Overcoming Silent Classrooms: Facilitating Richer, Student-Centered Class-Wide Discussions to Support Learning Through Exposure to Multiple Perspectives and Practicing Scientific Argumentation

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Discussion is a vital component of the scientific process and dialogic learning opportunities support student learning gains and scientific epistemic learning. Discussions can improve connections between concepts and support student engagement which can increase retention in STEM programs. It has also been reported that a correlation exists between students that are more comfortable speaking in class with increased gains in learning class content, being better prepared for their classes, and earning higher grades.

Despite these benefits, generating robust, student-centered, class-wide discussion around student research in my inquiry-based research labs is challenging. Students often do not engage in class-wide discussions in meaningful ways and this dialogue tends to fall into the routine of the instructor asking questions in which often a student will provide the “right” answer then silence returns to the classroom. Actual dialogue rarely takes off.

To better facilitate more robust, student-centered dialogue during the lab meeting activity in my courses I utilized literature-based practices to help students better understand the purposes of the lab meeting activity and develop their authority in the classroom. I implemented three PDSA cycles within the context of improvement science utilizing these practices.

Each cycle utilized a unique practice (making the implicit explicit, utilizing teacher noticing, and using the “teacher-as-partner” model). I then collected data from students, using a

Qualtrics survey, and the course instructional team, using journaling and focus group interviews, to gauge the success of each practice in facilitating richer class-wide discussions.

The first intervention, utilizing explicit learning objectives seemed to drive an attitude change and generally led to higher engagement and efforts to utilize scientific arguments. The two interventions focused on authority did not seem to impact class-wide discussion in clear ways.

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Preface

This dissertation is the culmination of three years of work and I would not have made it to this point without the support of numerous people. I would like to briefly take a moment to express my gratitude for supporting me in my pursuit and accomplishment of earning the degree this document helps me to fulfill.

First, I would like to thank the many faculty that support the Ed.D. program. Many of the classes were insightful and provided meaningful concepts, tools, and/or approaches to advancing my work in applying education theory and literature into my practice. There are many faculty that make this possible, but in particular I would like to thank Dr. Tom Akiva, Dr. Jill Perry, Dr. Keith Trahan, Dr. Michael Gunzenhauser, Dr. Veena Vasudevan, Dr. Kevin Crowley, Dr. Lori Delale-O'Connor, Dr. Rachel Robertson, and especially Dr. Mary Kay Stein for the additional support in and out of the classroom.

I would also like to thank the chair of my committee, Dr. Cassie Quigley. I met Dr. Quigley at the faculty orientation, she and I actually began at Pitt at the same time. She also met with me prior to starting the program and helped me to decide that the Ed.D. program was the path for me. Finally, she supported me as I engaged with education literature, my research, and was supportive as I completed my dissertation.

I would also like to thank both Dr. Russell Clarke and Dr. Rip Correnti for serving on my committee. I appreciate the time they spared to engage in meetings, review my work, and provide insights along the way.

I would also like to provide my thanks to peers in my cohort. We began small and lost some people along the way. In this final year of the program, I would not be where I am without

the reminders of deadlines, ability to ask questions, advice provided, proof-reading, and just general encouragement of my cohort. Thank you, Karen Avery, Sue Geer, and Christa Togans!

The faculty that I work with in the Dietrich School of Arts and Sciences have been incredibly supportive throughout the process. My colleagues at work, Aimee Danley, Nancy Kaufmann, Bri Reed, Jess Robertson, Scott Stuckman, and Katie Wagner, have been engaged in my progression through this program in a variety of ways. This includes providing support and encouragement, serving as guinea pigs for assignments in my classes, providing insights and history of the Foundations of Biology program, even simply engaging in discussion with the material I have learned through this journey.

I also could not have generated this product with as much depth if it were not for the course developer and instructors of Flower Microbiome: Katie Wagner, Narthana Jeganathar Kanmanii, Bri Reed, and Jess Robertson. They put in extra time and effort to absorb the practices at the heart of my interventions, implement those practices in the labs, and help to provide the data for analysis. Without their extra effort my sample sizes would have been limited to my four sections, but instead I was able to analyze 16 sections.

Finally, I would like to thank my family. My wife, Katy, was an ever-present support and the first person to proof-read and revise my work. At times I do not think I would make it through this program while working full-time without her support and love. My kids, Logan, Liam, and Chloe had patience with me during these last few years as I attended Saturday classes or missed out on time with them while working on assignments or was writing. They provided their support in their own ways and were understanding of the time I missed out on with them.

1.0 Naming and Framing the Problem of Practice

1.1 Broader Problem Area

Discussion is a vital component of the scientific process and dialogic learning opportunities are related to student learning gains in supporting scientific epistemic learning (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Furberg & Silseth, 2022; Knight & Wood, 2005; Shemwell & Furtak, 2010). Increasing discussion improves connections between concepts and impacts engagement, increasing retention in STEM courses (Böheim et al., 2021; Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Furberg & Silseth, 2022; Gasiewski et al., 2012; Shemwell & Furtak, 2010).

1.1.1 The Dialogic Classroom Environment

A dialogic classroom is a learning environment in which open discussion occurs between teacher and students while limiting the use of traditional lecture where the teacher presents content (Knight & Wood, 2005; Lehesvuori, et al., 2013; Lyle, 2008). Dialogic classrooms are powerful supports for content learning even for students who are not particularly talkative. O'Connor et al. (2017) and Shi and Tan (2020) provide evidence that students can be engaged in class discussions as non-vocal participants and benefit. These participants are students who are engaged in the conversation (paying attention, thinking, taking notes, etc.) but do not participate in the dialogue in a vocal way. In the literature, these are termed non-vocal participants. (O'Connor et al., 2017; Shi & Tan, 2020). I acknowledge this does not follow "person-first" terminology and recognize it can be viewed as reductionist. However, I also want to acknowledge that this terminology is used by the literature.

Dialogic classrooms support learning objectives in various ways. The sharing of different perspectives and providing space where students can engage in argumentation seem to be two primary drivers that support STEM epistemic learning (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Gibbons and Cobb, 2016; Lehesvouri et al., 2013; Shemwell & Furtak, 2010Smith et al., 2011; Tabak & Baumgartner, 2004; Windschitl & Calabrese Barton, 2016).

1.1.1.1 The Dialogic Classroom Allows for the Sharing of Multiple Perceptions to Support Learning.

Dialogic teaching can function to highlight students' perspectives and put thinking "on display." The incorporation of students' previous life experiences and unique perspectives which are "made visible" using dialogic teaching can benefit peers within the classroom (Ford & Wargo, 2012; Lehesvouri et al., 2013; Smith et al., 2011; Tabak & Baumgartner, 2004; Windschitl & Calabrese Barton, 2016).

Discourse has an important role in supporting STEM learning. Gibbons and Cobb (2016) argue that it is important to give students chances to engage in class-wide discussion to "'voice out' their thinking" (p. 248) as they practice with mathematical content. Students need to experience others' perspectives and thinking to see there is more than one way to approach solving a problem or using STEM concepts. It is essential for students to have the opportunity to work through problems in small groups but then "…[build] on [their] solutions during a concluding whole-class discussion by pressing students to justify their reasoning and make connections between their own and others' solutions." (Gibbons and Cobb, 2016, p. 239).

1.1.1.2 The Dialogic Classroom Provides a Space for Students to Practice Argumentation.

Dialogic teaching with student-centered discussion aids in building meaningful connections between concepts in various ways. Argumentation is a form of dialogic teaching employed in many science classrooms that helps to build scientific reasoning and communication skills (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Shemwell & Furtak, 2010). Duschl and Osborne (2002) define scientific argumentation as “the special case when [dialogue among peers] addresses the coordination of evidence and theory to advance an explanation, a model, a prediction, or an evaluation” (p.55). Argumentation requires students to use evidence in support of their claims and be critical of the claims and support used by their peers. This form of dialogic teaching helps build critical thinking and scientific communication skills while mimicking science in practice (Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012). Thus, using argumentation in the classroom can build meaning through student practice (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Shemwell & Furtak, 2010).

1.1.2 Silent Classrooms may Stifle Learning Opportunities

I have noticed that if students do not engage or participate in class-wide discussions, the potential benefits of “putting thinking on display” and practicing with argumentation are lost. Getting students engaged and active in class-wide discussions has been a challenge I have observed and experienced in my twelve years of teaching at the college level. This has also been widely noticed amongst peers within my teaching experiences. As an instructor of undergraduate science students at the University of Pittsburgh, I have noticed a lack of robust class-wide discussion. My colleagues and I are often concerned about how low student participation in class-wide discussions might contribute to lower educational outcomes. I seek to disrupt this pattern by pursuing the question: How can I better facilitate student-centered discussions so students can learn from one another by making their thinking visible and providing a space for students to practice argumentation?

1.2 Organizational System

1.2.1 Setting: Foundations of Biology Laboratory Program

The biology department within the Dietrich School of Arts and Sciences, part of the University of Pittsburgh, created the Foundations of Biology program. This program is designed to educate students in biological science content and consists of two lecture courses and two lab courses. Students typically take the first lecture in their first semester, the second lecture with their first lab in their second semester, and finally, the second lab course in their third semester.

My problem of practice is firmly rooted in the first lab courses within the Foundations of Biology program due to their nature of teaching science through engagement with science. These lab courses are designed to deliver an authentic research experience to support undergraduates in their biological education. These authentic research experiences include several activities rich in dialogue and scientific argumentation that mirror professional scientific research.

Promotional material on the Department's webpage describes that the lab courses are designed to

> fulfill requirements of traditional biology labs while students engage in the discovery process of tackling real research. The research questions are generated

> by faculty, but approaches and methods are feasible for students participating in research for the first time. Every term is a little different from the last; coursework adapts as discoveries are made or challenges are faced in preceding semesters. Courses are designed to maximize student experience and learning while doing meaningful research. (Department of Biological Sciences, n.d.)

This lab program aims to provide students with foundational skills in biological research while engaging them in authentic research experiences. The hope is that students will engage in real research that generates meaningful data and drives student curiosity while providing education around tools to support their learning through the research process. It is a form of ambitious teaching that drives science education beyond learning static facts and processes but instead has students learn science by engaging in the actual process of scientific research (National Research Council, 2007; Windschitl & Calabrese Barton, 2016).

The National Research Council (2007) and Windschitl and Calabrese Barton (2016) posit that ambitious teaching practices focus on student construction of knowledge in the sciences through active, cognitively demanding processes. Both sources emphasize authentic investigation, using science as a process and performing experiments that center on building connections between scientific concepts (National Research Council, 2007; Windschitl and Calabrese Barton, 2016). Both sources heavily encourage the use of communication to practice using scientific language and data to support student responses (National Research Council, 2007; Windschitl and Calabrese Barton, 2016). These ambitious teaching practices rely on the process and move away from rote memorization reducing the emphasis on recalling the “right” answer (National Research Council, 2007; Windschitl and Calabrese Barton, 2016).

Several different lab offerings within each level (Foundations of Biology I laboratory and Foundations of Biology II Laboratory) offer students different research options to align with their interests (i.e. microbiology, genomics, ecology, etc.).

1.2.1.1 The Evolution of the Foundations of Biology Program.

The Foundations laboratory program has progressed through several iterations over the last few years. Changes in leadership drove most variations, but the overall driver of those changes has been improving student education. Prior to 2007 all Foundations lab courses were completely "cookbook," where students were provided with or purchased a lab manual and arrived to the lab where they followed the protocol. The experiments had predetermined outcomes which were meant to teach basic lab skills but also reinforce conceptual ideas from the related lecture course. Students were also quizzed on technical and conceptual skills to gauge their understanding. This approach was typically low cognitive demand and relied heavily on rote memorization. In 2011 a faculty member, JS, took control of the Foundations I lab course. She believed in constructivist pedagogy and thought the labs were a place where students should experience science "in action." She revamped the Foundations I lab from the traditional non-inquiry style labs to inquiry-based learning experiences. While these labs were not authentic research experiences, they were inquiry-based.

The Foundations I lab had some kinks to work out, as any new program would. Students, instructors, and prep staff complained about the increase in workloads. They were also expensive to run and required great deals of creativity to develop. However, the revisions started to catch on. Students were engaged in lab and gained valuable experiences (J. Robertson, Personal Communication, November 19, 2021). The administration worked to balance instructor workloads, lowering the number of courses required to be full-time. They also recognized the potential opportunity for labs to generate data to support research goals.

The Foundation II lab courses stayed "cookbook" for a lot longer, an additional four semesters, until the Foundations lab program's leadership expanded. As three new faculty joined the program, they recognized the success in Foundations I labs, which inspired the development of two new Foundations II labs: Pathways Over Time and Small World/Tiny Earth, to replace the non-inquiry style labs entirely. Thus increasing the reach of inquiry-based instruction to more students.

The program continued to develop, and new roles were formally created with the advent of the course developer. Course developers were tasked with developing new authentic research courses that linked to research labs and principal investigators within the department. During this time leadership changed again; NK, KB, and MW would become course developers tasked with creating authentic research experiences for students that provided laboratory education and acted as a pipeline for data to ongoing research projects across the department. Students could now engage in research practices supporting learning, while also generating real data that contributes to the advancement of science.

1.2.2 Foundations of Biology Laboratories and the Role of Class-wide Discussion

The Foundations of Biology laboratory courses are designed to mirror real-world research experiences; this includes shifting away from traditional content delivery and toward inquiry-based learning. Students in these courses do not take quizzes and homework assignments are meant to provide background knowledge to support research both technically and conceptually. Students are encouraged to work collaboratively, mirroring how professionals engage in research.

The courses are structured around central research questions instead of biological concepts covered in the lecture courses. The flow of the semester, techniques they are using, and supporting homework assignments are centered on addressing those research questions. The structure of the course is meant to mimic an authentic research experience, with the goal of supporting student learning of science by engaging in the process of conducting scientific research.

Two of the important educational components of these courses include lab meetings and journal clubs; both designed to include class-wide discussions. Lab meetings are important activities where research teams, often working with different treatments or aspects of the research, present findings to the class, probe the data, look for the emergence of trends, and communicate with each other scientifically. Journal clubs expose students to primary literature that supports their research and are meant for them to discuss the literature, interpret figures, and practice scientific communication.

Lab meetings typically begin with a brief introduction that links the goal of the meeting to the overarching research questions tied to the course. Students then break into their research teams to analyze the data set (often using Excel to generate graphical representations of their data) and discuss this data within their teams. In the directions for the lab meeting students are provided prompts to aid in their team discussions. Generally, we move to whole-class discussion hoping that students will present their unique understandings of the trends within the data. The intention is that students will present their thinking and then use data to support their conclusions. At the same time, other teams can then present their perspective or potentially pull in data from different treatments they are working with. These allow for mirroring real research meetings and allow students to learn from perspectives they may have overlooked and practice with scientific argumentation.

1.2.3 Foundations of Biology and my Problem of Practice

The Foundations of Biology Laboratory program is designed to mirror an authentic research experience and generate actual data to fuel scientific investigation. Thus, students are encouraged to think critically and practice scientific communication. The semester centers on research questions that drive the course and objectives. The lab course ultimately culminates with a poster session in which students present their research findings.

1.2.3.1 Foundations of Biology Structures that Facilitate my Problem of Practice.

As the Foundations program has evolved, the focus has primarily been to support better student learning. The emphasis of the program and course structures has become grounded in modeling actual scientific research. With this evolution, the program has shifted from traditional educational pedagogy toward ambitious and constructivist pedagogy. The course are steeped in small group work, authentic investigation through guided experimentation, and class-wide discussion and debate. The nature of this program lends itself to supporting robust, student-centered, class-wide discussion where unique perspectives can be put on display, and students can practice scientific argumentation while engaging with science.

One of the newer courses I teach (Flower Microbiome) is currently working to incorporate more class time to support student group work and increase the time available for data analysis. There is also a significant interest in my problem of practice from the course developers who strongly support my work. They are on board for me to experiment in my courses and share what I have learned with them and the instructional team to better support students.

1.2.3.2 Foundations of Biology Structures that Obstruct my Problem of Practice.

The program has evolved to a point where students are engaging in real-world research that is taking place within the department. These courses are meant to engage the students and entice them with the knowledge that their data will help drive scientific discovery. Previous labs have generated data that does not go anywhere, but here students have the chance to contribute to actual scientific discovery. For example, students in our SEA PHAGES program can discover and name previously unknown bacteriophages.

However, this is a delicate balance at times. With the new partnership between the Foundations program (with its educational goals) and research labs (with their research goals), there is a balance that can be difficult to maintain. Sometimes the labs shift a bit too far towards the goal of generating data to be used for research purposes and away from the support of student education.

One of the most common ways these issues manifest is time constraints. Often the instructor will need to make choices about how to spend class time, particularly when experiments or activities take longer than initially planned. When recouping this time, sometimes instruction is covered faster and in less depth than intended; instructors will lecture instead of using questioning and discussion as tools to gauge student understanding. Another common area instructors will cut time from as it becomes restricted is student-centered, class-wide discussion.

1.2.4 A Difficult Balance Between Educational and Research Values

The Foundations of Biology program is designed with a team of course developers and instructors that are driven to improve the education of our students. The goal of authentic inquiry and tying the development of skills to actual research was to expose students to research methodologies, support the learning of science as a process, and enhance critical thinking and scientific communication skills. "Students are doing real science. They are acting just as they would in a research lab and not only that, but they have the opportunity to complete a research project. I think it's an exciting time to be a student taking bio lab in our department" (J. Robertson, Personal Communication, November 19, 2021). Our course developers are "always willing to engage in discussions about best practices in teaching and diversity, equity, and inclusion" (J. Robertson, Personal Communication, November 19, 2021).

With the established links between these Foundations labs and the Pitt researchers, two values are being addressed; the value of Pitt student education and the department's research goals. Pitt researchers benefit from this arrangement. "[T]hough extra time is spent steering the course and envisioning what to do with the data, [they] strongly benefit from additional data to augment research, spark additional research questions, and/or serve as projects for other lab members" (J. Robertson, Personal Communication, November 19, 2021). However, at times it can feel like the course can sway too much into the realm of data generation for the principle investigator. This often manifests as time limitations during lab. Instructors can feel a pressure to complete an experiment or ensure data is being generated at the expense of having time for dialogic teaching. This may manifest as teachers providing condensed lecture-style introductions instead of engaging with students in dialogic teaching patterns and some instructors feel this can potentially result in lower educational outcomes.

1.2.5 Equity and Justice

Our department has taken strides toward recognizing equity and justice. Much of this work stems from the social unrest occurring after the events of 2020, such as the murders of George

Floyd and Breonna Taylor. Several wide-spread departmental initiatives have been to increase faculty inclusion and change our practice to support equity and inclusion within our classrooms.

> With our Foundations program we believe that the research-based nature opens doors for under-represented students as it provides that first research experience that can go on their resumés. I think it also helps to have people on the team (and I can think of a few people like this on our team) who are thinking about students from less privileged backgrounds and are making sure that those students are being supported" (J. Robertson, Personal Communication, November 19, 2021).

Social justice themes have been built into some of our assignments, for example environmental racism ties into our Duckweed Survivor course blog post assignment. A "fall walk" in Flower Microbiome links urban ecology and redlining to highlight intersections between systemic racism and biodiversity. "[These assignments represent] a huge leap forward in our program as we recognize injustices and weave them into the narrative of our courses. I think there's still a long way to go to move towards equity, but the switch to research-based courses is a huge leap forward and shouldn't be overlooked" (J. Robertson, Personal Communication, November 19, 2021).

1.3 Stakeholders

1.3.1 The Users Involved with and Impacted by my Problem of Practice

My problem of practice is strongly rooted in classroom activities and centered in constructivist pedagogy. Therefore, the primary groups involved are students and faculty. In my place of practice the faculty group is composed of two distinct groups.

The Foundations of Biology lab program is heavily structured and consists of two groups of faculty to support the program. Course developers are content designers. They work with research labs and principal investigators across our department to develop authentic research lab courses that provide data to the research labs while educating freshman/sophomore students in inquiry-based research labs. They design the course structure, lab activities, and learning activities, while also serving as course administrators.

The next group of faculty are the course instructors who serve as the in-class teachers of these courses. They instruct students and guide them through the research process. They are responsible for instructing students in their sections, delivering educational concepts that tie into the research projects, grading student work, and section administration (managing learning management software, student disability accommodations, etc.).

Outside of the faculty, students are the other user group involved in my problem of practice. They are engaged in the learning process and the individuals participating in the research and instruction. This is a large group and is not homogenous; there are important divisions and groupings within this category of users.

1.3.1.1 Course Developers.

My problem of practice impacts the course developers as they are engaged in designing course content to be engaging and educationally rewarding to students within these courses. The Foundations labs include lab meetings and journal club activities that are heavily rooted in class-wide discussion. The course developers have included these activities to support critical thinking while practicing interpreting and communicating scientific data.

Course developers often include two activities heavily centered on class-wide discussion: lab meetings and journal clubs. The goal of the lab meetings is to provide students with opportunities to engage in data analysis and "talk about data, having different perspectives [allowing for] a deeper analysis, and just providing an opportunity for communicating with data" (K. Wagner, personal communication, October 20, 2021).

The course developers also need to balance time within the course between educational pedagogy, hands-on research technique, and the generation of useable data that funnels back to the research labs within the department. Course developers need to balance those demands within the framework of course structure and weekly two hour and 50 minute lab periods. This need to balance can shorten time for lab meetings and student discussion resulting in a feeling of never being "100% satisfied [with the discussions] but feel like students are [still] better off after discussion" (K. Wagner, personal communication, October 20, 2021).

1.3.1.2 Course Instructors.

The course instructors are heavily tied to my problem of practice as they are the in-class facilitators of class-wide discussions during pre-lab discussions, lab meetings, and journal clubs. They need to balance issues of supporting students' learning, keeping conversations on task while building conceptual linkages, addressing student misconceptions, and maintaining equity within the class-wide discussion.

Instructors also need to maintain the pacing of class time. The course schedule and lab period limit the time in which class-wide discussion can occur. Hands-on, wet-lab procedures are the emphasis of the course. Therefore, instructors need to balance educational goals with the research goals of the course.

1.3.1.3 Students.

Students are impacted heavily by my problem of practice as well; they are both the recipients of the benefits as well as a large cause of the problem. Class-wide discussions aim to put student thinking on display for concept building and to practice scientific communication. Specifically, in lab meetings the hope is that students engage in scientific argumentation, making claims and supporting those claims with data, analyzing claims and the data used by others, supporting/rejecting claims based on data not fitting, and arriving at a consensus that is supported by the data available. When discussion is not robust it fails to deliver educational outcomes.

Students are also the drivers of my problem of practice. Their limited engagement and unwillingness to discuss and present their ideas, perspectives, and arguments reduce the educational outcomes of these types of activities centered on data analysis and scientific communication.

1.3.2 Relationships Between Users

There are clear power dynamics at play between and within user groups. The course developers are content developers and establish the course schedule and objectives for the course and each lab period. Their schedule and defined goals need to be maintained and met by the instructional team. This creates clear time issues within the lab period and one of the places time is most easily lost is the time dedicated to class-wide discussion to support educational goals. The hands-on lab procedures are emphasized and can only occur within lab spaces during the lab period.

Instructors have some leeway within their sections but are bound to the larger course objectives and schedules. Within this flexibility, as little as it can be at times, instructors can choose to emphasize/deemphasize topics and activities as they feel best supports their students' learning. Thus, some instructors will drop minor practice activities and adjust direct instruction time, data analysis time, and discussion time as needed within their individual sections. These decisions are discussed within instructor meetings and can influence how other instructors run their sections and influence the course developers to amend the schedule.

Instructors directly impact students as the instructors are immediately responsible for the educational delivery and instruction within their lab periods. Instructors are also the ones who assess and grade students in their lab performance. Thus, students may not sense much perceived authority/power within the lab course. Students, however have substantial control over the dynamics within class-wide discussion.

Students create much of the social environment within the classroom despite the intent of the instructor. Students' perceptions of their peers often drive their willingness to engage and participate in class-wide discussion (Sidelinger & Booth-Butterfield, 2013). If there is a strong sense of judgment from peers, students are not willing to risk being wrong in front of the class. Additionally, this social interaction can be amplified within and across different social groups of students. Many female students have told their instructor that "they do not want to look dumb" in front of the class and would not participate in class-wide discussion (J. Koehl, personal communication, October 22, 2021).

Another dynamic between groups (students and teachers) is centered on authority. Students view their teacher as an authority within the subject and do not feel justified in presenting their perspective, which may be incorrect, in front of authority within the subject (Lyle, 2008; Tabak & Baumgartner, 2004). Instructors need to recognize this dynamic, work to relinquish their authority, and foster students' sense of authority in their learning/research.

