge of computational procedures to a friend or fellow graduate student helping them “do it with their data.” These peers offer an avenue for students to seek help, often voiced to be more comfortable than asking an adviser, where participants described both the fear of asking and “feeling dumb,” as well as being “brushed off” because their adviser thought they should “be able to figure out how to do it.” However, as opposed to the help participants received from their singular consultant, the students voiced the negative experiences they have encountered when seeking help from their peers, such as a peer sending them their code that they do not understand.

Lastly, the adviser plays an important role in students acquiring the computational knowledge necessary to perform applications, by both emphasizing the importance of these skills, as well as introductions (or recommendations) for students to store their data in an Access database. The ability of many participants to understand both data structures and sorting or filtering data was largely attributed to their experiences working with these types of databases. Although this study found that advisers are not often used, they are viewed as an accessible way for students to better understand the computation necessary for their independent research projects, which overall contributes to better computational understanding and skills for these students.

The second purpose of this study was to describe how these themes impact students' computational abilities across different backgrounds. The theme of research experiences, with its overall positive tone by participants, produced different experiences for students with fewer computational skills and understandings than students with more. The frustrations of simple tasks, such as subsetting data or removing NA's, were felt by the participants who had completed a bachelor's without any computational elements to their coursework, while those who were exposed to small amounts of computing in their undergraduate coursework, such as a general computer science courses, a GIS course, or experience with Access databases, were able to begin computational tasks in their research walking and not crawling.

The largest difference in the impacts of a factor between computational skill groups, came in the theme of a singular consultant. One participant, Stephanie, who entered graduate school after completing a year's work as a research assistant working in R, instead serves as the singular computational consultant for many graduate students in the Environmental Science department. She still described the theme of seeking help from her peers, predominantly her lab-mates, but, for her, the singular consultant was her adviser. Potentially due to her more substantial computational background, Stephanie voiced that she feels less of a power difference than her peers when seeking help from her adviser.

While the methodology used to determine graduate environmental science students’ experiences with statistical computing in the present study provided useful themes, it is not without its limitations. Eliciting descriptions of computational knowledge acquisition yielded varied experiences with each of the main themes, but richer data could be gathered in a future longitudinal study, following graduate students throughout their program of study. While the current study provides a window into graduate environmental science students’ computation experiences, it is important for future studies to investigate what types of computational knowledge students are in acquiring throughtout their coursework, as well as, the computational burden students experience for varying aspects of their coursework and research.

Finally, it should be noted the present study focuses on describing environmental science graduate students’ experiences in acquiring statistical computing knowledge, but not in what computational knowledge they possess. Therefore, we have learned primarily about the resources students rely on in acquiring computational knowledge expectations beyond their ability. Again, in performing a longitudinal study researchers could have the ability to isolate specific statistical computing knowledge students acquire and where it is learned.

we are able to see how both instruction and learning could be improved. It is possible that students are acquiring computational skills in the classroom, however there is also the possibility that the concepts being taught are not done so in an approachable manner for students to grasp them independent of their peers.

Statistical computing has become a foundational aspect of research in the environmental sciences. This small-scale study brings forward the experiences of graduate envrionmental science students in acquiring the computational understandings necessary to successfully perform field related statistical applications. These themes bring to light the factors students rely upon when gaining these computational understandings, and suggest the need for the integration of computational training into these programs. The present study begins the discussion of the computational knowledge necessary for research in the environmental sciences, since it provides an overview of the resources graduate students rely on in their aquistion of these understandings. To better inform faculty in these departments, a thorough investigation of both the coursework and structure of courses completed by these participants could be performed. This will allow for a discussion of how to best integrate these computational concepts, so that students leave the classroom with understandings they can implement immediately in their own research.