1.3.3 Whose Perspective am I missing? How can I gain that Perspective?

I feel that the most significant perspective I am missing is from the students and several subgroupings within the student group. I followed up with students upon the completion of my courses but respondents tend to be students that were typically more engaged and willing to participate. Quiet or disengaged students usually have not kept in touch or responded to requests for information. There is also a power dynamic that keeps students currently enrolled from being open about their willingness/hesitation to participate in class-wide discussion. This is a common theme in empathy interviews of various faculty. My empathy interviews included course developers, instructors, and faculty outside of the Foundations program and even the University of Pittsburgh.

The majority of my understanding of the student perspective is informed by literature with some limited information coming from previous students (both my own and students who spoke with faculty I interviewed). One idea to improve my understanding of student perspective is to use anonymous questionnaires (such as Qualtrics) after class-wide discussions, a short survey that tries to gauge their perspective and feelings about the successes/challenges associated with lab meetings and journal clubs.

1.4 Statement of the Problem of Practice

How can I foster a welcoming learning environment for all students, tap into the social dynamics, and promote students' sense of authority within my lab sections to facilitate robust, class-wide, and student-centered discussion?

1.4.1 Inquiry Questions

1)What practices can I employ to make my classroom feel like a welcome environment that will invite students to engage in class-wide discussions?

2)How can I help students to recognize and empower their authority within the classroom to drive more engagement in class-wide discussion?

3)How can I learn to recognize the social dynamics at play in my classroom and use them to foster an openness to engage in class-wide discussion?

1.5 Review of Supporting Knowledge

1.5.1 What Constitutes Dialogic Teaching and Learning in Undergraduate Science Courses?

1.5.1.1 Constructivist Pedagogy.

Windschitl and Calabrese Barton (2016) define ambitious teaching as pedagogy focused on creating opportunities for students to learn science through the process of performing science, not as memorization or treating science as a collection of static facts describing the natural world and phenomena. This can also be referred to as constructivist pedagogy. In this style of teaching, students work to construct knowledge by practicing tools or engaging in the process itself (Cartier et al., 2013; Lehesvuori et al., 2013; Lyle, 2008). There are several tools, such as inquiry-based learning, performing unscripted experimentation, dialogic teaching, etc., available in the sciences to support constructivist learning and ambitious teaching (Cartier et al., 2013; Lehesvuori et al., 2013; Tekkumru-Kisa et al., 2015; Weiss et al., 2003; Windschitl & Calabrese Barton, 2016).

Knight and Wood (2005) conducted experiments measuring outcomes of interactive, constructivist structured learning against traditional lecture courses in upper-level developmental biology courses. In the constructivist-themed classrooms, there was less traditional lecture, increased student participation, collaborative problem-solving sessions, and more in-class assessment (Knight & Wood, 2005). The first experiment compared two sections (traditional versus constructivist) that ran concurrently while the second collected data from the additional implementation of the constructivist structured course to replicate the findings (Knight & Wood, 2005). Both experiments found that students performed better when engaged in these learning activities; in-class participation, preparation for the course, and performance on exams was improved by constructivist restructuring of the course (Knight & Wood, 2005).

Weiss et al. (2003) observed 364 math and science K -12 lessons across the U.S. They ranked the effectiveness of the lessons, reporting that teacher-centered lessons were rarely effective (Weiss et al., 2003). In contrast, lessons that employed constructivist activities that were more student-centered tended to be more effective, arguing that there were high degrees of questioning, rigor, and respect in these math/science lessons (Weiss et al., 2003). This questioning took place in spaces that foster learning, ensured equal access, used questioning to more profound understanding, and aided in content mastery (Weiss et al., 2013). However, the forms of communication within science classrooms can vary in structure and cognitive demand.

Tekkumru-Kisa et al. (2015) focused on student engagement and "instructional tasks;" the part of a lesson where students execute the activity at the center of instruction. They focused on the cognitive demand of various activities commonly encountered within the science classroom, defining cognitive demand as the "kind and level of thinking demanded of students to successfully engage with a task" (Tekkumru-Kisa et al., 2015, p. 666). Tasks such as rote memorization, recitation, or following scripted investigations were classified as having low cognitive demand (Tekkumru-Kisa et al., 2015). While highly scaffolded, guided inquiry and unscripted scientific investigation were of moderate cognitive demand, the authentic investigation had the highest demand (Tekkumru-Kisa et al., 2015). Highly demanding cognitive activities tend to support higher gains in student mastery of scientific content (Cartier et al., 2013; Lehesvuori et al., 2013; Tekkumru-Kisa et al., 2015).

Constructivist pedagogy is a well-documented approach to supporting student learning across many disciplines but is particularly effective within STEM courses (Cartier et al., 2013;

Lehesvuori et al., 2013; Tekkumru-Kisa et al., 2015; Weiss et al., 2003; Windschitl & Calabrese Barton, 2016). Activities within constructivist pedagogy feature, but are not limited to, guided investigation, authentic investigation, and student-centered discussion. The focus of this review is dialogic teaching: utilizing student-centered dialogue to drive the learning and appropriation of scientific tools through class-wide discussion.

1.5.1.2 Dialogic Teaching; using Argumentation to Build Scientific Reasoning.

There are a variety of forms of dialogue that occur within the classroom. In most science classrooms discussion tends to follow a triadic dialogue - the teacher asks a question of the class, a single student responds, and the teacher evaluates the student's response (Lehesvuori et al., 2013; Tabak & Baumgartner, 2004). This form is frequently referred to in the literature as an IRE pattern; the teacher will **I**nitiate the questioning, a student will **R**espond, and the teacher then **E**valuates the response, essentially an oral assessment of basic understanding (Christodoulou & Osborne, 2014; Lyle, 2008). This type of teacher-student interaction tends to be of low cognitive demand and very similar to rote memorization (Lehesvuori et al, 2013; Lyle, 2008; Tekkumru-Kisa et al., 2015). To support the goals of constructivist pedagogy, questioning needs to be carried out in ways that assess understanding and conceptual linkages, not simple recall questions (Weiss et al., 2003).

Argumentation is a form of dialogic teaching employed in many science classrooms that helps to build scientific reasoning and communication skills (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Shemwell & Furtak, 2010). Duschl and Osborne (2002) define scientific argumentation as "the special case when [dialogue among peers] addresses the coordination of evidence and theory to advance an explanation, a model, a prediction, or an evaluation" (p.55). Argumentation utilizes the need for students to use evidence to support their claims and be critical of the claims and support used by their peers. This form of dialogic teaching helps to build critical thinking and scientific communication skills while mimicking science in practice (Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012).

Duschl and Osborne (2002) present a review discussing the history of argumentation in science education and its lack of implementation despite 50 years of education research emphasizing the use of this tool. They argue that tasks supporting social construction of knowledge, that expose student thinking, and enable critical evaluation by the teacher and peers improve student learning (Duschl & Osborne, 2002). Duschl and Osborne (2002) argue that student learning is hindered when structures enabling and supporting dialogical argumentation are absent; stating "teaching science as a process of enquiry without the opportunity to engage in argumentation, the construction of explanations and the evaluation of evidence is to fail to represent a core component of the nature of science or to establish a site for developing student understanding" (p. 41).

Christodoulou and Osborne (2014) present a case study centered on a single participant of a more comprehensive study: a 2-year professional development study for secondary science teachers across 4 schools aimed at utilizing argumentation within science classrooms in grades 7 through 11. They found that when implemented well in the classroom, argumentation (students' construction, justification, and evaluation of knowledge claims) increased student understanding and supported epistemic learning (Christodoulou & Osborne 2014). This approach highlights that argumentation is a useful tool for increasing critical understandings of science and using scientific concepts to construct arguments presented to the class, a fundamental skill in science.

Ford and Wargo (2012) investigate the use of argumentation in a high school evolutionary biology class and claim that utilizing argumentation is vital to science education to support two epistemic goals: learning to argue and arguing to learn. These goals are vital for students to truly understand science as an investigative process. Ford and Wargo (2012) maintain that these two goals are often contrary to each other, as there needs to be some basic understanding of content for effective argument before one can engage in learning to argue and arguing to learn. However, with the implementation of useful scaffolding students can be supported in the early stages of concept building and transitioning into learning to argue (Ford & Wargo, 2012). Once these skills become more developed teachers, can move into arguing to learn by providing students with opportunities to "explain natural phenomena, being aware that it is one [explanation] among a multiplicity of alternatives, and that the scientific idea is superior to alternatives based upon a scientific evaluation which involves relating it to evidence" (Ford & Wargo, 2012, p. 369).

In another review article, Ford (2008) makes the case that argumentation supports student learning goals through both the construction and critique of argument. Most of the previous articles leaned into the construction of arguments as building scientific reasoning and communication skill whereas this article suggests that the critique of peers' arguments is just as important and can aid in the development of authority in dialogue (Ford, 2008). This evaluation of others' claims forces students to utilize scientific concepts and the evaluation of data used in the claim. It also grants them the ability to make counterarguments or rejections, thus increasing epistemic understanding and creating a sense of authority (Duschl & Osborne, 2002; Ford, 2008).

1.5.1.3 Dialogic Teaching makes Thinking Visible

Dialogic teaching with student-centered discussion aids in building meaningful connections between concepts in various ways. Using argumentation in the classroom can build meaning through practice (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Shemwell & Furtak, 2010). Basic dialogic teaching can also function to highlight students' perspectives and put thinking "on display." The incorporation of students' previous life experiences and unique perspectives which are "made visible" using dialogic teaching can be of benefit to peers within the classroom (Ford & Wargo, 2012; Furberg & Silseth, 2022, Lehesvouri et al., 2013; Smith et al., 2011; Tabak & Baumgartner, 2004; Windschitl & Calabrese Barton, 2016).

Additionally, the dialogic classroom provides a rich collection of student ideas and perspectives for the class to then reason with and work through (Furberg & Silseth, 2022). Teachers are central in supporting these additional conversations by utilizing follow-up questions to have students "share their reasoning, build on each other's ideas, and acknowledge their contributions" (Furberg & Silseth, 2022, p. 281).

Windschitl and Calabrese Barton (2016) focused on eliciting student ideas as students come to class with a lot of real-world experience, knowledge, and skills though they are underdeveloped and incomplete. By utilizing student's prior knowledge and engaging them, instructors can help to foster the development of deeper scientific understanding and reasoning through class-wide discussion (Windschitl & Calabrese Barton, 2016).

Lehesvuori et al. (2013) analyzed classroom interactions relating to student learning outcomes. This research focused on twenty-five different ninth-grade science classrooms across Finland. The study followed two teachers that utilized dialogic teaching in a whole class context whereas other classrooms were eliminated from the study due to a lack of dialogue as an instructional tool or small group work being utilized more heavily (Lehesvuori et al. 2013). Of the two teachers that were followed, researchers concluded that the students of the teacher who allowed for more student-centered dialogue tended to hit educational goals more effectively (Lehesvuori et al. 2013). Lehesvuori et al. (2013) note the observed trend that in most science classes, discussion tends to follow a triadic dialogue noting that this form of classroom communication is low in cognitive demand and functions similarly to rote memorization. Student-centered discussion tends to better support student learning by allowing students to share their thinking and learn from those unique perspectives (Lehesvuori et al. 2013).

Smith et al. (2011) investigated the use of several techniques in a college genetics course (both majors and non-majors) on student understanding. They found that most students tended to benefit from a combination of peer discussion and instructor explanation (Smith et al. 2011). These gains were observed in all groups (designated strong, medium, or weak based on earlier quiz scores) and the benefits seemed to come from sharing peer insight and having those insights framed by instructor explanation (Smith et al., 2001). Smith et al. (2001) noted that “strong students learned more in interactive courses, possibly because they were cementing their own understanding by helping their peers” (p. 61). This study focused on how small groups help convey the idea that peers can learn from each other but there needs to be time dedicated to peer discussion.

Finally, discussion allows for reasoning to be made visible. As Tabak and Baumgarter (2004) state “when reasoning processes are invisible, it not only precludes them from being an object of observation, which is central to learning but it also mystifies the process” (p. 419). Students sharing their insights, arguments, and reasoning can create opportunities to dig deeper into the ideas, highlight thinking processes/perspectives, and correct inaccuracies/misunderstandings, but this is not possible if discussion does not occur. As Ford and Wargo (2012) state, “by considering a multiplicity of ideas students can become better able to think with the idea being learned” (p. 371). Class-wide conversation has the power to “project student thinking into a social, meta-cognitive workspace where it can be examined and shaped” (Shemwell & Furtak, 2010, p. 223).

1.5.1.4 Resistance to Dialogic Teaching.

Despite the benefits of constructivist teaching, dialogic teaching, and the use of argumentation in the classroom, there is resistance by students to engage in these types of activities (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Shi & Tan, 2020; Sidelinger & Booth-Butterfield, 2010; Tabak & Baumgartner, 2004; White, 2011).

Root Cause Analysis. While considering potential causes limiting student engagement during class-wide discussions, several patterns emerged in the literature and interviews with course developers and instructors. These causes are potential places that warrant further investigation. They may also act as places where change could be implemented to support more robust, student-centered discussion to better support learning goals in the use of class-wide discussion as a pedagogical tool.

O'Connor et al. (2017) report that many college classes do not use discussion often since engaging students in meaningful dialogue is challenging despite theoretical and documented gains. Sidelinger and Booth-Butterfield (2010) reported that many college instructors switch back to traditional lectures because of a lack of student response. Ramsey and Baeth (2013) found that courses that incorporated constructivist activities designed to increase engagement in introductory science courses only had success rates of 50%, with similar low success rates in other studies cited.

Reflecting on some of the common themes across these studies, other research, and interviews with faculty, there were several major areas that impacted student willingness to engage in discussion. These emerged from a root cause analysis and contributed to the development of an Ishikawa or Fishbone diagram (Appendix A).

Several significant causes are linked to the instructor of a course, including the instructor's training and pedagogy, issues around equity and inclusion, teachers limiting the development of student authority, and pressure on teachers to balance learning in the classroom. Instructors must carefully think about, design, and implement constructivist activities with the students as the focus (Sidelinger & Booth-Butterfield 2010; Tanner 2013). Numerous instructors I work with have good intentions, engage in professional development, and strive to be good teachers, but many college instructors are traditionally not formally trained as teachers (Hammerness et al., 2007).

Teachers need to be mindful of their authority as they link students' content into the discussion. Bleicher et al. (2003) followed a high school chemistry course and noted that the teacher in this course utilized class-wide discussion as an instructional tool but did not yield authority, therefore hindering potential gains. They noted instances where the instructor controlled the flow of class discussion, repeated student responses, stressed key vocabulary, and even interrupted student speakers (Bleicher et al. 2003). These tactics stifled student discussion and limited opportunities for students to talk about science and think scientifically (Bleicher et al. 2003).

Another consideration is equity in the classroom. O'Connor et al. (2017) reported that instructors struggled to manage in-class discussion for three primary reasons: keeping the conversations coherent, in context of conceptual material, and equitable. Instructors wanted to ensure equity across their students and ensure everyone was getting a turn (O'Connor et al., 2017). This can be a challenge when some students feel a better sense of belonging and come from different backgrounds that better equip them to think through content faster or have more confidence to speak up (Tanner, 2013). This can lead to the omission of other students, compounding their sense of not belonging (Tanner, 2013).

Differences in culture and recognition of language cues can be a source of frustration for students from minoritized backgrounds during discussion-based activities when instructors are not culturally and contextually sensitive (Delpit, 1988, Gay, 2002, Shi & Tan, 2020). Without cultural reference there is often confusion over what is being asked of students; there is a need for explicit language to define the approach and a building skill (Delpit, 1988, Gay, 2002, Shi & Tan, 2020). Delpit (1988) also notes that professionals generally lack respect for minoritized groups and their experiences when planning, constructing, and implementing curricula around ambitious teaching including class-wide discussions, further silencing minoritized voices.

The next section of major causes centers on the student. Several common themes emerge regarding student preparation for class, social systems within the learning environment that impact student participation, students not recognizing their authority in constructivist teaching, and student disengagement.

One of my suspicions is a lack of preparedness of the students; they do not read materials or have data prepared for lab meetings or journal club meetings. There are several likely reasons for this lack of preparation. One reason is that students do not have a duty-driven ethical system pushing them to complete work on time and do what is needed to pass a course because it is what is correct (Ramsey & Baeth, 2013). Ramsey and Baeth (2013) interviewed students and they found that many students in introductory courses stated that completing course work was secondary to other activities, such as "emotional attachment to friends, responsibility to family, over-commitment at work, and failure to use study-time efficiently" (p. 28). If students lack this ethical sense of responsibility, they often tend to fail STEM courses, even when constructivist assignments are built in and students are enthusiastic about the content (Ramsey & Baeth, 2013).

Another issue linked to not being prepared to engage in constructivist activities in the Foundations lab is having difficulty balancing the demands of this lab with the workload of their other classes. I suspect that this lab, which is only 1-credit, is often skipped as students prioritize their success in 3-credit courses.

A lack of explicit instruction could also limit students' preparation to engage in class-wide discussion. A lot of information in instruction is transferred to students implicitly, or at least there is hope that it is transferred to students. Many instructors know what lab meetings are based on our experiences in research. I realized that as we teach and set up this activity, we are often not explicit about how lab meetings work or explain their purpose. With students lacking exposure to this type of activity and instructors not being clear, students cannot know what these discussions "should" look like. This lack of explicit framing limits their ability to prepare but can also limit their participation as they do not know how to participate in meaningful ways. Despite a potential link to instructor pedagogy, this implicit instruction leads to student resistance to participation due to a lack of preparation for discussion.

Another major cause is being nervous about speaking in front of the class. There could be anxiety about being "wrong" in front of their peers and instructor. Sidelinger and Booth-Butterfield (2013) reported college students' participation and willingness to speak in class are based largely on perceptions of friendliness and the support of their peers. Student perception of the instructor was important but less than perceptions of peers (Sidelinger & Booth-Butterfield, 2010). Yet, instructors need to contribute to the classroom environment in many ways to support the willingness of students to speak in class (Sidelinger & Booth-Butterfield, 2010). There was also a correlation to student preparedness; if willingness to talk in class was high, students also tended to complete assigned readings and outside work more diligently (Sidelinger & Booth-Butterfield, 2010).

To expand on Sidelinger and Booth-Butterfield's (2010) ideas, Fassinger (1997) addresses the idea that classes constitute groups and that we should view the classroom through the lens of sociology. Fassinger (1997) surveyed students and faculty to better understand the social interactions occurring and how those related to students' willingness to engage in class and contribute to class-wide discussions. This approach found, similarly to Sidelinger and Booth-Butterfield (2010), that social interactions between students had a significant impact on course dynamics and the willingness of students to engage in class-wide discussion (Fassinger, 1997).

The shift from traditional lecture to more student-centered learning, including activities such as student-centered discussion, can be problematic. Students resist the transition to active learning and attempt to keep the teacher as the source of knowledge and authority in the classroom (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak and Baumgartner, 2004). In most science classrooms discussion tends to follow a triadic dialogue - the teacher asks a question of the class, a single student responds, and the teacher evaluates the student's response (Alkhouri et al., 2021; Lehesvuori et al., 2013; Tabak & Baumgartner, 2004). Students' previous exposure to triadic dialogue may limit their perceived authority to engage in true dialogic teaching (Lehesvuori et al., 2013; Lyle, 2008; Tabak & Baumgartner, 2004). This may form the norm in which students lack the authority to drive the conversation or question the authority within the classroom (teacher or content that the teacher represents) (Lyle, 2008; Tabak & Baumgartner, 2004).

As I constructed my root cause diagram (Appendix A), I saw several interconnected threads within the major groupings centered on the student. The primary heading describing student disengagement could be influenced by many of the issues described above, such as not feeling a sense of belonging to the class or using a relativistic ethic system to decide the challenge is not worth the effort (Ramsey & Baeth, 2013; O'Connor et al., 2017; Tanner, 2013). These issues could cause a student to become disengaged and unwilling to communicate in discussion. However, I decided diengagement should be its own root cause as even successful students can become disengaged in today's world with numerous electronic distractions available.

Similarly, I have encountered many students who approach lab topics with disdain when they are not interested in the specific research topic or feel the course will not further their career goal - they are solely in the course to complete a requirement. For example, when I have students who plan to move into a pre-professional track in healthcare, they have limited interest in ecological topics or research. In these cases, I try to emphasize the applicable skill-building (learning to approach primary literature and scientific communication) even if the research is not what they consider to be of professional importance.

Finally, colleges may not be as student-centered as they wish to be. Sidelinger and Booth-Butterfield (2010) reported that post-secondary schools are not indeed student-centered in several ways; a central focus on research at the expense of traditional education, educators may lack formal education training but are experts in their fields, and administrators shifting to more non-permanent positions reducing capacity in long-term relationships between faculty and students (Hammerness et al., 2007; Sidelinger & Booth-Butterfield, 2010). These issues can all lead to difficult relationships between learners and their teachers. Students engage in education and learning is their responsibility. Still, they need support systems to aid in their learning, prepare for class, make them want to stick with something challenging, and ultimately feel comfortable to speak up during a conversation, even to simply ask a question.

As observed during the root cause analysis, resistance stems from a few sources but there appear to be two central issues: authority within the classroom and cultural differences (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Shi and Tan, 2020; Sidelinger & Booth-Butterfield, 2010; Tabak & Baumgartner, 2004; White, 2011). Students resist the transition to active learning and attempt to keep the teacher as the source of knowledge and authority in the classroom (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak and Baumgartner, 2004). There are also issues centered around inclusivity and creating a welcome space making students feel comfortable engaging in dialogic practices (Clarke et al., 2016; O'Connor et al., 2017; Shi & Tan, 2020; Sidelinger & Booth-Butterfield, 2010; White, 2011).

Teachers as the classroom authority. Students' previous exposure to triadic dialogue may limit their perceived authority to engage in true dialogic teaching (Lehesvuori et al, 2013; Lyle, 2008; Tabak & Baumgartner, 2004; Windschitl & Calabrese Barton, 2016). This may form the basis of the norm that students lack the authority to drive the conversation or question the authority within the classroom (Lyle, 2008; Tabak & Baumgartner, 2004).

Inclusivity and the Classroom as a Welcoming Space. O'Connor et al. (2017) reported that instructors struggled to manage in-class discussion for three primary reasons: keeping the conversations coherent, in context of conceptual material, and equitable. Instructors wanted to ensure equity across their students and ensure everyone was getting a turn (O'Connor et al., 2017). This can be a challenge when certain students feel a better sense of belonging and/or come from different backgrounds that equip them to think through the content faster or have more confidence to speak up (Tanner, 2013; White, 2011). This can then lead to omission of other students compounding to their sense of not belonging (Tanner, 2013).

Differences in race, class, and culture can drive differences in the recognition of language cues and norms within the classroom. This can be a source of frustration for students from minoritized backgrounds during activities that support constructivist pedagogy when instructors are not culturally and contextually sensitive (Delpit, 1988). Without a shared cultural reference there is often confusion over what is being asked of students; there is a need for explicit language to define the approach and building of skills during constructivist activities (Delpit, 1988). Delpit (1988) also notes many professionals have a general lack of respect for minoritized groups and their experiences when planning, constructing, and implementing curricula around ambitious teaching; further silencing minoritized voices.

However, there are scholars that have argued that by engaging in constructivist activities and utilizing students' preconceptions, experiences, and ideas about science, students can become more engaged in the subject (Furberg & Silseth, 2022). These "student resources" are the basis for reconstructing and framing their previous experiences in new ways. This approach must be done in a clear and intentional way but can "establish profound, inclusive, and authentic learning environments in science classrooms" (Furberg & Silseth, 2022, p. 279). One issue is that many students experience class-wide discussions as "cognitively, socially, or emotionally challenging… [as] the classroom climate may be experienced as exclusive" (Furberg & Silseth, 2022, p. 281). If there are not inherent participant structures or the participant structures are not familiar this may limit the willingness of students to participate (Furberg & Silseth, 2022).

White (2011) followed four first-generation students from minoritized backgrounds, students on academic probation for a semester. The researcher interviewed these students and specifically focused on requirements of participation in their courses (White, 2011). White (2011) reported that a failure to participate by these students was not reflective of "disrespect for the teacher or the class, a disinterest in subject matter, or apathy in general" (p. 250) but may have been limited due to issues of culture. White (2011) argued that minoritized students may lack codes of power to express themselves appropriately during class-wide discourse and thus feel unwelcome to participate.

Shi and Tan (2020) investigated non-vocal participation and challenged the assumption that vocal participants are the only students engaged and benefitting from class-wide discussion. They report a variety of factors that limit participation, tying into cultural differences and providing a number of examples, including "Chinese students remain[ing] silent in classroom discussions to show their respect to the teacher (as a symbol of authority)" (Shi & Tan, 2020, p. 252). These cultural differences may be an important factor that drives non-vocal participation in class-wide discussions (Shi & Tan, 2020; White 2011). Students who are engaged in discussion but are not contributing vocally should not be penalized and the authors make suggestions for creating more inclusive learning environments (Shi & Tan, 2020).

1.5.1.5 Conclusions Regarding Dialogic Teaching.

Dialogic teaching is a powerful tool within constructivist pedagogy that can help to build deeper understanding in STEM students. It can help to build scientific reasoning, create conceptual linkages, and generally enrich the learning process. Class-wide dialogue structured around argumentation, where students must support their conclusions/claims with data and critically examine peer arguments, helps to build scientific reasoning and communication skills while engaging students in dialogue typical of professional scientists. Class-wide dialogue also acts to showcase student thought and build conceptual linkages. The "visualization" of student thinking and assemblage of ideas through discussion can highlight peer thinking and facilitate learning amongst the class. Despite benefits of dialogic teaching there is resistance by students to engage in robust discussion therefore limiting the potential gains that could be made in scientific reasoning and communication.

1.5.2 What are Principles or Promising Approaches for Facilitating Discussion?

1.5.2.1 Providing Students with Explicit Goals and Expectations.

As discussed previously, one reason in which students may not participate in class-wide discussions is that they are unclear of the expectations or reasons for doing so. Howell et al. (2003) stress that while professors "may have taught [a] course many times and [are] intimately familiar with the contents … it is the students' first time through." (p. 829). The instructors teaching these lab courses have all engaged in lab meetings and are well aware of their structure and the purposes for engaging.

If instructors shift to an explicit approach, explaining the purposes for engaging in both the context of advancing the research and the students learning it may help students to see the value of the activity thus increasing their willingness to participate. When "objectives are explicitly defined … students can be more responsible for directing their own learning" (Howell et al., 2003, p. 833). Additionally, Martin and Mahat (2017) argue that explicit communication of learning objectives provide students "clear information about what the expectations are for their learning" (p. 9).

Students may be more willing to engage in the lab meeting activity and see the value of the exercise if it is framed clearly and explicitly as a space to engage in discussion about their data to more deeply understand it, thus mirroring what professional researchers do while in the context of true, scientific investigation. This could also foster students' sense of scientific identity.

Additionally, students may see an educational benefit to participation if we introduce the educational goals associated with the lab meeting activity as a place to experience other perspectives, learn from their peers, and to begin practicing with scientific argumentation to develop and enhance their science communication skills. As Rothgeb (2022) states, clear learning objectives "encourage students to become active learners, and their interactions with others push them not only to delve more deeply into course material, but also to consider alternative ways to understand course material as they are exposed to additional arguments and points of view during their discussions" (p.67).

Using explicit framing when the lab meeting activity is first introduced and clearly detailing the learning goals and expectations may act as a guide for students to see meaning and educational benefit to engaging with and participating in all parts of the lab meeting.

1.5.2.2 Creating a Welcome Classroom Environment.

There are numerous factors that impact robust, class-wide discussion but a recurring theme encountered in the literature centers on the classroom being a welcoming environment. Sidelinger and Booth-Butterfield (2010) report that peer interactions are an important driver of students' willingness to engage in class-wide discussion. Despite the importance of peer social interactions instructors can and should create a welcoming environment to help foster the willingness to engage (Gasiewski et al., 2012; O'Connor et al., 2017; Sidelinger & Booth-Butterfield, 2010; Shi & Tan, 2020; Tanner, 2013; Weiss et al., 2003; White, 2011). This environment should also be centered on inclusivity, ensuring all feel welcome and their unique perspectives are respected and encouraged (Delpit, 1988; O'Connor et al., 2017; Shi & Tan, 2020; Sidelinger & Booth-Butterfield, 2010; Tanner, 2013; White, 2011).

Gasiewski et al. (2012) investigated retention in introductory STEM courses and utilized pre- and post- tests and faculty surveys to assess the impacts of course engagement across 15 university campuses and multiple introductory STEM courses. The researchers found that retention and student engagement increased when courses were designed to be engaging and included aspects of constructivist pedagogy, such as student-centered discussion (Gasiewski et al. 2012). Environments where instructors were open to student questions/discussion and recognized explicitly their role in helping students succeed tended to increase student feelings of comfort in asking questions in class, seeking out tutoring, attending supplemental instruction sessions, and collaborating with other students (Gasiewski et al. 2012).

Sidelinger and Booth-Butterfield (2010) reported that student-connectedness was a primary predictor of student engagement in class, willingness to speak, and completing work outside of class. Their work compared undergraduate students (all levels) across a variety of courses through surveys (Sidelinger & Booth-Butterfield, 2010). Their findings indicate student connectedness is an important factor that drives a willingness to participate in class-wide discussion (Sidelinger & Booth-Butterfield, 2010). They also discuss that the classroom environment arises as a co-construct between instructor and students, and despite having a limited role in student perception the instructor can aid in creating this environment (Sidelinger & Booth-Butterfield, 2010).

Expanding on Sidelinger and Booth-Butterfield's (2010) ideas, Fassinger (1997) addresses the ideas that classes constitute groups, and we should view the classroom through the lens of sociology. Fassinger (1997) surveyed students and faculty to better understand the social interactions occurring and how those related to students' willingness to engage in class and contribute to class-wide discussions. This approach found, similarly to Sidelinger and Booth-

Butterfield (2010), that social interactions between students had a significant impact on course dynamics (Fassinger, 1997).

It should also be noted that the classroom can be a stressful environment, which can be compounded for minoritized students, as discussed previously (Delpit, 1988; O'Connor et al., 2017; Shi & Tan, 2020; Tanner, 2013; White 2011). Making participation mandatory can exacerbate this stress and act to hinder class-wide discussion (O'Connor et al., 2017; Shi & Tan, 2020; White 2011). Both O'Connor et al. (2017) and Shi and Tan (2020) monitored classroom engagement and found non-vocal participants benefited from robust discussion. Non-vocal participants were defined as being engaged in the conversation (paying attention, thinking, evaluating peers' contributions, etc.) but did not contribute vocally and performed without a significant difference to those that had contributed vocally (O'Connor et al., 2017; Shi & Tan, 2020).

Based on these findings O'Connor et al. (2017) suggest that teachers can eliminate stressing about the need to ensure each student "gets a turn" to speak in the discussion; while Shi and Tan (2020) and White (2011) suggest eliminating heavy point values on participation aspects of student grading. These factors together can aid in eliminating undue stress on students that act as non-vocal participants and/or come from minoritized backgrounds.

1.5.2.3 Recognizing and Accounting for Authority Issues in the Classroom.

Despite the intents of constructivist learning, students arrive to class viewing the teacher as the authority on subject matter (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak & Baumgartner, 2004). The shift from being passive recipients of knowledge to active learners and authorities in constructivist learning can be a challenge and limits students in class-wide discussion as they do not view their own agency to engage (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak & Baumgartner, 2004).

Many science college classrooms have faculty that engage in student-centered, evidence-based, constructivist activities, yet often there is still low, dialogic, interactive discourse (Alkhouri et al., 2021). This is indicative of faculty engaging with constructivist pedagogy but maintaining teacher-centered discourse patterns while dominating class-wide discussion (Alkhouri et al., 2021). This type of discourse does not allow for the development of student authority or foster a willingness of students to engage in dialogic teaching activities (Alkhouri et al., 2021, Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak & Baumgartner, 2004).

As noted previously, most classroom conversations follow an IRE pattern; the teacher will **I**nitiate the questioning, a student will **R**espond, and the teacher then **E**valuates the response, essentially an oral assessment of basic understanding (Alkhouri et al., 2021; Christodoulou & Osborne, 2014; Lyle, 2008). Yet, other discourse patterns exist that can aid in fostering student authority, limiting the authority of the teacher. In the IRF pattern, the teacher still **I**nitiates the question, in which a student will **R**espond, however the teacher will than prompt another student in **F**ollow-up dialogue to evaluate, expand, question, or engage with the previous response (Alkhouri et al., 2021). IRF patterns are used much less frequently than IRE patterns but have the benefit of creating opportunities to support further learning and fostering student authority (Alkhouri et al., 2021, Duschl and Osborne, 2002). These IRF patterns ask students to "think beyond whether their answer is correct or incorrect but, rather, spend more time reasoning through and supporting their answers with evidence" (Alkhouri et al., 2021, p. 1064).

Aside from altering to an IRF discourse pattern there seem to be additional means to aid students in recognizing their authority to engage in inquiry and constructivist teaching practices: utilizing teacher noticing and acting as a partner.

Utilizing Teacher Noticing as a Tool to Increase Student Authority. One powerful method to aid students in the transition to recognize their own authority in learning and help to inspire richer classroom discussion is for instructors to incorporate student ideas/comments into their own language and scaffold the lessons to allow students to build confidence and authority in their learning (Barnhart & van Es, 2015; Bleicher, 2003; Cartier et al. 2013; Ford, 2008; McNeill & Pimentel, 2010; Smith et al. 2011; Webb et al., 2008).

Barnhart and van Es (2015) observed two groups of pre-service teachers, one group had a course that worked to develop skills in teacher noticing (the ability to attend to, analyze, and incorporate student thinking into lessons). The group that underwent training was better at noticing, which increased student engagement, participation, and learning (Barnhart & van Es, 2015). Teacher noticing of student contribution and then utilizing student responses in continued discussion or lecture acted to empower the students (Barnhart & van Es, 2015). This empowerment can contribute to an increase in self-esteem and/or recognition by the student that they can impact the progression of the discussion and/or content of the course, increasing the recognition of their own authority in the learning process.

In addition to teacher noticing, teachers can encourage students to elaborate more fully on their responses and explain their answers, helping to foster student authority building and driving better class-wide conversations. Webb et al. (2008) followed three teachers who had been provided training on eliciting details of student thinking and monitored their classroom interactions with students. One of the teachers prompted students to elaborate on their problem-solving in nearly every interaction, regardless of the correctness of the response, and in this classroom, students tended to engage in longer and more robust discussion (Webb et al., 2008). This teacher did not offer immediate feedback on responses allowing for student authority to build as they explained their thinking, critiqued each other's responses, and thus saw gains in class-wide discussion (Webb et al. 2008).

Teachers need to be mindful of their authority as they link students' content into the discussion. Bleicher et al. (2003) followed a high school chemistry course and noted the teacher in this course utilized class-wide discussion as an instructional tool but did not yield authority and hindered potential gains. They noted instances where the instructor controlled the flow of class discussion, repeated student responses, stressed key vocabulary, even interrupted student speakers (Bleicher et al. 2003). These tactics stifled student discussion and limited opportunities for students to talk science and think scientifically (Bleicher et al. 2003). Recommendations resulting from these observations indicate that the teacher needed to allow for more student-centered discussion by giving students more authority, allowing longer time for student response before supplying key vocabulary terms, not repeating students' responses verbatim when student responses were loud enough to be heard throughout the room, and not interrupting student talk (Bleicher et al. 2003).

Giving students a chance to "struggle" with the material, use their experiences to link scientific ideas, and be the source of their learning (not needing the authoritative figure to act as a final say in the matter) is important in constructivist pedagogy but also in empowering students to engage with class-wide discussion. The teacher needs to attend to students' thinking to gauge whether the lesson was successful and helped students to better understand topics being addressed. Teachers need to develop skills that enable them to attend to student thinking through the analysis of student learning (through teaching) and respond (tailor their teaching to support student learning) without diminishing the authority and voice of the student (Barnhart & van Es, 2015; Bleicher et al. 2003).

The Teacher-as-a-Partner Model in Investigation to Increase Student Authority. In student-centered discussion the instructor cannot act as the authority (or by proxy conceptual content). Instead, they should allow the conversation to naturally proceed giving students the authority to investigate arguments, analyze the evidence, and ultimately accept or reject the ideas and supporting evidence presented in the discussion (Christodoulou & Osborne, 2014; Duschl & Gitomer, 1997; Ford, 2008). "It is the responsibility of science educators to enable their students to participate in the epistemic practices of science and engage with epistemic discourse by modeling these practices with and for them" (Christodoulou & Osborne, 2014, p. 1279).

Tabak and Baumgartner (2004) investigated the role of the teacher during class discussions in inquiry-based coursework; their investigation follows five teachers in five different schools using two different science curricula as they teach evolution to high school students. In their study they found students were more willing to engage in discussion when their teacher acted as a partner in the investigation, not as an authority within the class (Tabak & Baumgartner, 2004). Teachers would often approach groups as they were working and inquire into their progress, ask if there were questions, or offer suggestions for groups that were stuck in their investigations (Tabak & Baumgartner, 2004). These interactions were often like triadic dialogue patterns and seemed to limit conceptual discussion, frequently students asked procedural questions and voiced frustration and confusion (Tabak & Baumgartner, 2004). However, when teachers interacted with the group as a partner in inquiry, with noted shifts in pronoun usage (we instead of you) and investigated alongside the students, students would open up and there were marked changes in dialogue (Tabak & Baumgartner, 2004). This change included more conceptual talk with the teacher and would even grant students authority to make arguments, in one example a student rejected the teacher's proposed idea stating it did not match the data (Tabak & Baumgartner, 2004).

Duschl and Gitomer (1997) present a series of case studies following three teachers that had received training in and utilized a project-based learning approach called Science Education through Portfolio Instruction and Assessment (SEPIA) in their classrooms. Research presented focuses on a tool utilized while engaging in inquiry-based education, the assessment conversation, a tactic using student conversations to collect varied student responses and analyzing those to aid teachers in building student understanding and reasoning skills (Duschl & Gitomer 1997). Classes where the assessment talk was enacted generally had more student engagement, and there was a pronounced shift from the teacher as the authority towards a more student-centered environment (Duschl & Gitomer 1997). This assessment conversation is a tool that, when successfully utilized, can empower students to recognize the authority in their learning and assess peer responses during these conversations (Duschl & Gitomer 1997; Ford 2008).

Much like previous studies referred to throughout this paper, McNeill and Pimentel (2010) found that teachers who used open-ended questions encouraged students to build on and more fully explain their responses, and modeled dialogic behaviors by explicitly linking student responses in her/his own teaching aided in fostering environments that supported student-centered dialogue. The researchers followed three teachers across three urban schools and found that only one teacher successfully fostered robust dialogue supporting instructional goals (McNeill & Pimentel, 2010). The successful teacher's use of open-ended questions supported student argumentation in both providing evidence and reasoning for their claims and encouraging dialogic interactions as students evaluated each other's claims (McNeill & Pimentel, 2010).

1.5.2.4 Conclusions Regarding Tools to Increase Student-Centered, Robust Dialogue.

There are a number of reasons that students resist participating in constructivist activities such as class-wide discussion, but the instructor can learn to recognize this resistance and work to overcome it. Creating a welcoming environment that incorporates student perspectives and shifts the responsibility of learning to students will empower them in their learning helping to drive engagement. Instructors also need to spend time modelling and scaffolding their dialogic teaching and argumentation so students can understand the aims of these activities.

2.0 Theory of Improvement and Implementation Plan

2.1 Theory of Improvement and Driver Diagram

A dialogic classroom is a learning environment in which open discussion occurs between the teacher and students; it is not just the teacher's presentation of content (Knight & Wood, 2005; Lehesvuori et al., 2013; Lyle, 2008). In our lab spaces, class-wide discussion serves two important goals. One, it allows for students to engage in and practice scientific argumentation. Two, students benefit from other students' thinking being "put on display" during classroom dialogue.

Argumentation is a form of dialogic teaching employed in many science classrooms that helps to build scientific reasoning and communication skills (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Shemwell & Furtak, 2010). Duschl and Osborne (2002) define scientific argumentation as "the special case when [dialogue among peers] addresses the coordination of evidence and theory to advance an explanation, a model, a prediction, or an evaluation" (p.55). Argumentation provides the opportunity for students to use evidence to support their claims and be critical of the claims and support used by their peers. This form of dialogic teaching helps to build critical thinking and scientific communication skills while mimicking science in practice (Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012).

Aside from argumentation, dialogue has an important role in supporting STEM learning. Gibbons and Cobb (2016) argue that it is important to give students chances to engage in class-wide discussion to "'voice out' their thinking" (p. 248) as they practice with mathematical content. Experiencing others' perspectives and thinking through discussion allow students to see there are multiple approaches to solving a problem or using STEM concepts. It is vital that students have an opportunity for working through problems in small groups but then also for "…building on [their] solutions during a concluding whole-class discussion by pressing students to justify their reasoning and make connections between their own and others' solution" (Gibbons and Cobb, 2016, p. 239).

When dialogue is not occurring, and the classroom is quiet these learning opportunities are not realized. Thus, an increase in participation by students would generate more robust class-wide discussion while supporting their learning opportunities. A classroom that supports and sustains robust, student-centered discussion aids in supporting science learning by providing students chances to engage in scientific argumentation and benefit from peer learning.

2.1.1 What am I Trying to Accomplish?

I seek to incorporate practices to foster student willingness to engage in class-wide discussion and push students to practice scientific argumentation while engaging in those discussions. Increases in student engagement can support broader student learning goals, enrich their conceptual understanding, help foster identities as a scientist, and increase retention in STEM (Gasiewski et al., 2012). Students who are more comfortable speaking in class tend to better learn the material and are more prepared for classes, while earning higher grades (Sidelinger & Booth-Butterfield, 2010).

Dialogic classrooms are powerful support for content learning, even for students who are not particularly talkative. O'Connor et al. (2017) and Shi and Tan (2020) provide evidence that students can be engaged in class discussions as non-vocal participants and benefit. These non-vocal participants are students who are engaged in the conversation (paying attention, thinking, etc.) but do not participate in the dialogue (O'Connor et al., 2017; Shi & Tan, 2020).

In classrooms where there is limited or no dialogue occurring both vocal and non-vocal participants are negatively impacted. Increasing students' willingness to engage will support their learning by practicing argumentation, allowing for the benefits of displaying multiple perspectives and approaches to problem solving.

2.1.2 What Changes can I Make that will Result in Improvement?

Despite the benefits of dialogic teaching and the use of argumentation in the classroom, students often resist these types of activities (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Shi & Tan, 2020; Sidelinger & Booth-Butterfield, 2010; Tabak & Baumgartner, 2004; White, 2011). This resistance stems from a few sources, but there appear to be two central issues: authority within the classroom and cultural differences (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Shi and Tan, 2020; Sidelinger & Booth-Butterfield, 2010; Tabak & Baumgartner, 2004; White, 2011). Students resist the transition to active learning and attempt to keep the teacher as the source of knowledge and authority in the classroom (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak and Baumgartner, 2004). Addressing issues centered in inclusivity and creating welcoming spaces will make students feel comfortable engaging in dialogic teaching practices (Clarke et al., 2016; O'Connor et al., 2017; Shi & Tan, 2020; Sidelinger & Booth-Butterfield, 2010; White, 2011).

I intend to focus on two central themes to better support and facilitate student-centered class-wide discussion. These next sections will address these ideas: issues centered on explicit instruction and fostering student authority within the classroom. These themes are areas where teachers can utilize pedagogical practices to better support and facilitate student discussion.

2.1.2.1 Making the Implicit Explicit.

A central issue within the Foundations of Biology labs is that students have not necessarily engaged in these types of discussions before and are unclear of the expectations. This lack of explicit instruction can limit students' preparation to participate in class-wide discussion. A lot of instruction is transferred to students implicitly (Howell et al., 2003; Martin & Mahat, 2017; Rothgeb, 2022). Many of the instructors know what these discussions should "look like" and how to argue with data based on their experiences in research. I realized that as we teach and set up these activities, we are often not explicit about the expectations.

Utilizing these ideas as drivers for change can aid teachers in better supporting robust, student-centered discussion. These discussions are sources of significant learning for students. It grants them opportunities to engage and practice scientific argumentation while benefitting from experiencing peers' thoughts, perspectives, and understandings.

2.1.2.2 Recognizing and Accounting for Authority Issues in the Classroom.

Many students arrive viewing the teacher as the authority in subject matter and the classroom environment, which discourages their participation (Clarke et al., 2016; Gasiewski et al., 2012; Lyle, 2008; O'Connor et al., 2017; Ramsey & Baethe, 2013; Tabak & Baumgartner, 2004). Two important mechanisms in increasing students' recognition of their authority in the classroom are the use of teacher noticing and establishing teacher/student partnerships in inquiry-based learning (Barnhart & van Es, 2015; Bleicher, 2003; Ford, 2008; Tabak & Baumgartner, 2004). Teacher noticing occurs when instructors incorporate student ideas/comments into their own language, allowing students to build confidence in their learning which aids students to recognize their own authority leading to richer classroom discussion (Barnhart & van Es, 2015; Bleicher, 2003; Ford, 2008).

In student-centered discussion, the instructor cannot act as the authority. Instead, they should allow the conversation to naturally proceed, giving students the authority to investigate arguments, analyze the evidence, and ultimately accept or reject the ideas and supporting evidence presented in the discussion (Christodoulou & Osborne, 2014; Duschl & Gitomer, 1997; Ford, 2008). "It is the responsibility of science educators to enable their students to participate in the epistemic practices of science and engage with epistemic discourse by modeling these practices with and for them" (Christodoulou & Osborne, 2014, p. 1279).

2.1.3 How Will I Know the Change is an Improvement?

As change is implemented, I hope to see increases in the level of engagement by students within the class. Increased levels of participation would have more students making claims, asking questions, engaging with the discussion, and engaging more with one another. I wish to see students engage directly with one another and not look to the instructor as an intermediary or authority. My goal is for students to engage with other teams based on curiosity, evaluation of claims and supporting data, or identification of misused data without prompting from the instructor (Table 1).

Table 1. Student Participation and Argumentation in Class Discussions.Aspects of student participation and argumentation in class-wide discussions, student argumentative claims become more complex towards the right of the table. Adapted from Figure 1 in Berland and McNeill (2010) - © 2010 Wiley Periodicals, Inc.

	Rubric Scoring		
Engagement in class-wide discussion	Student participation in argumentative discourse is prompted by instructor	Student participation in argumentative discourse is prompted by instructor and other student arguments	Students engage in argumentative discourse without prompting from instructor

Level of claims and use of data	Claims are articulated, defended, questioned, OR evaluated	Claims are articulated, defended, questioned, AND evaluated	Claims are articulated defended, questioned, AND evaluated prompting revision of initial claim
	Claims are defended but there is little use of data in the evidence	Claims are defended with appropriate evidence	Claims are defended with appropriate evidence and reasoning

I would also like to see an increased progression of scientific vocabulary and complexity of arguments being made. I would like students to make claims supported by data collected during their research and include insight into reasoning for how the data supports their claim. Additionally, in the class-wide discussion, I hope students will begin to evaluate, compare, and discuss claims formulated by the class and push for further justification (Table 1).

2.2 Aim Statement

Student participation in class-wide discussions in Foundations of Biology I laboratory courses will increase 20% during the lab meeting activities with increased complexity of student argumentative claims by Fall 2024.

2.3 System Drivers

2.3.1 Primary System Drivers

I have identified three primary drivers to improve student engagement in class-wide discussion: student preparation, student authority, and equity and inclusion (Fig. 1). Students need time and scaffolding to increase preparation which will help to increase their willingness to engage in class-wide dialogue. The development of student authority in their learning will yield increases in the willingness to engage in exercises to support and drive the learning process. Finally, addressing equity and inclusion issues can help break down barriers that students may feel prevent them from interacting with peers in class-wide discussions.

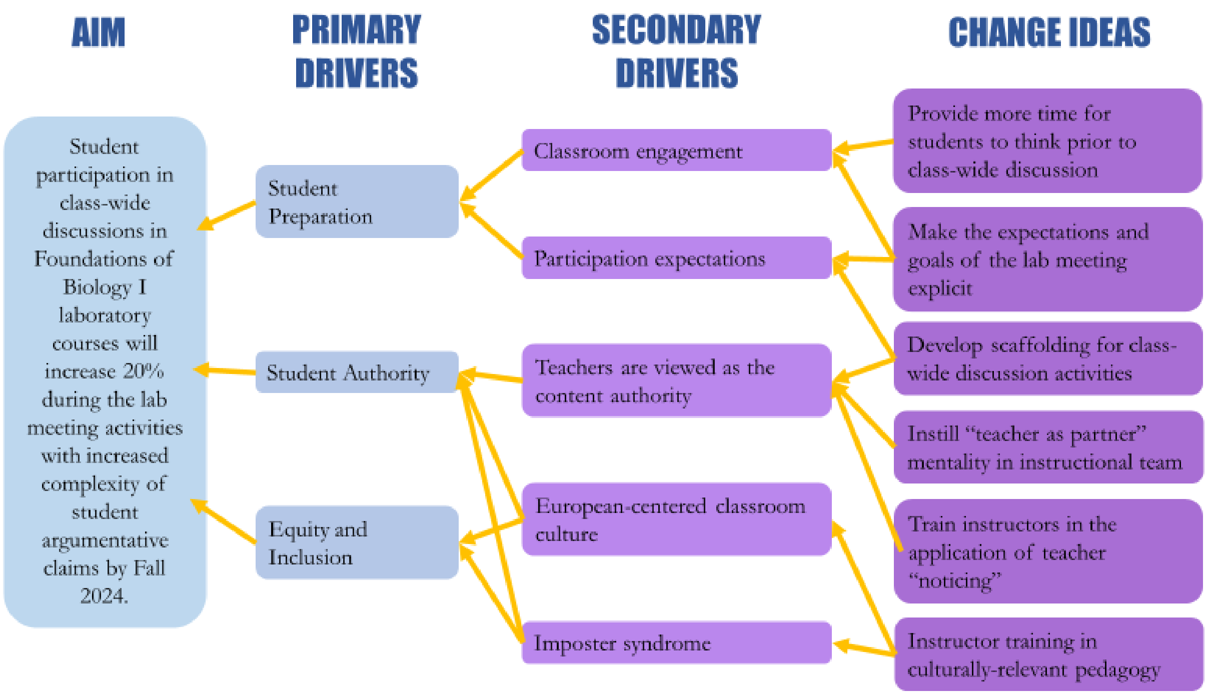


Figure 1. Diagram of Drivers and Change Ideas for Influencing the Desired Aim.

2.3.2 Secondary System Drivers

Many minor or secondary factors influence the primary drivers influencing students' participation in discussion (Fig. 1). If students are better prepared for discussion by being given adequate think time, scaffolding, and explicit expectations of class-wide dialogue, this can lead to improvements in participation. These secondary drivers, classroom engagement and participation expectations, influence the primary driver of student preparedness (Fig. 1).

Practices that foster students' authority, another primary driver, and aid in developing identity can support students in viewing themselves as scientists and recognizing their authority in learning. This sense of authority can bolster their willingness to participate in activities centered on their learning and investigation. These secondary drivers, teachers viewed as the content authority, European-centered classroom culture, and imposter syndrome, link to the primary driver of student authority (Fig. 1).

Classrooms that actively work to recognize and respect different cultural backgrounds and are cognizant of the potential presence of imposter syndrome can employ tools that break down these barriers and create spaces where students feel welcome. This can help to welcome students to engage in class-wide dialogue, lead to recognizing these activities as a means to develop skills, and support their continued development of viewing themselves as scientists. These secondary drivers, European-centered classroom culture and imposter syndrome, influence the primary drivers of equity and inclusion (Fig. 1).

2.3.3 Change Ideas

2.3.3.1 Making the Implicit Explicit.

The first change idea I used was making the expectations and goals of the lab meeting explicit. I addressed the objectives of the class-wide discussions in more detail (use and practice argumentation), detail explained what that means, and modeled it for the students. As part of this instruction, I introduced the lab meeting as a normal occurrence at the professional level and introduced the purpose of this event, which is to compare data across different research endeavors, address unexpected data, troubleshoot or plan new experiments, or basically drive the research goals forward in a collaborative fashion.

As this course mirrors a research experience but still retains the goals of teaching, I also addressed the educational goals of the lab meeting activity: to have students engage with their data and perform meaningful analyses, discuss the trends within their team, focusing on their treatments/variables, and to then transition to class-wide discussion to discuss the data more globally and in the context of the guiding research questions.

The students were also introduced to scientific argumentation and the elements that make up an argument (the claim, support, and reasoning.) It was then explained that the class-wide discussion is a place where students can practice scientific argumentation and get feedback from instructors on the quality of their scientific arguments. Additionally, students were told that argumentation allows them to gain deeper understanding by experiencing other students' perspectives and evaluating the use of support and reasoning. This style of framing will help students to see the value of engaging with and participating in the lab meeting to deepen their learning (Howell et al., 2003; Martin & Mahat, 2017; Popham, 1973; Rothgeb, 2022).

2.3.3.2 Building Student Authority.

The next two change ideas focused on incorporating pedagogical skills that will help instructors to foster the development of student authority. The first was utilizing teacher noticing as a tool to increase student authority. The second was employing the "teacher-as-partner" model. Both were presented to laboratory instructors with the goal of supporting their practice in developing student authority within their sections.

Teacher noticing is a powerful method to aid students in recognizing their authority in learning and to help inspire richer classroom discussion (Barnhart & van Es, 2015; Bleicher, 2003; Cartier et al., 2013; McNeill & Pimentel, 2010; Webb et al., 2008). While utilizing this practice, instructors attempted to incorporate student ideas/comments into their language and then scaffold using these ideas to allow students to build confidence and authority in their learning (Barnhart & van Es, 2015; Bleicher, 2003; Cartier et al., 2013; Ford, 2008; McNeill & Pimentel, 2010; Smith et al. 2011; Trujillo & Tanner, 2014; Webb et al., 2008).

The "teacher as a partner" model in investigation can be used to increase student authority. In student-centered discussion, the instructor cannot act as the authority, instead, they should allow the conversation to naturally proceed, giving students authority to investigate arguments, analyze the evidence, and ultimately accept or reject the ideas and supporting evidence presented in the discussion (Christodoulou & Osborne, 2014; Duschl & Gitomer, 1997; Ford, 2008). "It is the responsibility of science educators to enable their students to participate in the epistemic practices of science and engage with epistemic discourse by modeling these practices with and for them" (Christodoulou & Osborne, 2014, p. 1279).

2.4 Methods and Measures

2.4.1 Positionality Statement

Prior to introducing my methods and discussing the study design, I wish to begin by reflecting on and presenting my positionality to the reader. "Positionality reflects the position that the researcher has chosen to adopt within a given research study [and] influences … how research is conducted, its outcomes, and results" (Holmes, 2020, p. 2). Additionally, as I am in the unique role of being both the researcher and a practitioner within the contexts of this study, Perry, Zambo, and Crow (2020) discuss the need to address this duality. Thus, my positionality statement will allow the reader to understand my experiences and perceived identity and its potential influences on the resulting research.

I identify as a white, heterosexual, cisgender man raised lower middle-class. My father was active duty in the Air Force and in the early parts of my life we lived in military housing at several bases across the United States. He left active duty to provide a more stable schooling environment from my sister and me. We began in Catholic schools which we were provided tuition aid from the church. In middle-school I transitioned to public school and was academically behind. I also become heavily involved with the Boy Scouts of America. It was here I discovered a love of science and teaching science when I taught for four years at a Boy Scout summer camp in the Ecology Conservation program area, teaching merit badges classes such as Environmental Science, Forestry, Mammal Study, Nature, Reptile and Amphibian Study, Soil and Water Conservation, Sustainability, and Fish and Wildlife management.

As I progressed through high school, I was not high achieving but hoped to attend college where I planned to pursue secondary education in biology degree and certification. During some of my early science courses I was exposed to scientific research with small mammals, invasive Zebra Mussels, and turtles. I also obtained a work-study position caring for the green house and a teaching assistant position in a Zoology lab. I opted to pursue a more intense biology-focused degree with aspirations for graduate school. I successfully completed my Bachelor's of Science in Biology becoming the first in my family to earn a bachelor's degree and was accepted into a Master's program.

I successfully completed my Masters of Science in Biology with an Ecology and Evolution tract with a focus in wildlife management. From there I completed several technician, lab manager, and teaching positions. I never lost my interest in education which drew me to the program I am currently completing.

In my current role I serve as a laboratory instructor, teaching labs with the University of Pittsburgh's Dietrich School for Arts and Sciences within the Biology Department. In this position I instruct students' science skills through authentic research experiences. We strive to teach science by engaging in the process of performing science.

Teaching allows me to fulfill, what I believe, a basic requirement to the field of science; the communication of scientific information and principles with others. By sharing this knowledge and exposing students to workings of the scientific process I hope to encourage them to think more scientifically about the world around them. Additionally, I feel students of the sciences should have an exposure to scientific research and appreciation for the application in a professional level. In my classroom environment I want students to think and participate in the research we perform. I want students to engage with each other as we work to co-construct their scientific knowledge.

I also acknowledge that biology courses carry with them a weight of being unequal. The collective fields of science, technology, engineering, and mathematics (STEM) has a well-documented issue with diversity and inclusion. There is an overrepresentation of white men with all other groups being underrepresented across several levels, ranging from enrollment and graduation in undergraduate college programs, enrollment and completion of graduate programs, hiring for research positions, awarding of grants, and faculty appointments (Botella et al., 2019; Sqoutas-Emch et al., 2016; Whittaker & Montgomery, 2012). Students of various minoritized backgrounds in my courses may have encountered this bias and may have had poor experiences making them feel unwelcome. I aim to acknowledge my own biases and implicit beliefs. I acknowledge that I come from a position of privilege and my particular perspective and experiences do not represent all others.

I also aim to recognize my position in this research as an educator to students and as part of an instructional team, and a researcher. As I designed and analyzed the results from the focus groups, surveys, and interviews I needed to balance my positionality and attempt to prevent my position from influencing the work. As an educator implementing changes in my practice, I had to be aware of my position of power and recognize the potential for students engaging in surveys or interviews to feel pressure to respond in certain ways. Additionally, as I educate as part of a very supportive team, I had to be mindful that other instructors may feel tempted to provide feedback that they believe I am looking for to aide in support of my work. By reflecting on and being cognizant of my positionality, I strived to ensure minimal influence of power was pushed on participants. This attempt hopefully led to people feeling they could answer based on their insights from their position and not in a manner that provides me with “what I want to hear.”

2.4.2 Inquiry Questions

1. How and what ways do instructors and students view the use of robust, student-centered discussion in supporting student learning and developing science skills (practicing scientific argumentation and putting thinking on display)?

2. How and in what way does explicit instruction of the educational and research goals of the lab meeting aid in fostering student willingness to engage in the class-wide discussion portions of the lab meeting?

3. How do students respond to the use of teacher noticing and the teacher-as-partner model? Does it help to facilitate more student engagement in the lab meeting?

2.4.3 Inquiry Design

This project utilizes improvement science as a framework to guide the research. I briefly introduce the concept of improvement science to the reader to frame my work and differentiate it from a more theoretical approach. My aim is to improve class-wide discussion.

Improvement science is a methodological approach to solving problems in a variety of systems, including educational systems. The principles of improvement science require that scholarly practitioners identify and explicitly define problems of practice, understand the forces within their systems that influence the problem, identify changes that could improve the system, test the impacts of those proposed changes, and spread beneficial changes through aspects of the system in which the practitioner has influence (Hinnant-Crawford, 2020; Langley et al., 2009; Mintrop, 2020).

As practitioners engage in improvement science and work to investigate their possible changes they do so through the framework of plan, do, study, act (PDSA) cycles (Bryk et al., 2015; Hinnant-Crawford, 2020). The basis of the current PDSA cycle process in improvement science stem from Langley et al. (2009), who describes it as an “efficient trial-and-learning methodology” (pp. 24 – 25). This cycle acts as the basis for continual improvement efforts as practitioners engage in developing improvement stratagems, testing them, and revising based upon the outcomes of each iterative cycle. The focus of these cycles is within the practitioner’s localized system and less so on the development of global theory development (Hinnant-Crawford, 2020; Langley et al., 2009; Mintrop, 2020).

2.4.3.1 Plan Do Study Act (PDSA) Cycles.

Plan. I utilized the change ideas, making the implicit explicit and fostering the development of student authority during the Fall 2022 semester of BIOSC 0057 Flower Microbiome. The change ideas were focused on lab meetings, a discreet event in which class-wide discussion is a central component.

The course developer administering Flower Microbiome in the Fall 2022 semester allowed me to implement my improvement plan not just in my section but throughout the course. She allowed me to utilize time during our weekly instructor meetings to introduce ideas, explain the rationale of my plans, and collect information.

Prior to our instructor meeting addressing the first lab meeting of the semester, I developed a brief introduction on explicit instruction and its importance to framing educational outcomes for the instructional team. I provided evidence from the literature that instruction needs to be explicit and clearly define an activity's objectives. Students may not have been engaging in this activity as we hoped previously due to our implicit introduction and framing of our expectations for this activity.

I also prepared a series of slides to accompany this introduction that detail, in brief, the objectives of the lab meeting activity and elements of a scientific argument. These objectives introduced the goals associated with each of the three phases of the lab meeting. The objectives for the class-wide discussion portion then expanded to explicitly address that it provides space to practice scientific argumentation while allowing for students to benefit by experiencing other perspectives of data interpretation. These slides were provided to the instructional team and used to introduce the first lab meeting.

As the semester continued, I developed two mini-workshops for the instructors introducing the idea of students often not recognizing their authority in the classroom and their learning. I also introduced two tools for instructors to use to help students overcome this and help foster the development of student authority. The two tools were teacher noticing and the teacher-as-partner model.

Do. In the instructor meeting before the first lab meeting of the semester, I explained to the instructor team that students may not understand the goals of engaging in the lab meeting which may hinder their willingness to engage in the activity. I addressed ideas I encountered in the literature about the implicit behavior of our instruction. I also provided the slides to the instructor team that allowed them to explicitly state the objectives of the lab meeting activity in their classes the following week.

As we moved into the final two lab meetings of the semester, I shifted my focus to developing students' sense of authority in the classroom. I introduced the practices of teacher noticing and teacher-as-partner model to the instructors during weekly instructor meetings in the second half of the semester.

I provided the mini-workshops two weeks prior to the next lab meeting and hoped for the instructional team to utilize these practices to develop student authority and foster a sense of ownership in their research prior to the lab meeting.

Study. I collected data about each improvement cycle after each lab meeting. I initially utilized three tools for data collection: surveys, journals, and focus groups. The surveys were Qualtrics surveys that were administered to students after the lab meeting. Journals had an associated rubric and prompts for the instructor team and myself to complete immediately following each lab meeting. Focus group interviews then occurred during the weekly instructor meeting following each lab meeting.

During the lab meetings we tracked student engagement, as it was a component of their grade for the lab meeting activity. Several students who consistently had low or no engagement in the class-wide discussions were identified and contacted for brief interviews in the Spring semester of 2023.

Act. Studying student and faculty responses may uncover unique patterns that can be further access points to engage students more deeply and center these lab meetings on the students. Giving students a chance to be the driving force in understanding their data and teasing out patterns allows them to act as scientists with the hopes of fostering that identity. Additionally, if the class-wide discussion portion of the lab meeting is used to full potential, it will allow students to practice scientific argumentation skills and benefit from seeing how peers make sense of the data (sharing novel perspectives) to deepen the learning process of this research-based course. These PDSA cycles' findings can help us continually improve and create the best environment to support student learning.

2.4.4 Inquiry Tools

During each of the PDSA phases a variety of tools were used to collect data to address the impacts of the change ideas. These tools consisted of instructor journals, instructor focus groups, and student surveys. These tools were designed to try and capture data efficiently from each of the user groups involved in this improvement process.

The journal entries were provided to instructors for each of their sections during the lab meeting and they were asked to complete them immediately following the lab meeting (full copies are provided in Appendix B). These were for instructors to record their thoughts after the lab meeting concluded. It asked them to rank the quality of the discussion using the modified rubric from Berland and McNeill (2010) (Table 1) Additionally, it asked them to compare previous efforts to lead class-wide discussion and their thoughts on the interventions for each distinct lab meeting.

After the conclusion of the lab meeting students were provided the link to a Qualtrics survey that asked a variety of questions (full copies are provided in Appendix C). There were some demographic questions, each with an option not to self-identify if students wished to keep the information private. There were questions that asked them to rank the parts of lab meeting based on difficulty and perceived benefit. Next came a yes or no question regarding their participation in the class-wide discussion; depending on their response it took them to a series of Likert scale questions attempting to address their reasons for participating or not participating in the discussion. Finally, there was a series of Likert scale questions gauging their perceived educational value of the class-wide conversation. In the surveys for Lab Meetings #2 and #3 new questions were added that included identifying their sections and a series of Likert scale questions to gauge students' feelings of being welcome to engage in the discussion; these questions were adapted from Böheim et al. (2021).

Finally, I conducted focus group interviews during the instructor meeting following the lab meeting (copies of questions are provided in Appendix D). During these interviews I asked the instructors a series of questions to try and understand how they felt engagement in the class-wide discussion phase was and the levels of argumentation occurring. I also tried to understand how instructors felt about the interventions and conceptual ideas around the interventions. I routinely asked about how they felt regarding inclusivity and equity in the discussions and if these interventions did anything to improve those.

2.4.5 Improvement System Measures.

The goal of improvement science is to drive improvements within a complex but localized system to understand the impact of proposed changes in which the practitioner must measure various parts of the system (Bryk, 2015; Hinnant-Crawford, 2020; Langley et al., 2009). "Improvement research requires gathering data about specific processes, and other key markers on the pathway toward achieving the network's ultimate aims" (Bryk, 2015, p. 15). Thus, I have linked specific data to the various processes that impact my aim, as outlined in section 2. These outcome, driver, process, and balance measures will be defined and outlined below.

Outcome Measures. Outcome measures are those directly related to my aim statement and measure the impact change at the system level (Hinnant-Crawford, 2020). My outcome measures drew from all three of my tools. Central themes I measured from the student surveys include:

students increasing their responses of "yes" to participating in lab meetings and decreasing numbers of students indicating they strongly agreed or agreed that they participated as it was required to earn participation points.

I also analyzed the rubric used on the instructor journal worksheets (Table 1). I assigned each category a value: 1 for the scoring criteria to the left and 3 for the right. The right-most column is associated with higher engagement and more complexity in the arguments. These were then compared as averages and modes to assess for changes across the lab meeting. Ideally, these would shift towards the increasing engagement and complexity. Finally, faculty journals and focus group transcripts were coded and I looked for increased frequency of codes linked to student engagement and argumentation use.

Driver Measures. Driver measures measure the change of the primary and secondary drivers (Hinnant-Crawford, 2020). My change ideas (Fig. 3) most directly relate to drivers of "Classroom Engagement" and "Student Authority."

I measured changes in "Classroom Engagement" by analyzing instructor responses in focus groups and journal reflections post-lab meetings. As the instructors discussed and reflected on the intervention, I worked to identify emerging patterns and how these class-wide discussions compared to previous discussions they facilitated.

Measuring "Student Authority" came primarily from student survey data. I compared students who responded "no" to participating in the class-wide discussion phase and how they responded to the prompt of "I do not feel comfortable speaking up in class-wide discussions" on the Likert scale (Appendix A). I hoped to see this parameter decrease during the progression of my PDSA cycles.

Process Measures. Process measures are measures of each change idea within improvement cycles and are intended to be quick and easy checks (Hinnant-Crawford, 2020). Using the post-lab meeting surveys from each intervention, I simply compared if more students were selecting "yes" to participating in the class-wide discussion phase. I was able to glean an understanding of the success of each specific intervention.

Balance Measures. Balance measures check the balance of the system as interventions are occurring, if changes are beneficial or harmful to the system overall (Hinnant-Crawford, 2020). This was addressed using the instructor post-lab meeting focus group transcripts and journals. Some questions were tailored to the demand of the intervention, while concerns of overloading the instructional team were also addressed. Mainly, I coded for time limitations in the lab period and if the interventions demanded instructors' preparation time and/or classroom instruction time.

2.4.6 Inquiry Setting

The setting for my improvement cycle occurred within a Foundations of Biology lab course. As described previously in section 1, these are courses designed to provide students with foundational skills in biological research while engaging them in authentic research experiences. The particular Foundations lab that served as the basis for my improvement program was BIOSC 0057: Flower Microbiome.

In this course, students engage in authentic research to characterize the microbiome of flower petals and compare if there are differences in the microbiome based on several characteristics (i.e., UV region of the petal, species of flower, location of the flower, etc.). The course proceeds in modules centered on aspects supporting the overarching research questions. At the end of each module, there is a "lab meeting" in which the students analyze the data from the module, discuss the data in their research teams, then engage in a class-wide discussion in which we hope to probe the data more deeply and look for trends emerging in the class-wide data set.

This course included three lab meetings throughout the semester. In the first meeting, I employed the change idea of making the implicit explicit. In the second and third lab meetings, I focused on developing student authority by employing teacher noticing and the teacher-as-partner model. These both aim to foster student authority in their research and discuss their findings as the experts (the instructor is not the expert in their data).

The selection of this course was solely based on my teaching assignment in the fall semester. My ranking in the department was Laboratory Instructor I with limited ability to dictate my course assignments. I have taught primarily at the Foundations I level in a variety of courses and this has driven much of my research.

My problem of practice and much of my research has largely been centered on freshman and sophomore students in STEM courses. Within the existing literature and data I have collected through empathy interviews of faculty, class-wide discussions tend to be more robust and student-driven in higher-level biology courses. I have some concerns with these findings, though, as attrition in biology programs is widely documented. I suspect that much of this attrition is driven by demographics and students who do not engage in constructivist activities, such as class-wide discussions (Ramsey & Baethe, 2013). Therefore, being able to implement my change ideas in a Foundations I-level lab was an ideal arrangement.

2.4.7 Population

Flower Microbiome ran 16 sections, which included one course developer, four course instructors, and began with 20 students per section. Generally, this course serves students in their second semester of college. As this course is designed to be the second semester in the sequence, the fall population tends to consist of students who had to repeat the Foundations I lecture and thus are in their third semester. Additionally, the fall semester tends to have students from other departments taking this course to fulfill other requirements for their perspective programs. For example, I had several students who were seniors in bioengineering programs.

2.4.7.1 Users and Their Links to my Problem of Practice.

I previously identified three user groups: course developers, instructors, and students. Each has a unique perspective and role in my problem of practice. Course developers and instructors are interested in the educational outcomes of their courses. The course developers need to balance the generation of authentic data in these courses with the educational outcomes of the Foundations lab courses. Instructors administer and teach the courses. Both groups have contributed to the development of this research through previous semi-structured and empathy interviews. There is a strong interest in my research and change ideas by both to improve our students' educational outcomes.

The student user group is the group I have the least understanding of but my problem of practice directly impacts them. When class-wide discussions are limited and superficial there is limited opportunity to learn from peers' perspectives or practice with scientific argumentation.

I have a minimal sense of students' perspectives from preliminary survey data collected in April 2022. The sample size of this survey is small (n=21) but provides some telling insight. Most respondents identified data analysis and small-group discussion as the more important phases of the lab meeting, aside from the class-wide discussion. Student survey data also indicated that the data analysis was the most challenging aspect of the lab meeting.

Despite the emphasis on data analysis, there was an appreciation for the class-wide discussion component of the lab meeting. Student respondents agreed or strongly agreed with statements that tied into the benefits of shared perspectives resulting from the class-wide discussion: “Seeing how other students discussed data helped me to think about data” and “The discussion helped me to better understand trends in data.” Additionally, student respondents seemed to agree with the premise that class-wide discussion allows them to engage in scientific argumentation: “Engaging in this discussion helped me apply skills employed by research scientists” and “Engaging in discussion about data helped me to feel more confident supporting my thoughts with data.”

2.4.8 Data Collection

Data was collected from various user groups interconnected to my problem of practice using the inquiry tools introduced above (Appendices A, B, & C). Data was obtained from the three identified user groups: course developers, instructors, and students. Data was collected from the student user group through Qualtrics surveys following each lab meeting of the semester and interviews with select students in the following semester. Data was obtained from the course developer and instructors through journals and focus group interviews following each lab meeting.

I collected both quantitative and qualitative data. The student surveys and instructor journals contributed to both data types, while the focus group interviews and student interviews contributed qualitative data.

2.4.8.1 Quantitative Data

I took participation measures from the student surveys and prepared graphical representations of this data as appropriate. I also used the scoring rubrics included with the journaling worksheets provided to instructors and modified from Berland and McNeill (2010). This allowed me to generate quantitative comparisons across the lab meetings during the Fall semester.

2.4.8.2 Qualitative Data

Qualitative data from student surveys, instructor journals, focus group interviews, and student interviews were collected to address my inquiry questions. This allowed me to gain insight into each groups' sense of participation changes, discussion quality, and the overall educational benefits of the class-wide discussion. This data also provided insight into my change ideas' effectiveness in class-wide discussions.

2.4.9 Data Analysis

2.4.9.1 Quantitative Data.

I obtained demographic data from the Dietrich School of the University of Pittsburgh for students completing BIOSC-0057. This demographic data was compared to demographic data from each lab meetings' student Qualtrics surveys. I used a Z-proportions test to determine if the student survey data was reflective of the student population.

I calculated the response rate for each lab meeting survey to understand how generalizable the survey results were in context of the student population. The response rate was calculated by taking the number of respondents on the survey and dividing by the enrollment number during the week of the lab meeting. Instructors released the surveys after the lab meeting which were introduced with student homework for the following week.

I analyzed additional quantitative data collected from the Qualtrics surveys and from physical copies of instructor journals using descriptive statistics. These were compared to address the improvement measures and inquiry questions.

2.4.9.2 Qualitative Data.

I conducted focus group interviews and student interviews via Zoom and transcripts were produced. These transcripts often contained multiple errors, so they were then checked and edited as necessary against the recording to ensure accuracy. After transcribing all focus groups and student interviews and reviewing open-ended survey responses and instructor journal entries, I began analyzing the qualitative data using multiple coding cycles. The first cycle of coding utilized the elemental method of In Vivo coding (Saldaña, 2016). In this coding process, I reviewed the data sources several times and grouped participants' words into appropriate codes to convey themes and relevant trends emerging from their responses.

Moving into additional cycles of coding I utilized Pattern Coding which allowed me to generate condensed and meaningful units from the In Vivo cycle for analysis (Saldaña, 2016). This allowed me to compare impacts of the improvement cycles across user groups and generalize patterns. As I engaged with the qualitative data, I made additional commentary and summary while also revisiting initial codes. From these notes pattern codes emerged representing commonalities and outliers from participants in the improvement cycles.

2.4.10 Institutional Review Board

This research was exempted from needing Institutional Review Board approval by the Human Research Protection Office of the University of Pittsburgh on August 8, 2022.

3.0 Results

3.1 Participants

3.1.1 Instructional Team

The course ran with 16 total sections meeting Monday through Friday with the first lab sections beginning at 8:30 AM and concluding at 9:05 PM. These 16 sections were taught by one course developer with two sections, one lab instructor II with two sections, a lab instructor II with four sections, a lab instructor I with four sections, and a visiting lab instructor with four sections. The instructional team was 80% female and 20% male, 80% white and 20% Asian. Each instructor will be recognized using pseudonyms.

The course developer, Holly Narcissus, taught two sections of the course. They have formal training primarily in molecular and developmental biology. They have taught at the college level in some capacity for six and a half years. They worked to develop this course and have taught it for four semesters.

The lab instructor II, Helia Anthus, taught two sections of the course. They have formal training in ecology, evolution, and science education. They have taught at the college level for 11 years and have taught this course for two semesters.

The lab instructor II, Bombus Terricola, taught four sections of the course. They have formal training in biology with a focus in ecology. They have taught at the college level for 10 years and have taught Flower Microbiome for two semesters.

The lab instructor I taught four sections of this course. They have formal training in biology with a focus in ecology, evolution, and wildlife management. They have taught in some capacity at the college level for 12 years and have taught this course for three semesters.

The visiting lab instructor, Rudbeckia Hirta, taught four sections. They have formal training in biotechnology, environmental engineering, and biology. This instructor has 10 years of teaching experience at the college level, and this was their first semester teaching Flower Microbiome.

3.1.2 Students

Class meetings for this course began Monday, August 29th, 2022, and at the start of the semester all sections of the course were full (20 seats available in each section) with a waitlist. After the add/drop period concluded (Friday, September 9th) all sections were full and there were 320 students during the survey period for lab meeting #1. There was an extended withdrawal period that concluded Friday, October 28th, which led to a reduction of students in the course. By the conclusion of the semester 11 students had withdrawn and the final enrollment was 309 students. Student demographic was data provided by the Dietrich School of Arts and Sciences for the students who completed the course.

The demographic composition from university records indicates that the student body consisted of students who self-identified as female 28.8%, male 10.0%, non-binary 1.0%, with 60.1% preferring not to answer or left the information blank (Table 2). Students self-identified as Asian 19.9%, Black/African American 4.6%, Hispanic/Latino 8.2%, Multi-Racial 3.3%, white 51.0%, and 13.1% preferring not to answer or left the information blank. The majority of students who completed this course were not first-generation college students (65.0%), with 13.7% self-identifying as first-generation college students and 21.3% preferring not to answer or left the information blank.

Table 2. Demographic Information for Students Enrolled in Study Course.Information provided for students completing BIOSC 0057 Flower Microbiome in the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

Gender	Sample	Percentage
Female/Woman	88	28.8
Male/Man	31	10.0
Non-Binary	3	1.0
Unknown/Not Specified	184	60.1
Racial Group		
Asian	61	19.9
Black/African American	14	4.6
Hispanic/Latino	25	8.2
Multi-Racial	10	3.3
White	156	51.0
Unknown/Not Specified	40	13.1
First Generation		
First Generation	42	13.7
Not First Generation	199	65.0
Unknown/Not Specified	65	21.3
Total	306	100

3.2 Lab Meetings

3.2.1 Lab Meeting #1

The first lab meeting occurred during the week of October 3rd through the 7th and conceptually focused on data about the UV regions of the flower petals collected by the students. I introduced the intervention and provided introductory slides to the instructors during our normal instructor meeting on Friday, September 30th. The instructors incorporated their slides as they prepared their teaching materials. All instructors delivered the introduction in a similar fashion with one exception. In one section Rudbeckia led a discussion and asked students what they thought the goals of a lab meeting were prior to introducing the provided slides explicitly stating both research goals and educational goals and how to structure a scientific argument.

Students engaged in all phases of the lab meeting beginning with data analysis. The course developer implemented a new structure for the data analysis phase. Students engaged in a “Jigsaw” activity (description in Amedu, 2015). They were placed in their flower groups with each group tasked with generating one of the analyses and visualizations of data. Students then returned to their bench team to share each analysis. In previous semesters bench teams would do all of the analyses. The approach using the Jigsaw freed up time that was then dedicated to small-group and class-wide discussion.

After the discussions, students were invited to complete the survey reflecting on their experiences in the lab meeting. Students were also given two points for completing the survey and providing a screen capture of the “thank you” message at the end of the survey. Surveys were available to students after their lab meeting with the survey window was ending on October 14th, 2022. I received 336 survey responses from lab meeting #1. Instructors completed journal entries right after their section, and the focus group meeting was held during the instructor meeting on October 7th, 2022.

3.2.2 Lab Meeting #2

The second lab meeting occurred during the week of November 14th through the 18th and focused on data of the students' UV tolerance assay of their isolated bacteria. The intervention for this lab meeting was the use of teacher noticing to foster the development of student authority. The instructional team was presented with this tool during the instructor meeting on Friday, October 28th, and utilized it during the two-week period leading to the second lab meeting.

Students engaged in the lab meeting, which maintained the Jigsaw structure for the data analysis portion. For this lab meeting one section did not get a chance to complete the small-group and class-wide discussion portions due to a fire alarm being pulled in the building.

Students were then invited to complete the survey reflecting on their experiences in the lab meeting. Surveys were available to students after their lab meeting and the survey window was extended to November 24th, 2022. The section that missed the discussion portions of the lab meeting were not invited to participate, lowering the number of surveys completed for this lab meeting. I received 290 survey responses from lab meeting #2. Instructors completed journal entries right after their section and the focus group meeting was held during the instructor meeting on November 18th, 2022.

3.2.3 Lab Meeting #3

The third and final lab meeting occurred during the week of November 28th, through December 2nd, and focused on sequence data and the identification of their bacterial isolates. The intervention for this lab meeting was the use of teacher-as-partner to foster the development of student authority. The instructional team was presented this tool during the instructor meeting on Friday, November 11th, and utilized it during the discussions of lab meeting #3. This intervention was short due to the limited time between lab meetings #2 and #3. The students were away on Thanksgiving break between the two lab meetings.

Students engaged in the lab meeting, which maintained the Jigsaw structure for the data analysis portion. Students were then invited to complete the survey reflecting on their experiences in the lab meeting. Surveys were available to students after their lab meeting and the survey window extended to December 9th, 2022. I received 303 survey responses from lab meeting #3. Instructors completed journal entries right after their section and the focus group meeting was held during the instructor meeting on December 2nd, 2022.

3.3 Relevance of Student Survey Data

I summarized the demographical data provided from the university from enrollment records of the courses and the survey data (Table 3). Using a Z-test for proportion I found there to be significant differences between the university's student data and survey data for gender identities of male and female but not for non-binary identity. The male and female identities were significantly underrepresented in the university data compared to the self-reported data in the surveys. I suspect this is likely due to the number of entries omitted in the enrollment data. There were no significant differences in any of the racial/ethnic categories or the first-generation college student category. I am assuming that the survey data represents the population of students enrolled in BIOSC 0057 Flower Microbiome with the differences in gender categories resulting from the incomplete record.

Table 3. Comparisons of Demographic Information from Univeristy Records and Student Self-Reporting in Survey Data.Data included from University records of students completing BIOSC 0057: Flower Microbiome and demographic data from lab meeting surveys collected during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

Gender	Enrollment Data (%)	Lab Meeting #1 (%)	Lab Meeting #2 (%)	Lab Meeting #3 (%)
Female/Woman	28.8	62.1	66.9	64.1
Male/Man	10.0	32.8	29.7	33.2
Non-Binary	1.0	1.8	1.4	1.3
Unknown/Not Specified	60.1	3.3	2.1	1.3
Ethnic Group				
Asian	19.9	26.0	24.1	26.2
Black/African American	4.6	6.0	6.2	6.0
Hispanic/Latino	8.2	5.1	6.2	6.0
Multi-Racial	3.3	n/a	n/a	n/a
White	51.0	58.2	59.3	58.1
Unknown/Not Specified	13.1	5.1	6.2	6.0
First Generation				
First Generation	13.7	20.6	16.9	18.3
Not First Generation	65.0	77.3	80.3	79.7
Unknown/Not Specified	21.2	2.1	2.8	2.0

The response rates were high aside from the strong similarities in the demographic composition between the university's provided demographic data and how student chose to identify on the demographic questions on the post-lab meeting surveys. The response rate for lab meeting #1 was actually above 100%, indicating some students took the survey more than once. Lab meeting #2 had a response rate of 93.8% and lab meeting #3 had a response rate of 98.1%. These high completion rates allow for me to generalize the following findings to the course population at large.

Coming back to lab meeting #1, there were 16 surveys completed above the 320 students enrolled at the time. However, there were a number of entries in the survey data that were incomplete. Sometimes only demographic information was provided. Other times whole sections of questions were incomplete. As I conducted the analysis on subsets of data the totals did not exceed 320. Based on this I am not worried about the survey data being skewed or not reflective of the course population.

3.4 Improvement System Measures

3.4.1 Outcome Measures

Outcome measures are used to detect if the improvement measures are moving the system toward the aim (Hinnant-Crawford, 2020). One of my outcome measures was an increasing number of students responding "yes" to participating in the class-wide discussion phase of the lab meeting. As the samples were uneven, I made comparisons using the percentages. In lab meeting

#1 83.6% of respondents selected "yes" that they had participated in the discussion, lab meeting #2 had 77.9%, and lab meeting #3 had 84.7% (Fig. 2).

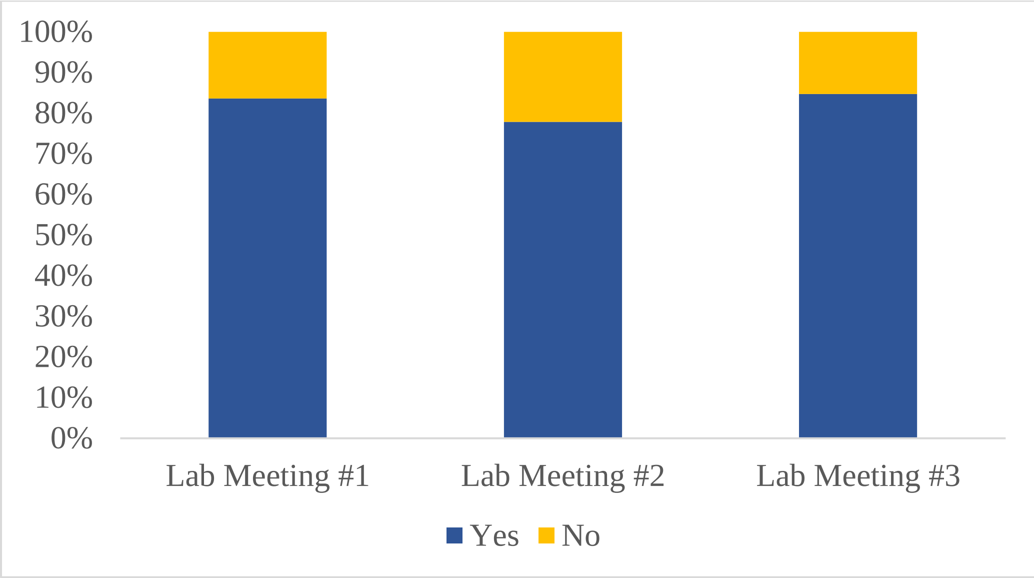


Figure 2. Percentages of Students That Vocally Participated in Class-wide Discussion.Percentages of students responding yes or no to vocally participating during the class-wide discussion portion of the lab meeting activity during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

In addition to simply tracking "yes" or "no" indications of participating, I wanted to see if students were participating in these class-wide discussions based more on an interest/desire to engage and less than it being required for points, as the structure of this course activity awards points for verbal participation. Students agreeing or strongly agreeing that their participation was driven by earning the points with the activity were 72.7% for lab meeting #1, 80.1% for lab meeting #2, and 78.3% for lab meeting #3 (Table 4). The trends for this Likert scale option did not vary drastically.

Table 4. Data for Understanding Why Students Participated in Class-wide Discussion for Associated Points.Likert scale reporting for questions designed to understand why students participated in the class-wide discussion portion of the lab meeting activity during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

Prompt	Likert Scale	Lab Meeting #1 (%)	Lab Meeting #2 (%)	Lab Meeting #3 (%)
"It was required for points"	I strongly agree	30.1	37.1	36.2
	I agree	42.6	43.0	42.1
	I neither agree or disagree	15.8	16.3	15.7
	I disagree	7.8	2.7	3.2
	I strongly disagree	3.7	0.9	2.8

There were other Likert scale questions addressing why students chose to participate that asked about engaging with other ideas or teams. The responses to these other Likert questions also did not change drastically across the three lab meetings (Fig. 5). Across all three lab meetings the trends seemed to remain the same with students indicating they engaged in the class-wide discussion for three primary reasons: it was required for points, they wanted to ask another research team a question, and having an idea they wanted to share inspired by another research team. Generally, students did not engage to disagree with other teams.

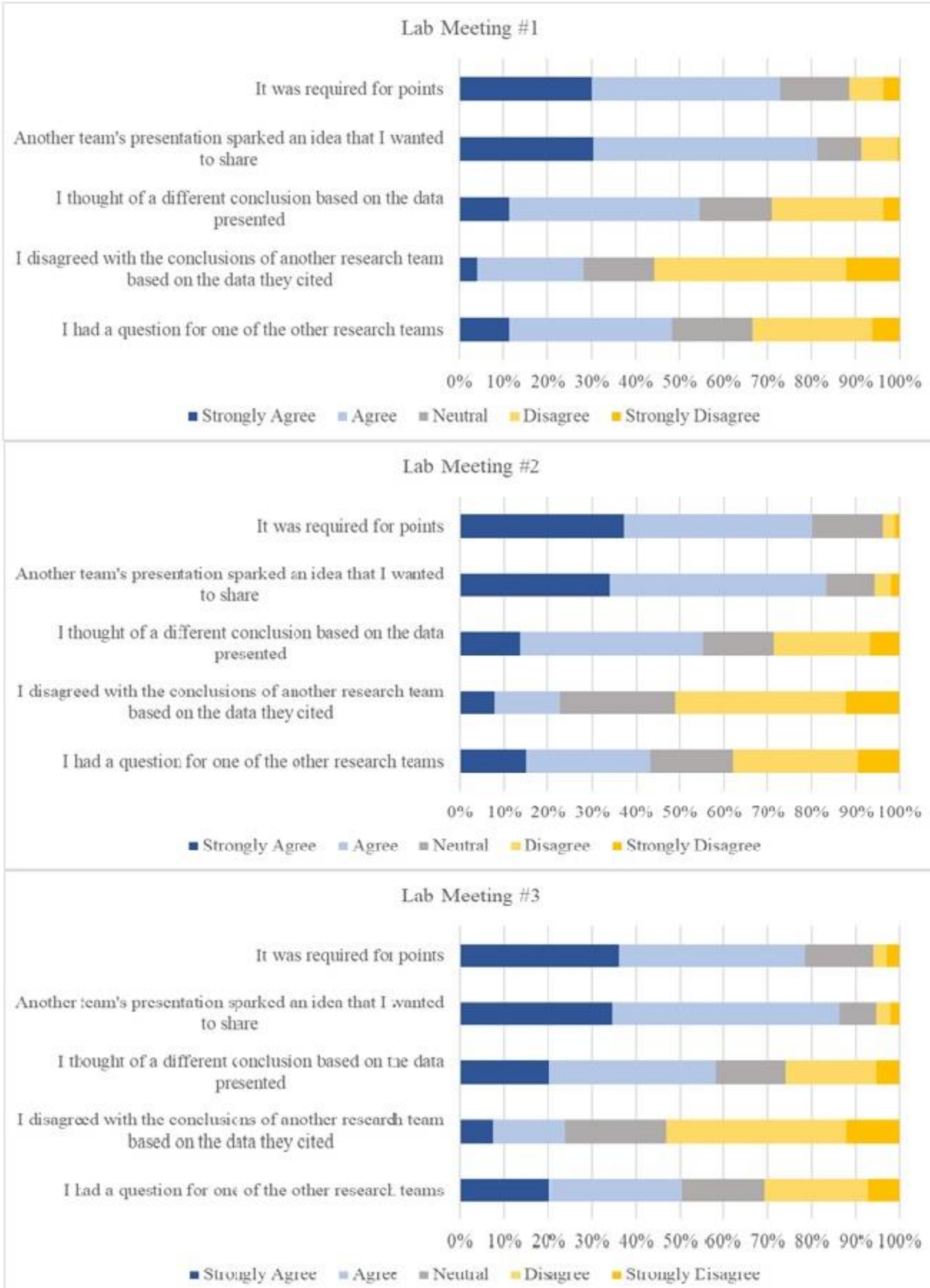


Figure 3. Data Attempting to Understand Why Students Participated in Class-wide Discussions.Likert scale reporting for questions attempting to understand why students participated in the class-wide discussion portion of the lab meeting activity during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

Another outcome measure was taken from the scores on the rubrics provided to instructors gauging student engagement and the use of scientific argumentation. Based on the averages scores, engagement for lab meeting #1 was 2.2 and lab meetings #2 and #3 both had an average of 2.5 (Fig. 4). When considering the mode, the most frequently selected option for lab meeting #1 was 2 while lab meetings #2 and #3 had modes of 3. The second category was used for “Student participation in argumentative discourse is prompted by instructor and other student arguments” while the third category was “Students engage in argumentative discourse without prompting from instructor.” Thus, lab meetings #2 and #3 were most often characterized by students engaging in discourse without instructor prompting.

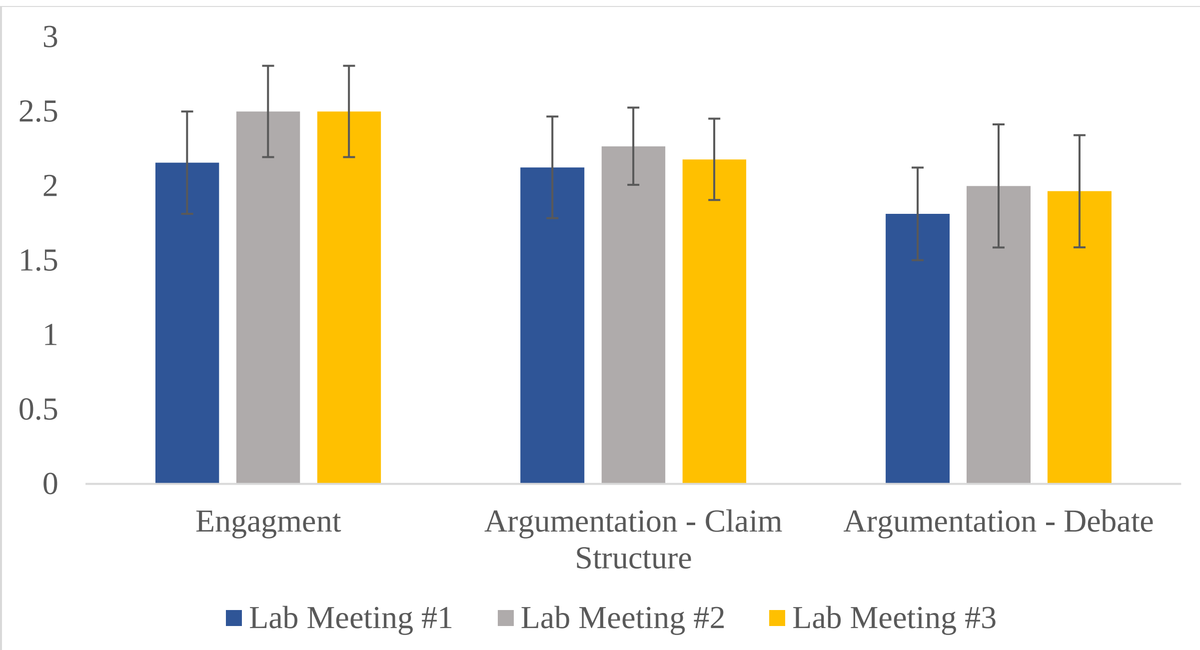


Figure 4. Data Describing the Engagment and Complexity of Argumentative Claims During Lab Meetings.Averaged data from the scoring rubric measuring engagement and the complexity of student argumentative claims during the class-wide discussion portion of the lab meeting activity during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

Note: Error bars represent the 95% confidence interval.

Instructors also used the rubrics to score the levels of scientific argumentation used in the class-wide discussion. The rubric scored argumentation on two criteria, the structure of individual students' scientific argument claim structure and the debate of these ideas between students. The claim structure is addressing the scientific question with a claim that includes data support and insight into the reasoning of the argument. The second aspect, debate, occurs as students engage with other students' claims and evaluate them. In both cases there was a slight increase in lab meeting #2, with averages of 2.3 and 3 (Fig. 4), but these were not significant. The scores for lab meeting #1 were 2.1 and 1.8 respectively and lab meeting #3 saw averages of 2.2 and 1.9 respectively.

The mode for all three lab meetings were 2 for both categories. The second scoring option for the claim structure was "Claims are defended with appropriate evidence" but lack insight to the reasoning of the how the data supports the claim. While the second scoring option for the debate of scientific arguments was "Claims are articulated, defended, questioned, AND evaluated" but fail to revisit and revise initial claims.

From the quantitative data collected to evaluate movement towards my aim (Fig. 1) there was no significant improvements resulting from the interventions. Though there is a weak case for increasing engagement in lab meetings #2 and #3 if considering the increase to 3 for the mode of the reported data. I will next investigate qualitative data collected from instructor journals and focus group transcripts.

When considering the outcome measures a common theme that emerged from the focus group transcript and journal entries from lab meeting #1 were improvements in engagement. Bombus Terricola stated "…that's probably the best class discussion I've had…" which was coded in my coding scheme as "good class-wide discussion." This code came up a number of times throughout the focus group transcript. From one of the journal entries, Holly Narcissus noted "it was the best lab meeting I've ever run! Students were engaged and ran it themselves!" Helia Anthus noted in their journal "only students talking and they really did use their data as evidence…"

Even considering later focus group discussions, the importance of the explicit framing came up as a meaningful intervention improving class-wide discussion. During the focus group from lab meeting #2, Bombus Terricola noted "I think … the earlier intervention … 'this is how you make an argument' I think that was still … more of a substantial …factor." Helia Anthus also stated "I didn't take that time to 'let's recall and argument' and … what pieces we should have whenever we're using … an argument. I feel like the discussion in both cases, even the really good discussion suffered because of that." There were additional references to explicit framing and even calls to utilize the approach with specific examples for each lab meeting of the semester.

Despite the general consensus that explicit framing of the lab meeting and scientific argumentation were beneficial some trends emerged in both the focus group transcript and journal entries that it was not uniformly effective. There seemed to be some strong differences across sections. For example, I noted on the lab meeting #1 journal "[I] felt like there was no buy-in… the class did not engage…discussion would occur when prompted and might bounce to another student or two but would drop back into silence." Another instructor, Bombus Terricola noted "[w]hile this group was less enthusiastic than the other section, I think they still got a lot out of it." Rudbeckia Hirta noted in the lab meeting #1 focus group that "…it depends on the section…quieter people were always quiet, so I have to push them."

The interventions working to foster the development of student authority by utilizing teacher noticing and the teacher-as-partner model did not seem to be effective. In the focus group transcripts and journal entries instructors did not feel these were effective in increasing participation and engagement in the class-wide discussion. Despite finding the practices of noticing and teacher-as-partner not effective at changing participation levels the instructional team felt these were good pedagogical tools. Holly Narcissus noted "I can't say … no this technique doesn't work, I still find it valuable, … even outside of lab meeting discussions." There was a clear sense that other changes to the lab meeting structure, the jigsaw, explicit framing, having students form a circle and remove ourselves as instructors, and the natural progression of the students, were more important in altering student engagement in class-wide discussion and developing with scientific argumentation.

3.4.2 Driver Measures

My driver measures were linked to the drivers of my aim statement (Fig. 1) and I was focused on the drivers of "Classroom Engagement" and "Student Authority." There is some overlap with the outcome measures, namely the response rates of students indicating their participation and the scoring rubrics from instructor journals, when addressing classroom engagement and there was not drastic change in those parameters, as mentioned above.

Despite the lack of quantitative data to support either the outcome or driver measures, with a focus on classroom engagement there were some trends that emerged in the qualitative data. Instructors generally noted that the first intervention seemed to change the dynamic and increased the willingness of students to engage in the class-wide discussion. Holly Narcissus noted "I've never introduced it to the extent that it was this week but I did find there was a little bit more of an attitude change [compared to previous semesters] … the energy was a little bit better…" They went on to expand that students saw the activity as a means to support them in better understanding the data and not some arbitrary activity to earn points. The other instructors agreed with this point and brought it up again on several instances throughout the lab meeting #1 focus group. This attitude shift did seem to correlate with increased participation compared to earlier experiences with teaching lab meetings in this and other Foundations lab courses.

I addressed increases in “student authority” by considering their confidence to engage in the class-wide component of discussion. For this parameter I compared the number of students who selected “no” to participating in class-wide discussion and diving into the Likert scale data. There were two Likert scale questions I measured to address student authority: “I do not feel comfortable speaking up in class-wide discussions” and “I do not feel confident in my answers to engage in the discussion.”

In the survey data from lab meeting #1, 54 students responded that they had not participated. When looking at their Likert scale responses 48.1% stated they strongly agreed and 38.9% agreed that they were not comfortable speaking in class (Table 5). This parameter dropped to 34.9% and 31.7% in lab meeting #2 but increased to 37.0% and 39.1% in lab meeting #3. Another related Likert scale question had to do with confidence in their answers to engage in the discussion; in lab meeting #1 18.5% of respondents strongly agreed and 51.9% agreed. These values saw some change in later lab meetings, 21.3% and 42.6% in lab meeting #2 and 15.6% and 40.0% in lab meeting #3, but nothing drastic (Table 5).

Table 5. Data for Understanding Student Authority and Lack of Participation Class-wide Discussion.Likert scale reporting for two select questions attempting to understand why students did not participate in the class-wide discussion portion of the lab meeting activity during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania

Prompt	Likert Scale	Lab Meeting #1 (%)	Lab Meeting #2 (%)	Lab Meeting #3 (%)
"I do not feel comfortable speaking up in class-wide discussions"	I strongly agree	48.1	34.9	37.0
	I agree	38.9	31.7	39.1
	I neither agree or disagree	5.6	11.1	10.9
	I disagree	5.6	12.7	10.9
	I strongly disagree	1.9	9.5	2.2
"I do not feel confident in my answers to engage in the discussion"	I strongly agree	18.5	21.3	15.6
	I agree	51.9	42.6	40.0
	I neither agree or disagree	18.5	14.8	17.8
	I disagree	7.4	16.4	22.2
	I strongly disagree	3.7	4.9	4.4

3.4.3 Process Measures

My process measures simply consisted of checking the numbers of students selecting "yes" to participating in the class-wide discussion phase of lab meeting between interventions and the corresponding lab meeting. While tracking these through the semester there were no drastic changes in students self-identifying as participating in lab meeting class-wide discussions (Fig. 2). This information was reported to instructors during the instructor meeting when introducing the intervention for the next lab meeting. There were no significant changes in the process measures.

3.4.4 Balance Measures

The balance measures focus on balance within the system, an improvement cannot destabilize the system and still be an improvement (Hinnant-Crawford, 2020). For this measure I primarily was interested in responses of the instructors on the journal worksheets completed after the lab meeting and themes that emerged during focus group discussions. Generally, instructors did not feel the interventions were challenging or demanding of their time.

Of the sixteen journal entries for lab meeting #1, the “yes” response was circled in five (31.2%) occurrences to the question “Did the introduction of the lab meeting and scientific argumentation impact your ability to successfully facilitate the lab meeting?” In four of these instances the instructors noted positive outcome, indicating that the introduction made it more successful. In the remining case the instructor noted the introduction took longer than anticipated while they were already behind, thus reducing time for student discussion.

The practice of teacher noticing was similar in which instructors did not find the practice demanding of their time to prepare or teach the class. There were actually three instructors who utilized this practice previously. Bombus Terricola indicated “I think that a lot of us were already … doing that [but] I certainly tried to increase the frequency of it.” Some of the instructors even noted they did not know there was a name or pedagogy behind using their students’ names but did it instinctively.

The teacher-as-partner model had similar feedback, where instructors did not find it demanding and three instructors were already using a similar approach, often describing themselves as a “guide” to their students through this authentic research experience. Despite viewing themselves as a guide to students there was some dissent about the use of specific pronoun usage. Tabak and Baumgartner (2004) describe pronoun usage of “we” in teacher’s language as a signal to students that they are partners in investigation and this shift in language was the focus of this intervention. One of the instructors noted that using “we” language may actually detract from building ownership of the research and data generated by students. They often would use “we” language when framing classes and activities but, prior to the intervention, would use “you” language when discussing the students’ data. This was intentional to help foster authority in the students.

Overall, the general trends are that these interventions were not harmful or destabilizing to the system but generally good pedagogical tools that the instructional team thought were beneficial to the class. On a journal entry from lab meeting #2 Holly Narcissus noted “I did try to use [teacher noticing] in the previous two weeks but think it would be more effective if I would have tried to incorporate it earlier.”

3.5 Inquiry questions

3.5.1 How and what ways do instructors and students view the use of robust, student-centered discussion in supporting student learning and developing science skills (practicing scientific argumentation and putting thinking on display)?

3.5.1.1 Instructors.

Generally, the instructional team believes in class-wide discussion as a means to support learning in these authentic research-based lab courses. The instructional team for this course, but also the Foundations of Biology lab instructors at large, feel that this is an important activity to support critical thinking about data, trends in that data, and how we can draw conclusions about scientific research questions.

In these Foundations courses time is always an element in short supply. We need to develop numerous skills with our students, but the central focus is normally on technical skills which sometimes leads to a loss of time for discussion. The course developer, Holly Narcissus, reflected in the focus for lab meeting #1 that dedicating time to these types of things is important.

> I think, that the combinations of, different factors introducing the lab meaning like we did, in the scientific argumentation, the data analysis, the jigsaw aspect of it, the small group work to get them to talk about something. Hopefully that then facilitated more of a discussion in a large group. I think I liked the format of that, and I'm … as a course developer… I dedicated the time to be able. Because I feel like last year, and we didn't have the time to talk about the data. And that was one of my goals. Is that to be able to have the time to not only generate a graph, but then have them talk about what it means, and so that part definitely. Because again we're restricted, not just the 'out of time' [but] the number of times we meet with them, and all the data that we want to get through. It's just… I'm glad that this semester especially that we've really tried to focus on being able to, like [Helia Anthus] said, devote the time to some of these practices, which I think is super important. So, I feel like that's half the battle for Foundations labs is just; do we have the time to input these interventions into place and to see but that they have a meaningful effect.

Generally speaking, the instructional team wanted to provide time for discussions and really wanted to see robust-student centered discussion and were excited when they did see it emerge. Bombus Terricola summed it nicely, stating “I do think … scientific argumentation and talking like is … part of this process [engaging in scientific research], and it's important for critical thinking.”

3.5.1.2 Students.

The student surveys from each lab meeting concluded with a series of Likert scale questions assessing the value that students found in engaging with the class-wide discussions. These questions included: “The discussion helped me to better understand trends in data,” “Seeing how other students discussed data helped me to think about data,” “Engaging in discussion about data helped me to feel more confident supporting my thoughts with data,” and “Engaging in this discussion helped me apply skills employed by research scientists.” On the survey for lab meeting #3, the final lab meeting I also added another question, “Engaging with the lab meetings throughout the semester has helped me to feel more confident in using scientific argumentation.”

The students overwhelmingly agreed or strongly agreed with these statements (Fig 5). The average positive results for all prompts for lab meeting #1 was 78.5%, lab meeting #2 78.0%, and lab meeting #3 81.2%. While negative responses, strongly disagree or disagree where always less than 8% of survey respondents.

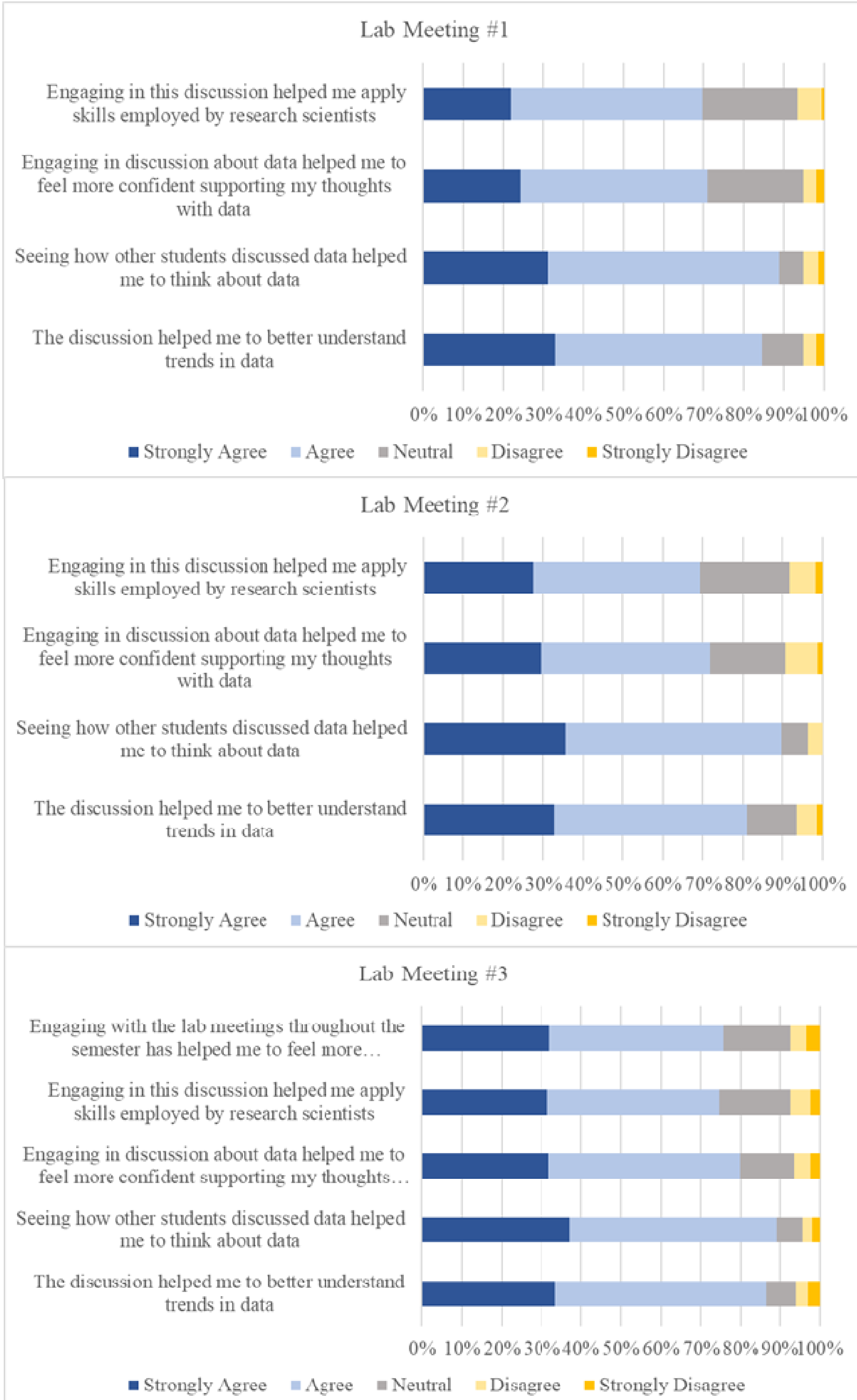


Figure 5. Data Describing the Perceived Educational Value of Class-wide Discussions.Likert scale reporting for questions attempting to understand if students felt class-wide discussion was beneficial to their lab experience during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

I also had a chance to interview four students after the Fall semester had concluded. These four students had little or no participation in the class-wide discussion component of the lab meetings and suffered a deduction of participation points. Despite not participating and being penalized all four stated that the conversations were beneficial. One of these students stated, “listening to others is definitely helpful to me, because not everyone thinks the same way, obviously. So, like some students, answers I’d be like, oh, like, yeah, it's a good perspective, like I didn't even think of that.” This sentiment of engaging with and framing their own thinking was common in all four student interviews but was also a theme that emerged in student responses on the lab meeting surveys.

When considering comments left by some students in the surveys, the qualitative data supports the quantitative in that students find the class-wide discussions beneficial. A few patterns seemed to emerge: students enjoyed experiencing others’ perspectives, they gained a deeper understanding of the data and trends, and it was a platform where they could ask questions and practice scientific communication.

There were several comments indicating that the lab meeting was a positive experience. One student left a comment on the lab meeting #1 survey. “Science is really interesting and I love talking so having this discussion was actually pretty fun and informational!” Another student from lab meeting #1 stated “[t]he lab meeting was an interesting and enriching experience for me!” From the final lab meeting’s survey, a student noted “I enjoy hearing all the perspective in a class-wide discussion, it makes research more interesting.”

In addition to enjoying engaging with the lab meeting some students noted benefiting from experiencing other perspectives. “I love to hear other's opinion on the data, especially those that inspire me or from a different perspective that I have not thought of,” a student commented on the lab meeting #2 survey. Additionally, a student who did not contribute said “[a]lthough I did not speak, I felt as if hearing others peoples [SIC] ideas had increased my knowledge of the topic on hand.” A student stated on the lab meeting #3 survey, “I think they are helpful when it comes to recognizing trends in class and course-wide data. I actually wish we had more time for these meetings at times because my peers bring up points that I haven't thought about before.”

Some students used the class-wide discussion as a platform to address questions or concerns they had with the data. From the lab meeting #2 survey a student noted, “I wanted to make sure my understanding of the charts was correct.” Another student stated, “I wanted to ask everyone a question about the validity of our results.”

There were also some students noting it was a place for them to practice and develop their scientific argumentation skills. For example, a student noted in the lab meeting #1 survey, “I simply chose to take the opportunity to practice my communication skills in a setting similar to that of an actual research team.” From the lab meeting #2 surveys another student noted, “I appreciated the discussion because [it] allowed me to practice and become more confident in my scientific conclusions. Also, it helped get [me] used to using some scientific terminology and disputing other's points.”

In summary, there seemed to be a number of comments left on the surveys indicating that the lab meeting helped them to gain a better understanding. “I found this one in particular to be very beneficial. It's nice to hear from other perspectives from when dealing with data like this where the trends are not quite as clear,” noted a student on the lab meeting #3 survey. Another student summed it up on the lab meeting #3 survey, “Class-wide discussion helped to bring it all together and solidify the big picture!”

Despite the overwhelming positive responses, there were also dissenting views. A student who strongly disagreed with evert Likert scale question gauging the value of the lab meetings left this comment on the lab meeting #3 survey: "The class wide discussion is just students repeating each other for 45 minutes, I only spoke to get points I didn't say anything that was new to the discussion." Additionally, another student added "class wide discussions aren't helpful. we all know the information already, but are forced to say it in front of the whole class and this gives many people loads of anxiety for something that doesn't make a difference" on the lab meeting #3 survey. The sentiment for these and other such comments seemed to indicate that the conversation provided nothing new for students to think about.

3.5.2 How and in what way does explicit instruction of the educational and research goals of the lab meeting aid in fostering student willingness to engage in the class-wide discussion portions of the lab meeting?

The instructional team seemed to find that explicit framing of the lab meeting helped to improve the overall quality of this activity. Many of the instructors in the focus group and journal entries from lab meeting #1 indicated this was a good lab meeting and improvement over lab meetings from earlier courses they have taught with the Foundations program. Bombus Terricola noted, "I do feel like there was a difference in energy and … class-wide discussion …a lot more energy," during the lab meeting #1 focus group. This response was coded as "Attitude Shift" which was a code that came up many times during the focus group interview.

The four instructors who had taught Flower Microbiome previously also consistently noted improvements in engagement and attributed this to students having a clear sense of the expectations. Helia Anthus stated,

> I felt like they were given the tools they needed to be successful in this type of discussion. I think we sometimes have a tendency to assume they already know how to do these things and they are choosing not to. I believe that is often not the case.

The framing seemed to help better drive student engagement because they saw it as something beneficial and not just an exercise to engage with for points. Holly Narcissus noted during the focus group interview,

> I … saw with some of my students, I would argue, that me introducing it, I did …feel like I saw an effect. Like, I could see their faces when I was talking about lab meeting … [t]he energy was a little bit better like it was, it was different than 'Oh, we have to do this right?' [instead] it was like, 'Hey, this is literally something for me!' This is not just something I'm going to check off. This is going to help [students] going forward, and maybe that's because … I've never introduced it to the extent that it was this week.

Additionally, there were noticeable increases in the use of argumentation in these discussions. Bombus Terricola noted "I do think [introducing] scientific argumentation and talking about it like this … [gave] students more permission to sort of question each other and to explore. When somebody proposed something else maybe explore that with their own data." Helia Anthus noted on the journal that "students knew right off the bat that they were expected to use their data to support their claims so they had their laptops out with the data in front of them." Making the expectations clear about scientific argumentation and introducing it seemed to drive more use of making structured scientific claims. Those claims were often incomplete, but students were making the effort. This supports the educational goal of the class; students' arguments are not expected to be perfect but present. Instructors can provide feedback and work with students to improve as this is a Foundations I level course.

One of the central ways that I wanted to understand if students understood was to compare how students responded to the Likert scale question "I did not understand what was being asked of me." Given the explicit framing the hope was to see low values for this parameter. Of respondents who encountered this question in the survey 0% strongly agreed and 7.5% agreed with this statement (Table 6).

Table 6. Data for Understanding if Students Understood the Rationale for Engaging in Class-wide Discussion.Likert scale reporting for a select question attempting to understand why students did not participate in the class-wide discussion portion of the lab meeting activity during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

Prompt	Likert Scale	Lab Meeting #1 (%)	Lab Meeting #2 (%)	Lab Meeting #3 (%)
" I did not understand what was being asked of me "	I strongly agree	0.0	1.6	2.2
	I agree	7.5	3.2	4.3
	I neither agree or disagree	18.9	22.2	10.9
	I disagree	49.1	52.4	60.9
	I strongly disagree	24.5	20.6	21.7

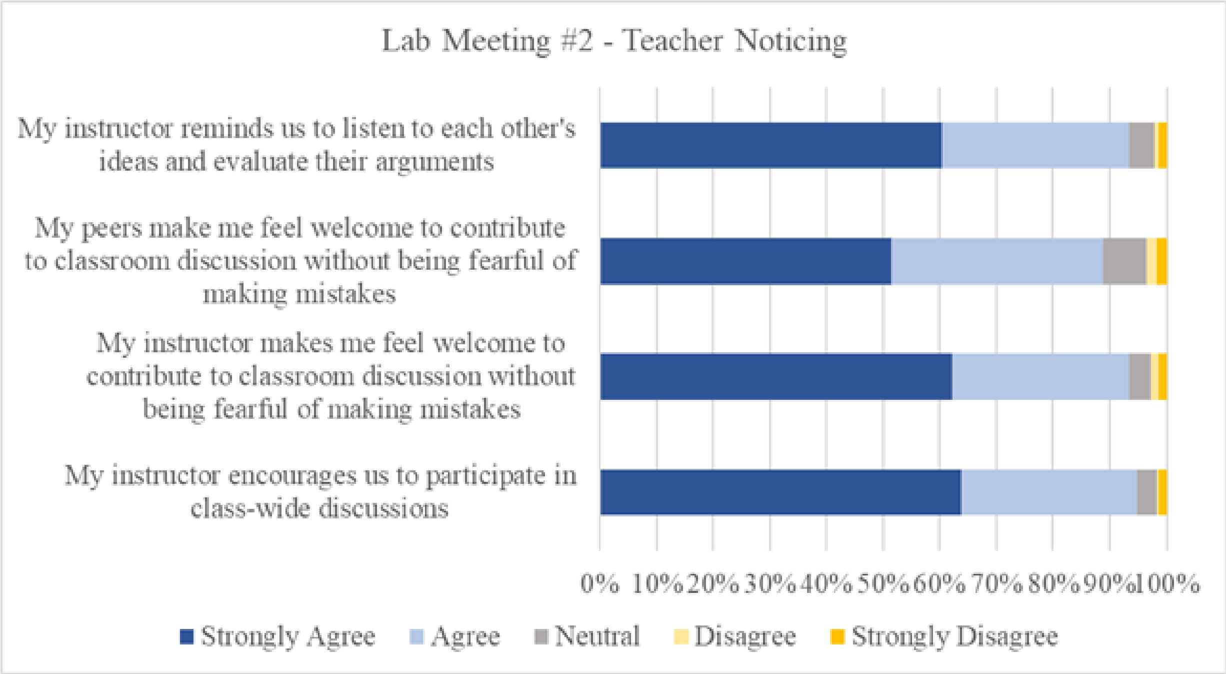
This response tended to increase over the later lab meetings. Lab meetings #2 and #3 did not have as detailed of an explicit introduction and most instructors noted in focus group interviews for those meetings, they wished they had given a brief introduction reminding students of the lab meeting purpose and how to structure scientific arguments.

I did not plan to measure this parameter from the open-ended survey questions available to students as I did not know what types of responses to expect. Based on their responses when provided it seemed most students benefited from the class-wide discussion with several students noting it was beneficial for them to experience other student perspectives and practice scientific argumentation. A student noted, “There is a lot to learn from class-wide discussion, and very interesting/important ideas to dive into” on the survey from lab meeting #1.

3.5.3 How do students respond to the use of teacher noticing and the teacher-as-partner model, does it help to facilitate more student engagement in the lab meeting?

Starting in lab meeting #2 I added a series of Likert scale questions to gauge students’ perceptions of how welcoming the environment was to engaging in conversation. These questions were adapted from Böheim et al. (2021), who used similar questions to understand how students perceived encouragement from their instructors to participate in class-wide discussions. These questions were aimed at understanding if students felt welcome to engage in the conversation and provided the following prompts: “My instructor encourages us to participate in class-wide discussions,” “My instructor makes me feel welcome to contribute to classroom discussion without being fearful of making mistakes,” and “My instructor reminds us to listen to each other's ideas and evaluate their arguments.” There was an additional question regarding the impact of peers, “My peers make me feel welcome to contribute to classroom discussion without being fearful of making mistakes.” Finally, in lab meeting #3, where the teacher-as-partner model was utilized as an intervention a survey question was added, “My instructor is a partner and supports me as I engage in this authentic research.”

Generally, the majority of students responded positively to these prompts, indicating they agreed or strongly agreed with these. When it came to feeling encouraged by the instructor, 94.8% of student respondents had a positive response during lab meeting #2 and 93.3% had positive responses in lab meeting #3 (Fig. 6). Most students felt comfortable with their instructors and not fearful of judgement, lab meeting #2 had 93.3% reported positively and lab meeting #3 91.7% reported positively (Fig 6). During the final intervention the vast majority of students felt their instructor was a partner to them during their research experience with 90.3% reporting positively (Fig 6).



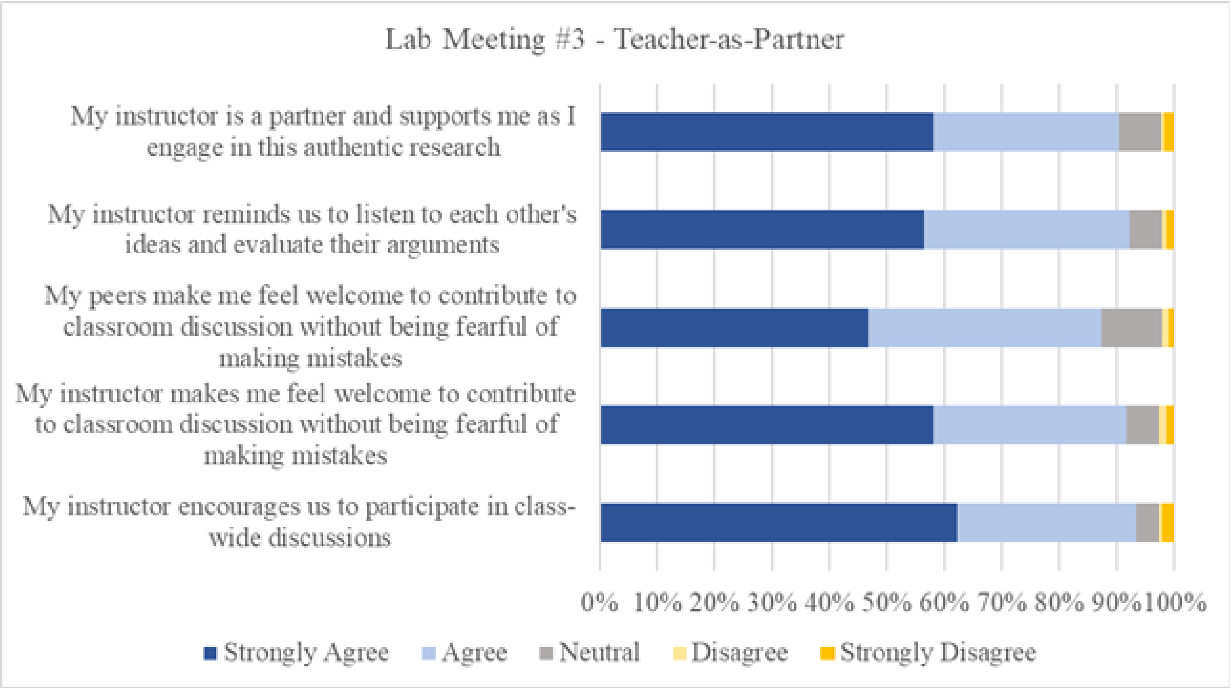


Figure 6. Data Describing Student's Perceived Sense of Comfort to Participate in Discussion.Likert scale reporting for questions attempting to understand if students felt welcome to participate in class-wide discussion during the authority interventions during the Fall 2022 semester. University of Pittsburgh, Pittsburgh, Pennsylvania.

In fact, the student respondents generally scored the instructor high and felt positively about their encouragement and a lack of judgement. Student respondents felt less so about their peers. When responding to the prompt, “My peers make me feel welcome to contribute to classroom discussion without being fearful of making mistakes” the scores dropped. In lab meeting #2, 88.7% responded positively to this statement while in lab meeting #3, 87.3% responded positively (Fig. 6).

Despite these positive responses and feelings of encouragement from their instructors this did not correlate to increases in student participation as noted by the stagnant changes of student response rates to engaging in the class-wide discussions (Fig. 2) and the instructor scoring rubrics (Fig. 4).

4.0 Learning & Actions

4.1 Discussion

4.1.1 Educational Benefits of the Lab Meeting Activity and Class-Wide Discussion

It was apparent from this work that all user groups (course developers, instructors, and students) recognized the benefit of class-wide discussions. This result was not surprising from the faculty users but it was exciting to see the students recognize the importance of the lab meeting and the benefits of class-wide discussion. With 78% or more of the student respondents agreeing that this was beneficial for a variety of reasons (Fig. 5) and the comments left in open-response fields, this activity was clearly beneficial.

It was apparent that students benefitted from the sharing of perspectives, with students overwhelmingly agreeing or strongly agreeing with the survey question "Seeing how other students discussed data helped me to think about data" (Fig. 5). This finding is in line with multiple sources that study dialogic teaching (Böheim et al., 2021; Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Furberg & Silseth, 2022; Shemwell & Furtak, 2010). Opening the space for dialogue allows for there to a rich collection of student ideas and perspectives that the class can then reason and work through (Böheim et al., 2021; Furberg & Silseth, 2022). When students share their arguments with support and reasoning it creates opportunities to explore their ideas, highlight thinking processes, and emphasize their use of the data (Böheim et al., 2021; Ford & Wargo, 2012; Furberg & Silseth, 2022, Lehesvouri et al., 2013; Smith et al., 2011; Tabak & Baumgartner, 2004; Windschitl & Calabrese Barton, 2016). This creates a space for other students to learn from these varying perspectives and to correct inaccuracies/misunderstandings, but this is not possible if discussion does not occur (Lehesvuori et al. 2013; Shemwell & Furtak, 2010; Tabak & Baumgarter, 2004).

Additionally, the four students I interviewed, who did not participate in the class-wide discussion, all noted that they thought it was class time well spent and all four noted that they learned from their peers' unique perspectives. These four students all were engaged in the discussion but they did not contribute and could be considered non-vocal participants as described by O'Connor et al. (2017) and Shi and Tan (2020). These students cited various forms of social anxiety that prevented them from contributing vocally to the discussion but noted they engaged with their small groups and actively paid attention and thought about the ideas from their peers. Despite not vocally participating, these four students enjoyed the class-wide discussion and stated it changed their thinking about the data and trends that emerged. This aligns with the literature in that not all students need to vocally engage in discussion to reap the educational benefits (O'Connor et al., 2017, Shi & Tan, 2020).

O'Connor et al. (2017) also go on to note that instructors should worry less about ensuring each student "gets a turn" to speak in the discussion, as this can be a stress that limits some instructors from utilizing class-wide discussion as a pedagogical tool (Appendix A). It is not important for each student to speak to derive benefit from these discussions. Eliminating the need for each student to speak may also reduce some of the negative reactions noted previously, where students felt the conversations became repetitive.

There were students who clearly linked the activity to practicing science communication during this class-wide discussion as well. A student noted on the lab meeting #2 survey: "I appreciated the discussion because it allowed me to practice and become more confident in my scientific conclusions. Also, it helped [me] get used to using some scientific terminology and disputing other's points." This response was coded as "practicing scientific argumentation" and was not common in the students' open-ended responses, but it did occur on multiple occasions throughout the student survey data.

This student's response contains a lot of information: they practiced argumentation, which reinforced their learning and comfort with specific terminology and increased their confidence/authority. This aligns with arguments presented in the literature. Ford (2008) notes the importance of the construction of arguments as building scientific reasoning and communication skills but goes on to highlight that the critique of peers' arguments is just as important and can aid in the development of authority, which this student seems to be speaking to.

Instructors noted in the focus groups that their students would attempt argumentation, often noting there was not a good balance of using data support and reasoning with their claims with it often skewing more heavily to one or the other. It was clear that there were concerted efforts by students to practice argumentation and the instructors were picking up on and discussing this in their journal entries and the focus group interviews. Helia Anthus discussed in depth an example of their classes' efforts to practice argumentation, "My [one] class was super successful with it. I, like, was almost in tears by the end of it … this was amazing." They generally noted stronger efforts by both sections but saw differences emerge. In one section, "Everything was kind of based on reasoning, but not using their data," while their other section was, "hyper-focused on the data, and just like picking apart the data, and … thinking about it, and just chewing into it, … in really awesome ways."

The effort to see students engage with and practice argumentation was apparent despite the students not necessarily doing it well. This aligns with ideas presented by Windschitl and

Calabrese Barton (2016) that students have a lot of real-world experience, knowledge, and skills but they are underdeveloped and incomplete. It is the role of the teacher to foster the development of deeper scientific understanding and reasoning (Furberg & Silseth, 2022; Windschitl & Calabrese-Barton, 2016). Providing students the space to practice with meaningful feedback is vitally important for them to grow in these skills (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Furberg & Silseth, 2022; Shemwell & Furtak, 2010; Windschitl and Calabrese-Barton, 2016).

This Foundations course is the first of two in the sequence; the goal is to get the students engaged with and build foundational skills in biological science. Therefore, the goal is not mastery but to increase students' familiarity and practice with this form of dialogue. Despite not hoping to achieve mastery seeing some growth in the complexity of argumentation (Fig 1) would have been rewarding. Unfortunately, there was no significant development in the complexity of students' arguments based on the scoring of the Berland and McNeill (2010) rubric (Fig. 4).

Another big takeaway from this research is that students clearly see the benefits of engaging in the class-wide discussion in this research-based science course and that many of those students linked the skill to that of a professional research scientist. On the lab meeting surveys, there was a Likert prompt, "Engaging in this discussion helped me apply skills employed by research scientists," to which the majority of students strongly agreed or agreed: 69.7% in lab meeting #1, 69.4% in lab meeting #2, and 74.5% in lab meeting #3 (Fig. 5). These values do not represent a strong majority but the disagree and strongly disagree values were low, the neutral option averaged 21.4% across the three lab meetings (Fig. 5). Thus, engaging in these discussions and employing scientific argumentation increased their sense of engaging with professional skill.

One of the goals of the Foundations lab program is to develop professional skills and increase the science identity of our students. Based on these results, it seems we are being successful in this goal but also the literature supports these ideals. Hunter et al. (2007) followed students as they engaged in summer research experiences at liberal arts colleges and found that students who engaged with these programs had increases in their science identity but also saw increases in their cognitive abilities. They state that “many students improve their ability to bring their knowledge, critical thinking, and problem-solving skills to bear on real research questions,” which aligns with the mission of the Foundations lab program and our educational goals. (Hunter et al., 2007, p. 45)

The instructors and students clearly see value to engaging in class-wide discussions; it creates a space where students can learn from peers’ perspectives and ways of thinking about the data. This aligns strongly with the literature. Böheim et al. (2021) state, “classroom discourse is especially effective when students have the opportunity to participate actively by sharing different ways of thinking, elaborating on their opinions, and building on each other’s ideas to construct knowledge collaboratively” (p. 1). It also provides space to practice science communication in the form of scientific argumentation. This drives critical thinking as students attempt to create their arguments, selecting data and reasoning how that data supports their claim (Christodoulou & Osborne, 2014; Duschl & Osborne, 2002; Ford, 2008; Ford & Wargo, 2012; Shemwell & Furtak, 2010). Additionally, students are recognizing this practice as a professional skill fostering their science identities and fostering professional skills (Hunter et al., 2007).

4.1.2 Interventions and Their Effectiveness

The goals of this improvement science research were to drive improvements in engagement in the class-wide discussion phase of the lab meeting activity and increase the use of scientific argumentation in that space. Based on my outcome, driver, and process measures, the interventions did not yield clear improvement in the system and there seemed to be no significant movement towards the aim (Fig. 1). The balance measures indicated that the interventions were not demanding of the instructors' effort or time in class and did not destabilize the system. In fact, many of the instructors indicated that they found value in the interventions even if they did not necessarily yield gains in discussion participation or complexity of scientific arguments.

Despite the lack of significant results in the improvement measures there were minor indications of improvement. We also had high levels of participation in class-wide discussions; 83.6% of the students vocally participated in the discussion in lab meeting #1, 77.9% in lab meeting #2, and 84.7% in lab meeting #3 (Fig. 2). The majority of students in the course were vocally participating and based on my discussions with the non-vocal participants there was still engagement with the lab meeting activity. These results taken together may indicate there is limited room for improvement in getting vocal participation. Perhaps future work should shift the focus to improving the quality of argumentation, scaffolding, and feedback to help foster growth of the quality of student arguments.

Finally, since this project was based in improvement science and the interventions were applied to all sections, there was no control data which made it difficult to measure the effects of the first intervention. There was also no meaningful baseline data from previous semesters to compare to. This intervention, being explicit, seemed to be significantly effective from the feedback given by the members of the instructional team that had taught Foundations I courses previously. The “attitude shift” felt in the student population indicated that the detailed, explicit framing seemed to help drive an increase in participation and efforts to engage in constructing scientific arguments during the class-wide discussion.

4.1.3 Explicit Framing of the Lab Meeting.

There were some instructors who were already utilizing some of these tools in their teaching prior to my introduction of the interventions. For example, two of the instructors had been framing their lab meetings more explicitly. Both Bombus Terricola and Helia Anthus would often introduce the lab meeting as a tool used in real research labs as a means to problem-solve and work to more deeply understand the data. They would use this approach to try and frame the activity as a tool that research scientists use for driving their research forward. This approach was to try and get students to see the value in the activity. Despite that portion of explicit framing, they did not previously address the educational goals of the lab meeting in context of a sophomore level research experience or introduce the parts of a scientific argument. Due to their previous efforts to frame the lab meeting as a worthwhile endeavor in previous sections of Flower Microbiome and other Foundations courses, they did not find as strong of an effect but still noted improvements.

Despite this blunted affect, the qualitative data generated by the lab instructors seems to indicate that the first intervention was effective. The explicit framing of the lab meeting in terms of the research goals, educational goals, and introduction of scientific argumentation really seemed to drive an attitude shift in the students. This shift was not universal, as Helia Anthus notes in the lab meeting #1 focus group interview, “I’m sure that there were some people in the back, that [were] like ‘whatever I want to get to this other thing I’m doing’ but … it definitely felt like they were hanging on to what I was saying… no eyes were glazed over.” Additionally, Holly Narcissus said “there is such variation, because while I thought my [one] section went well, I would say that [in my other section] with maybe two-thirds …it was a palpable attitude change.”

The framing of this activity helped set the stage for the activity and the outcomes from the student responses but also aligned with the literature. Helia Anthus, an instructor who previously taught Flower Microbiome noted,

> I felt like they were given the tools they needed to be successful in this type of discussion. I think we sometimes have a tendency to assume they already know how to do these things and they are choosing not to. I believe that is often not the case.

This idea aligns with the literature and the previous argument that instructors teaching these lab courses have all engaged in lab meetings and are well aware of their structure and the purposes for engaging but we need to make that apparent to the students. Howell et al. (2003) stress that while professors “may have taught [a] course many times and [are] intimately familiar with the contents … it is the students’ first time through.” (p. 829). This framing is important to help the students see the value in engaging in the discussion.

The explicit framing used this semester seemed to help better drive student engagement because they saw it as something beneficial and not just an exercise to engage with for points. Holly Narcissus noted during the focus group interview,

> I … saw with some of my students, I would argue, that me introducing it, I did …feel like I saw an effect. Like, I could see their faces when I was talking about lab meeting … [t]he energy was a little bit better like it was, it was different than ‘Oh, we have to do this’ [instead] it was like, ‘Hey, this is literally something for me!’ This is not just something I’m going to check off. This is going to help

> [students] going forward, and maybe that's because … I've never introduced it to the extent that it was this week.

This attitude shift may also be responsible for the majority of students linking this activity with educational gains discussed in the previous section. Shifting the focus from an activity to generate points for the class into something for them lead to increases in students using it as a space to ask questions about their data. From the lab meeting #2 survey, a student noted "I wanted to make sure my understanding of the charts was correct." Using the discussion as a place to "practice my communication skills" and "become more confident in my scientific conclusions [and use of] some scientific terminology" as two students noted in the lab meeting #2 survey. With the explicit framing there seemed to be a clear shift in student attitude.

This use of clear framing of an educational activity is supported in the literature. Popham (1973) argues that clear learning objectives are tools that promote learning as "learners who have been informed of the teacher's instructional intentions can far more readily accomplish those goals" (p. 108). Popham (1973) goes on to note that "disclosing objectives to students … [can make] students less anxious and generally more positive" (p. vi), helping them to overcome challenging expectations and increase their willingness to engage with a difficult challenge. Rothgeb (2022) adds to this idea stating that clear objectives "encourage students to become active learners, and their interactions with others push them not only to delve more deeply into course material but also to consider alternative ways to understand course material as they are exposed to additional arguments and points of view during their discussions" (p.67).

Rothgeb (2022) used explicit learning objectives in his courses but found no strong correlations to educational outcomes. One potential limitation of his study is that these learning objectives were embedded in his course syllabus and not explicitly framed orally with students

(Rothgeb, 2022). The fact that the lab meeting was framed with an oral introduction of the activity and its purpose in both a professional setting and the educational goals may have helped to make this an effective intervention

The explicit framing may generate the observed “attitude shift” these instructors were speaking to and leading to students recognizing and reporting the educational benefits associated with the class-wide discussion, as noted in the previous section. Explicit framing supports students in actively engaging with learning objectives and finding value in participating in active learning tools, such as class-wide discussion (Howell et al., 2003; Martin & Mahat, 2017; Popham, 1973; Rothgeb, 2022).

4.1.4 Fostering of Student Authority.

The two interventions aimed at fostering the development of student authority did not seem to be effective, in regards to improvement science measures and the general discussion amongst instructors during focus group interviews and in their journal responses. There are a few reasons suspected for this. Most of the instructors in these Foundations labs already seem to yield authority in other ways, the interventions were practices that some instructors were already utilizing, and one of the changes implemented this semester to the general lab meeting structure more effectively yielded instructors’ authority.

One of the new changes implemented in the lab meeting by the course developer was to physically alter the student arrangement during the class-wide discussion phase of the lab meeting. Holly Narcissus did this in the first section of the week, which the whole instructional team observed weekly. As the class transitioned from small-group to class-wide discussion, student groups dissolved by having the students forming a large circle in the lab. Holly Narcissus then made a point to remind the students the lab meeting was for their benefit and removed themself from the circle. This yielded the instructor's authority and placed it on the students immediately after framing the goals of the lab meeting as a chance to dive into the data collectively.

After observing this, all instructors removed themselves from the circle and allowed the students control over the lab meeting to discuss the data, look for trends, ask questions, etc. In fact, Helia Anthus noted,

> I think … it was really powerful for them to see. I put them in the circle just like [Holly Narcissus] [and] … I'm going to sit down here, and I'm going to shut up. And they were like, 'Whoa!' It … made a funny moment, but it just like created that … Okay, it's on you now and I think that that was a big part of the, … discussion and how they felt comfortable participating.

This occurred in lab meeting #1, prior to any of the authority fostering interventions this improvement research focused on, and had a profound impact on developing and fostering student authority in the space of the lab meeting.

Another factor not addressed in the planning phase of this improvement research is that most of the laboratory instructors do not view themselves as the authority in the classroom. As engagement with the instructional team occurred during the course of this research it became apparent that most instructors view themselves as "guides" to the students through this research experience. They are in charge of the classroom: working to progress the students through experiments, maintaining safety standards, managing the learning environment, but really they view themselves as partners with the students during the collection, interpretation, and communication of the data. This "baseline" attitude once again seemed to mute the impacts of the interventions focused on fostering student authority simply because these instructors were already doing so.

When focusing specifically on the practice of teacher noticing it became apparent that several of the instructors already utilize this. Helia Anthus, who has a strong background in education, noted during the lab meeting #2 focus group interview, "[f]or whatever, … reason … I pride myself on memorizing their names … in the first week of class." Bombus Terricola likewise noted that they use their student names and did not realize that this was a named practice and feared that already engaging with the practice may have impacted the results of the intervention.

These instructors would utilize student names and recognize student contributions to the discussion at large as they framed experiments conceptually. As these instructors incorporated student ideas/comments into their own language and credited them by name, it allowed for a transition of authority from them to their students which should help to inspire richer classroom discussion (Barnhart & van Es, 2015; Bleicher, 2003; Cartier et al. 2013; Ford, 2008; McNeill & Pimentel, 2010; Smith et al. 2011; Webb et al., 2008). Based on this occurring prior to the intervention, the measures for the improvement research were likely not detecting them.

This practice of using students' names and teacher noticing has profound impacts on the class environment and can create a welcoming space to support students learning (Clarke et al., 2016; O'Connor et al., 2017; Shi & Tan, 2020; Sidelinger & Booth-Butterfield, 2010; White, 2011). Murran (2018) argues that instructors who use student names and implement the correct pronunciation have already taken "the first step in becoming a multicultural and culturally responsive educator" (p. 6).

I use this to pivot to some concern with the implementation of this practice that arose. Many of the instructors noted fear of misidentifying or mispronouncing students' names and that this caused them to utilize this practice less than they would have liked. Rudbeckia Hirta stated during the focus group for lab meeting #2, “I didn't tell names if I’m not comfortable. … I don't want to be wrong in front of everyone.” Holly Narcissus also noted, “I second guess myself in the moment, because I don't want it to be an awkward like ‘That's not my name.’ ‘My Professor Doesn't know me.’” Bombus Terricola adding “a student who always is willing to … share and [participate] … but, she's … Asian and … her name is very difficult to pronounce … because I’m not familiar with it [and] her NameCoach [a tool students can record their name to for instructor to hear the pronunciation] recording is a “Hello” and that is it.”

These instructors spoke to their concerns to alienate the students and actually have the opposite effect, decreasing their likelihood to participate in the future. Bombus Terricola summed it up well,

> I feel really bad when they have to… I tell them to…. correct me, but I know that it is frustrating … [and] I feel like it … puts them in a spot where they have to correct me, in an area of authority. So, there, there definitely is sometimes some hesitancy on my part…

While these are valid concerns, Marrun (2018) notes that while naming of students is a vital inclusive practice, if “educators mispronounce, Anglicize, or (re)name students of color” (p. 6), they risk highlighting or enforcing inequities. Additionally, minoritized students may be used to the mispronunciation of their names as a subtle form of racism (Kohli & Solórzano, 2012). Kohli and Solórzano (2012) go on to argue that if mis-naming, mispronouncing, or trivializing the names of students results in the alienation of students, ensuring the correct use of students’ names and pronunciation can achieve the opposite: it assures students that their identity, culture, and context matters and has value. This value can then contribute to fostering a sense of community in the classroom (Kohli & Solórzano, 2012, Marrun, 2018; Trujillo & Tanner, 2014; Venkatesh et al. 2021) To address instructor concerns, as mispronouncing names in languages unsimilar to our own is common the best recourse is to apologize and try again (Bagar-Fraley, 2020; Kohli & Solórzano, 2012, Marrun, 2018). Even asking for assistance on the pronunciation can be important in overcoming potential negative outcomes (Bagar-Fraley, 2020; Kohli & Solórzano, 2012, Marrun, 2018). It is just as important to intervene if a student's name is mispronounced by another student; the instructor should step in to provide a correction (Bagar-Fraley, 2020; Kohli & Solórzano, 2012, Marrun, 2018).

Despite the hesitancy and lack of clear improvement, instructors felt that teacher noticing was an effective practice to foster belonging. Helia Anthus stated in the focus group for lab meeting #2,

> I do relish the opportunity, which I'm sure we all do, to … utilize their names in a way that like, 'Oh remember what so-and-so said' this was great… I think its … good because the instructor feels good that they're mindful of the name, mindful of what they've [the student] said, and I think the student feels good because … what I say is important…"

This sense of community supporting learning goals is supported in the literature. While thinking about the development of authority, class-wide discussion can also foster a greater sense of belonging to the learning community (Trujillo & Tanner, 2014; Venkatesh et al., 2021). This sense of community can in turn, instill better learning outcomes for students. (Trujillo & Tanner, 2014; Venkatesh et al., 2021). Venkatesh et al., (2021) argue that active learning tools such as class-wide discussion can foster the development of learning communities. Trujillo and Tanner (2014) note that this sense of belonging increases students' sense of well-being and corresponds with mental alertness and course engagement. This sense of belonging can also support students in seeing value in educational activities, increasing the likelihood in engaging which supports better student outcomes (Trujillo & Tanner, 2014; Venkatesh et al., 2021).

As we transitioned to teacher-as-partner to foster student authority, this again had very limited effect and the situation was complex. It was implemented during the lab meeting #2 class meeting. Therefore, instructors employed it during instruction but this was limited as much of the class was dedicated to student-centered discussion. Additionally, it was implemented the week before Thanksgiving break and upon return students engaged in the final lab meeting of the semester, effectively limiting the intervention to one week.

Additionally, instructors struggled with the intervention due to a philosophical argument with the premise. As noted previously most instructors already view themselves as a “guide” to students and frame classes often with “we” pronouns that serve as a basis for this practice but then change to “you” pronouns when discussing experimentation or engagement with data. The reason for this strong preference is to try and foster a sense of ownership of their research.

Much of the basis and approach to teacher-as-partner stemmed from Tabak and Baumgartner’s (2004) investigation of the role of the teacher during class discussions in inquiry-based coursework. In their study, they found students were more willing to engage in discussion when their teacher acted as a partner in the investigation not as an authority within the class (Tabak & Baumgartner, 2004). One of the central findings was a shifting in pronoun usage, “we” versus “you,” and students seemed to resonate better with “we” as the teacher folded them into a shared authority (Tabak and Baumgartner, 2004).

In planning this investigation, I had already underestimated the yielding of authority these specific instructors already do, but also likely oversimplified the practice. Tabak and

Baumgartner’s (2004) work was at the high school level whereas we are working at the college level, and it is important for students to view their instructors as supports but the identity of ownership is likely important. Perhaps if students feel that there is too much “sharing” of authority in their research it diminishes their ownership and willingness to speak on its behalf. Additionally, a shifting of this model to teacher-as-guide is perhaps more apt. Letting students know we are there to support them, help them if they stumble, but to really foster their ownership and authority of their research and their data. Helia Anthus summed it up as

> I try to like, find moments … where I'm like, push back, push back, push back, push back, stay away, until I’m needed and then I’m like, oh, well, what does this mean? That this is here and that is there. I try really hard to … help them. Yield [my] authority as much as I can, but I also don't want them to feel lost or frustrated.
>
> [For example] when the gels were coming up … I … would not really say anything and look for their reaction. … Did they understand … when the picture came up? Did they understand what that meant? If they're all going like ‘Yes’ [then] I’m like, okay, good, then they understand what they're doing here.

4.1.5 Multifactorial Nature of Improvements.

Despite the perceived benefits of explicit framing, instructors generally spoke to improvements of the lab meeting activities this semester as being multifactorial. This improvement research was in tandem with other structural changes to the lab meeting driven by the course developer Holly Narcissus who aimed to improve the activity generally. Two of these changes, outside of the interventions studied in this paper, were a Jigsaw activity and physical positioning of the students during the class-wide discussion.

In the Jigsaw structure, as described by De Paz (2001), occurs when a subset of students from one group are sent to form another team and work to master some skill these new groups are given time to work until the students return to their former team as a representative for this new element. In Flower Microbiome, the students were placed in their flower teams, teams of five students, to each generate one type of data visual during the data analysis phase of the lab meeting. Once completed students returned to their bench team, each representing a unique analysis and presenting a visualization of that data analysis to the team.

This activity cut down on the time demanded by the data analysis phase. In the past each team would generate all the data visuals while freeing up lab time to engage with small-group discussions and class-wide discussion.

These additional changes really led to noticeable differences in the lab meeting activity and multiple instructors spoke about how the improvements were multifactorial but clearly felt. The explicit framing likely would have had a more measurable impact if there was stronger baseline data to compare it to, but it generally shifted the dynamic from previous semesters with the noticeable attitude shift in the majority of students. Additionally, the Jigsaw freed up time to allow for more depth in student-centered discussion; in previous semesters there was often a considerable time crunch, with time often being reduced for class-wide discussion. Finally, multiple factors seemed to improve student authority; students clearly felt encouragement to engage (Fig. 6) and found meaning in engagement (Fig. 5). The use of noticing and teacher-as-partner may not have been effective in increasing participation, but they impacted students.

The explicit framing of how the lab meeting is used professionally and how it supports student education seemed to help students identify this activity as being a useful learning activity and increase their science professional identity. The "attitude shift" that instructors reported feeling likely stemmed from increases in student engagement due to students being informed of the educational value of engaging which is supported by arguments of Howell et al. (2003); Martin and Mahat (2017); Popham (1973); and Rothgeb (2022). As students engaged, they likely felt a sense of greater belonging to the learning community helping to foster authority and engagement which is supported by the findings of Tabak and Baumgartner (2004), Tanner (2013), Trujillo and Tanner (2014), and Venkatesh et al., (2021). The course developer also saw value in spending this time on dialogic teaching and the incorporation of the new approaches to the lab meeting helped to support student learning while balancing the experimentation and generation of data. Smith et al. (2001) argues that adequate time dedicated to peer discussion is vital to get the benefit of dialogic teaching practices. The use of the Jigsaw saved time, allowed for the analysis of multiple modes of data, and supported student learning, which is supported by themes presented by Amedu (2015) and De Paz (2001). There seemed to be several factors that led to the overall success that all instructors reported throughout the semester as well as the vast majority of students.

4.2 Next Steps and Implications

4.2.1 Continued Use and Suggested Expansion of Explicit Framing

As discussed previously the intervention of explicit framing seemed to be the most successful and was widely praised by the instructional team. In fact, the course developers overseeing our Foundation I Duckweed Survivor course kept the explicit framing in place. They also had me introduce it and frame the benefits with an instructional team of twelve instructors. The introductory slides were incorporated into the teaching materials for this course as well.

Throughout the analysis of this intervention, it also become apparent that this intervention could even potentially be expanded both in the depth of the introduction and frequency of its use. There were some instructors who thought that providing some additional scaffolding with the introduction of the scientific argument could help students better understand what is meant by support and reasoning for their claims and how these three elements can be effectively combined to make a strong scientific argument. Providing some modeling could help to support them.

There were also a few calls to incorporate the framing ahead of later lab meetings. There was one instructor who noted they wished they had made a reminder of the structure of a scientific argument ahead of lab meeting #2, thinking it may have helped with reminding the students of not only the structure but the expectation to practice. Instructors noted that inclusion of this explicit reminder would need to be kept short as to avoid losses of time for the discussions themselves.

Combining the effectiveness of the explicit framing with the call to utilize it beyond the first lab meeting can potentially lead to effective scaffolding. The first introduction would be longer, provide more examples and then gradually decrease throughout the semester as students grow in the skill. By approaching this explicit framing as a scaffold, it could lead to some increases in argumentation, which were not observed in this study.

4.2.2 Interventions of Fostering Authority Need More Structure and Study

The interventions on fostering authority were generally found to be important by instructors as one of the goals of the Foundations program is to foster science identities in the students to increase persistence in the sciences, even if they did not yield more participation in class-wide discussion. Many of the instructors were already using these practices even if they were not fully understood or named. In order for these to potentially yield increases in engagement, they will need to be modified; the potential for teacher-as-partner to shift to teacher-as-guide is discussed above.

It seems clear that instructor interactions with students are important. Outside of this study I had a student leave a comment on one of the final assignments for the semester. She thanked me for the semester but went on to say,

> I really like when you call us ‘researchers!’ For students like us, we not only need guidance but also encouragement to support us. The name of ‘researchers’ can motivate us to be more passionate about biology, especially for a pre-med student like me. We will have more years of college than other majors and it's a long process that needs positive stimulations like this.

I would send weekly announcements to my students to introduce the week and remind them of homework assignments due before class. I opened these with “Hello Researchers” trying to instill that identity in my students. As instructors we can foster the development of student authority in many ways.

One other concern that arose from the authority interventions was that instructors seemed to notice that these interventions seemed to have a disproportional effect. Students who were already confident became more confident and would sometimes dominate the conversation while quiet students remained quiet. In the lab meeting #2 focus group Bombus Terricola noted, “the whole [noticing] thing depends on students volunteering to answer questions, and I think those students are already sort of inherently comfortable sharing ideas.”

There were some students who provided comments in the surveys as well. A student added this in the open-ended response about not participating, “[s]ome people talk too much in the discussions and chime in every other minute and ends up taking away time and opportunities to highlight certain data points from students who haven't talked yet." Another student from the same lab meeting wrote, "[e]veryone took everything I wanted to say (should have only 1 thing per person until everyone goes) and kept speaking up so fast I did not even get a chance!!!!!!!" Finally, a third response that sums up this frustration well: "[a]fter a couple times or so it should be that that student has to stop and let every other student get an opportunity to talk before they can again. In a classroom where a lot of students are super comfortable with each other, it's easy to talk a lot and take opportunities away from students who don't exactly feel that way."

It may be important for instructors to moderate these discussions in some fashion that allows it to be student-centered while allowing for students the opportunity to participate. This clearly links to concerns reported in O'Connor et al. (2017) where instructors felt pressure keeping the conversations coherent, in context of conceptual material, and equitable; often instructors wanted to ensure all students were getting a turn to speak. This made managing the discussion a challenge. It can be compounded when not all students want a turn. O'Connor et al. (2017) and Shi and Tan (2020) introduce the idea of non-vocal participants; students who do not participate verbally but are otherwise engaged in the class-wide conversation. Trying to work out who is engaged while not vocally participating while also trying to create space for those not getting a chance to participate due to others can be a struggle. How to address this balance is a potential avenue for further study.

4.2.3 Reconsider the Scoring of Participation for the Lab Meeting

With issues highlighted about students dominating the conversation and the presence of non-vocal participants, there is a discussion that should be addressed about the scoring of participation in this activity. In the current approach, students are scored for engaging and instructors monitor and tally participation. If a student contributes something to the discussion, they generally get credit for the participation points associated. As noticed above, there were some students who did not participate because others dominated the conversation. However, there is also the emergence of another trend that may be reducing the quality of the conversation and the social aspect of scientific argumentation.

On the lab meeting #3 survey one student captured this idea well, stating “The class-wide discussion is just students repeating each other for 45 minutes. I only spoke to get points I didn't say anything that was new to the discussion.” This trend emerged in the instructor focus group interviews as well. There are times where the discussion felt like a “check-the-box” issue. Instructors would note that at times there was low quality discussion and students would contribute with unlinked ideas that did not get followed up or discussed. Additionally, Holly Narcissus was being observed by a staff member from Pitt’s Center for Teaching and Learning. The observer noted the overall structure of the lab meeting was beneficial but asked, “How do we know that the students are listening to one another?”

This is a place where further study and refinement are needed. We need to address how students can have a meaningful conversation and work to evaluate other’s responses, teaching them to better evaluate other scientific arguments: assessing the effectiveness of the data selected as support, if the data truly supports the claim, if the reasoning is clear, etc.

The other concern about points comes from an equity stand-point from the open-ended questions on the survey and the four student interviews conducted after the conclusion of the course. There is an element that students are not speaking up due to social anxiety. From my interviews all four students, despite not participating vocally, were engaged in the conversation and noted benefits of listening to others.

O'Connor et al. (2017) and Shi and Tan (2020) provide evidence that students can be engaged in class discussions as non-vocal participants and benefit. These non-vocal participants are students who are engaged in the conversation (paying attention, thinking, etc.) but do not participate in the dialogue (O'Connor et al., 2017; Shi & Tan, 2020). Penalizing them could be detrimental to these students and perhaps we need to reconsider ways of scoring this activity.

Penalizing students could be detrimental from a social justice aspect as well. The classroom environment can be a source of stress for some students whether they come from a minoritized background, have different cultural perspectives as it pertains to authority, and/or may be anxious in social situations (Delpit, 1988; Kohli & Solórzano, 2012; Marrun, 2018 O'Connor et al., 2017; Shi & Tan, 2020; Tanner, 2013; White 2011). Shi and Tan (2020) and White (2011) suggest eliminating or reducing the scoring of participation as heavy aspects of student's grades in order to eliminate undue stress on students that act as non-vocal participants and/or come from minoritized backgrounds. Further discussion of approaches on how to score this activity and entice students to participate in class-wide discussions may be warranted so there is enough participation taking place to provide the educational benefits of class-wide discussion.

This improvement study showcased the benefits of the explicit framing of learning outcomes with this activity. The continued use of explicit framing is being incorporated into the Foundations lab courses as the lab meeting activity is introduced. Further framing of the introduction may be able to act as a source of scaffolding to further support learning. As the first lab is introduced the goals can be explicitly framed with examples of scientific argument. Then as the semester progresses the introduction becomes shorter with less support as the students grow. The interventions that foster authority need some revision and further study as they seemed to have limited effect and did not foster authority uniformly. Finally, addition consideration is needed on how to best evaluate the use of scientific argumentation in those not wishing to vocally participate in the class-wide discussion.

5.0 Reflections

5.1 What did I learn about improvment?

Engaging with the improvement process has been rewarding in several ways. First, as I explored my problem of practice, the approach to understanding the system and the root causes that influenced the seeming disengagement of students in participating in class-wide discussion was much more complex than I thought. As this complexity emerged it seemed like approaching improvement would be challenging, but again the tools of improvement science helped me to focus on specific threads to apply change. It also provided tools to utilize to measure whether or not that change was effective. By utilizing this systems approach it makes future work seem less daunting and more in the realm of possibility. I feel that I now possess meaningful tools to tackle future problems of practice.

The root cause analysis and construction of the Ishikawa (fishbone) diagram were particularly meaningful. It really changed my perspective on how to study and approach solving these types of problems. It opened my eyes to additional factors I had not considered, exposed me to new ideas and tools through exposure to education literature and theory, and it showcased a level of complexity I had not considered. I originally thought that there were only a few causes of my problem of practice, but it turned out to be much more complex and really helped to change my perspective of the problem. This in turn lead to some fundamental shifts in my own practice and helped to change and improve my relationship with students in my classroom.

After seeing this complexity and the number of factors that influenced student disengagement in class-wide discussion, improvement science provided systematic ways to approach solving them. The construction of the driver diagram and considering appropriate measures to understand how my proposed changes influenced those drivers provided a targeted approach to implementing change.

5.2 What did I learn about myself as an improver/leader/scholarly practitioner?

I began this program with a very limited background in education. I started out in my undergraduate program as a secondary-education biology major and only took a couple of courses before switching to a more focused science path. The rest of my formal education was in biology. I never lost my interest or spark for education though. As I engaged with the education literature, I encountered pedagogical practices that I was doing sometimes in rudimentary forms. It was reassuring to see that the practices I was employing in the classroom were beneficial, had names, and could be refined. I have generally considered myself to be a decent teacher and this discovery helped to reassure me that I was utilizing good practices. Despite this confirmation, it was nice to know that additional tools exist, and this process helped give me the means to locate them and work them into my practice.

As I worked through this program, I often utilized tools from the courses with my colleagues. Working with them, I got to learn more about them, their perspectives, and the Foundations program I teach in. This has given me a much deeper perspective and appreciation for the complexity of educational systems. It also opened my eyes to how much these professionals care about their own practice and the quality of the education students receive.

I would explore ideas in the education literature and share them with several of my colleagues who were always excited to learn about them. In fact, there were a few times that people seemed surprised that there was a named practice for various things they did while educating their students.

As I engaged in the improvement process, trying to increase student participation in class-wide discussion, it was nice to have the support of the course developers in our program. This allowed the whole course to be the canvas for my interventions. It was a bit overwhelming at times, but exciting nonetheless. I truly felt like I got to be a leader within the program, sharing my ideas and vision for the lab meeting and introducing practices meant to empower students to engage and participate. This also gives me a sense that my ideas could reach and impact more students as we strove to enrich their science education.

This work and much of my STEM themed coursework really reinforced the ideas of authentic research-based coursework to drive meaningful science learning for students. It is also a powerful tool to foster the development of science identities in those students and has the power to increase inclusivity in STEM. I would love to see students who traditionally have been excluded from science feel welcome to participate in science and even go on to pursue majors and careers in science. I have always wanted to have a hand in training the next generation of scientists, and I feel like this program has equipped me with tools to do a better job of that for everyone.

Another potential on the horizon is moving away from authentic research experiences for the Foundations labs. There is talk of moving away from this model as it is too expensive and too difficult to manage and maintain. I want to take the tools and knowledge that I have now to prevent a move away from these types of lab experiences. Based on my exposure to the education literature, this type of teaching has massive rewards for students and enriches their learning of scientific content. It also helps to disrupt the pattern of science's exclusivity of white men by helping to foster science identities in racial, ethnic, and gender groups traditionally underrepresented in science.

5.3 How will I apply improvement to other Problems of Practice moving forward as a scholarly practitioner?

As I mentioned above, engaging in the root cause analysis was rewarding and gave unique perspectives on approaching my problem of practice. This is going to be a great starting point for tackling other problems of practice in the future. Problems are often more complex than initially thought. Had I not engaged in better understanding the problem and the unique context within my system I would have missed out on potential opportunities to approach solving the problem. This will be my baseline starting point in all future efforts to address problems of practice. Engaging with the literature, trying to understand the users and their roles in the problem, and considering the problem more wholistically than my narrow perspective.

Once I have generated a comprehensive Ishikawa diagram, I will engage with it to identify the drivers of the problem. Using those drivers, I will approach strategies to move the system towards my aim. This process will help to more systematically approach and work to solve problems. This tool kit also helps to identify parameters as measurement points to ensure that the changes are in fact generating positive change.

Appendix A Ishikawa Diagram

The Ishikawa (Fishbone) diagram resulting from a root cause analysis. This analysis of the problem of practice helped to identify influences in the problem that could be acted upon to drive the improvement process (Hinnant-Crawford, 2020).

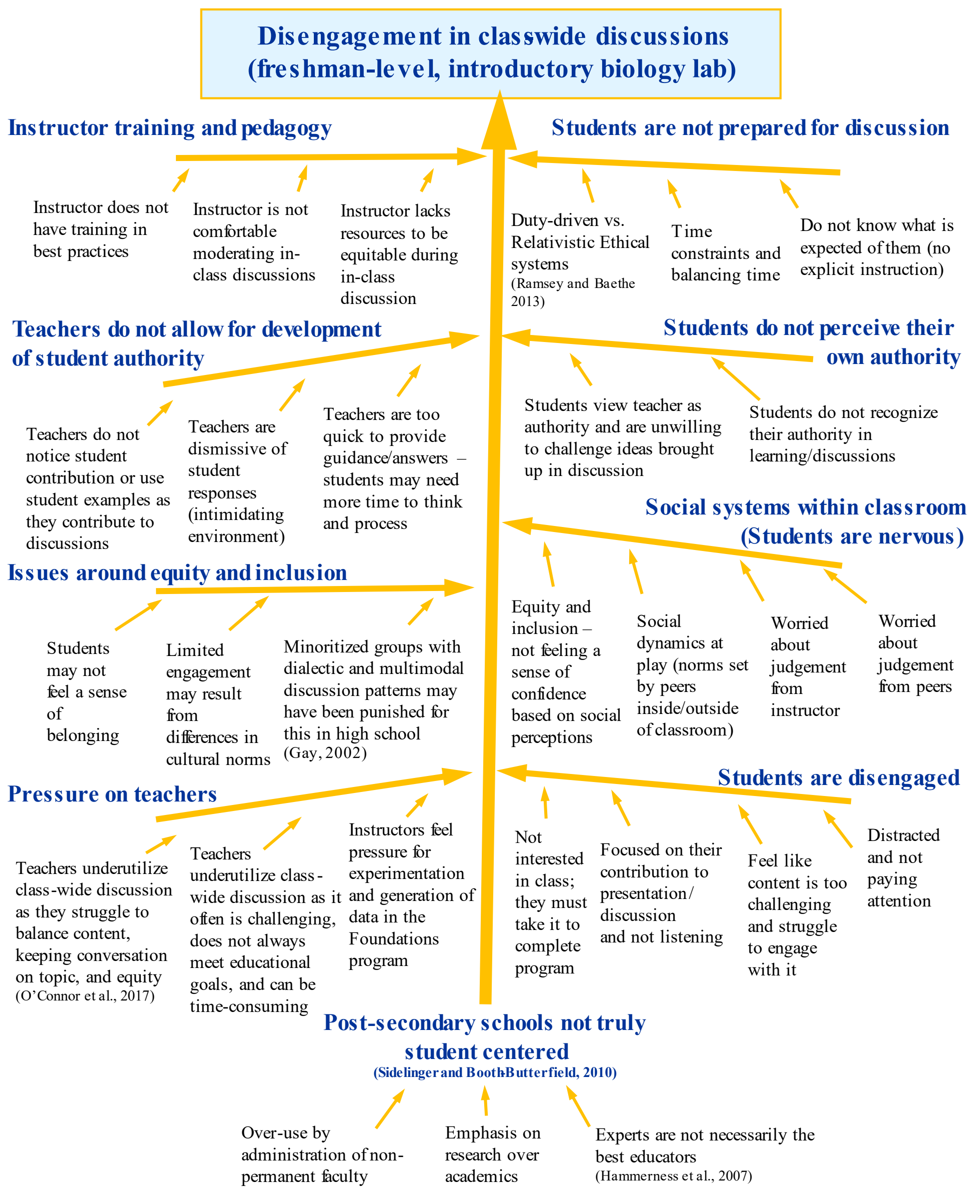


Figure 7 Ishikawa Diagram of Proposed Causes of Low Student Engagement in Class-wide Discussion.

Appendix B Instructor Journaling Worksheets

Copies of these worksheets were made available to instructors to complete after each lab meeting. These were printed on a single double-sided paper and filled out in the lab at the conclusion of their section.

Appendix B.1 Journal Worksheet Lab Meeting #1

Instructor Name: ____ SEC #:_____________

Please select one option in each row below that best characterizes your section's lab meeting:

Engagement in class-wide discussion	Student participation in argumentative discourse is prompted by instructor	Student participation in argumentative discourse is prompted by instructor and other student arguments	Students engage in argumentative discourse without prompting from instructor
Level of claims and use of data	Claims are articulated, defended, questioned, OR evaluated	Claims are articulated, defended, questioned, AND evaluated	Claims are articulated defended, questioned, AND evaluated prompting revision of initial claim
	Claims are defended but there is little use of data in the evidence	Claims are defended with appropriate evidence	Claims are defended with appropriate evidence and reasoning

Adapted from Figure 1 in Berland and McNeill (2010) - © 2010 Wiley Periodicals, Inc.

How did the lab meeting class-wide discussion compare with your previous experiences with class-wide discussion?

Do you feel that introducing the goals of the lab meeting increased student participation and engagement in the class-wide discussion? Circle one: Yes No

Please briefly explain:

Did the introduction of scientific argumentation increase student attempts to make scientific arguments? Circle one: Yes No

Please briefly explain:

Did the introduction of the lab meeting and scientific argumentation impact your ability to successfully facilitate the lab meeting? Circle one: Yes No

Please briefly explain:

Additional thoughts, comments, criticisms, questions you might have about the class-wide discussion portion of your class's lab meeting:

Appendix B.2 Journal Worksheet Lab Meeting #2

Instructor Name: ____ SEC #:____________

Please select one option in each row below that best characterizes your section's lab meeting:

Engagement in class-wide discussion	Student participation in argumentative discourse is prompted by instructor	Student participation in argumentative discourse is prompted by instructor and other student arguments	Students engage in argumentative discourse without prompting from instructor
Level of claims and use of data	Claims are articulated, defended, questioned, OR evaluated	Claims are articulated, defended, questioned, AND evaluated	Claims are articulated defended, questioned, AND evaluated prompting revision of initial claim
	Claims are defended but there is little use of data in the evidence	Claims are defended with appropriate evidence	Claims are defended with appropriate evidence and reasoning

Adapted from Figure 1 in Berland and McNeill (2010) - © 2010 Wiley Periodicals, Inc.

How did the lab meeting class-wide discussion compare:

-with your previous experiences? -with Lab Meeting #1?

Please select one of the following rankings of your ability to incorporate the practice of teacher noticing into your teaching these last two weeks:

I do not fully understand the practice of teacher noticing	I understand teacher noticing but do not feel I did it effectively	I understand teacher noticing and incorporated it into my teaching but used it minimally	I understand teacher noticing, incorporated it into my teaching, and used it often

Please explain your selection:

Do you feel that teacher noticing helped you to yield your expertise/authority and foster it in your students? Circle one: Yes No

Please briefly explain:

Did your use of teacher noticing help to increase student participation in class-wide discussion during the lab meeting? Circle one: Yes No

Please briefly explain:

Additional thoughts, comments, criticisms, questions you might have about the class-wide discussion portion of your class's lab meeting and/or teacher noticing:

Appendix B.3 Journal Worksheet Lab Meeting #3

Instructor Name: ______________________________ SEC #:__________

Please select one option in each row below that best characterizes your section's lab meeting:

Engagement in class-wide discussion	Student participation in argumentative discourse is prompted by instructor	Student participation in argumentative discourse is prompted by instructor and other student arguments	Students engage in argumentative discourse without prompting from instructor

Level of claims and use of data	Claims are articulated, defended, questioned, OR evaluated	Claims are articulated, defended, questioned, AND evaluated	Claims are articulated defended, questioned, AND evaluated prompting revision of initial claim
	Claims are defended but there is little use of data in the evidence	Claims are defended with appropriate evidence	Claims are defended with appropriate evidence and reasoning

Adapted from Figure 1 in Berland and McNeill (2010) - © 2010 Wiley Periodicals, Inc.

How did the lab meeting class-wide discussion compare:
-with your previous experiences? -with Lab Meeting #2?

Please select one of the following rankings of your ability to incorporate the practice of teacher-as-partner (i.e. using pronouns we, us, etc. to indicate your partnership) into your teaching week #12:

I do not fully understand the practice of teacher-as-partner	I understand teacher-as-partner but do not feel I utilized it effectively	I understand teacher-as-partner and incorporated it into my teaching but utilized it minimally	I understand teacher-as-partner and incorporated it into my teaching and utilized it often

Please explain your selection:

Do you feel that teacher-as-partner model helped you to yield your expertise/authority and foster it in your students? Circle one: Yes No
Please briefly explain:

Did your use of teacher-as-partner help to increase student participation in class-wide discussion during the lab meeting? Circle one: Yes No
Please briefly explain:

Additional thoughts, comments, criticisms, questions you might have about the class-wide discussion portion of your class's lab meeting and/or the teacher-as-partner model:

Appendix C Student Survey Prompts

Student surveys were conducted using Qualtrics and the link was released to students upon the conclusion of the lab meeting. They had one week to complete the survey and received two points for completion of the surveys.

Appendix C.1 Student Survey Questions Lab Meeting #1

Introduction: This brief survey collects data on the lab meeting activity, used in Flower Microbiome, for research one of our instructors is doing on class-wide discussion. Lab meetings are used as a means to analyze and communicate scientific data generated in your research.

Lab meetings typically follow three phases: data analysis, small-group discussion, and whole class discussion. The data analysis involves analyzing the data and preparing it for visual presentation (such as a graph). Small group discussion typically involves prompts that will have you and your team focus on the data for your flower, site, or bacterial isolate. Finally, during the class-wide discussion phase the data is evaluated for larger trends across treatments or samples.

Please think about the lab meeting you have just engaged in as you answer the following questions.
Thank you!
Sean

Questions:

1. What year are you in your program?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Other
2. I self-identify as...
    a. Female
    b. Male
    c. Non-binary
    d. Prefer not to answer
3. I self-identify as...

    a. American Indian/Alaska Native
    b. Asian/Asian American
    c. Black/African American
    d. Hawaiian/Pacific Islander
    e. Hispanic/Latino
    f. White/European American
    g. Prefer not to answer
4. Do you identify as a first-generation college student (a student whose parents did not complete a 4-year degree)?
    a. Yes
    b. No
    c. Prefer not to answer
5. Please order the phases of the lab meeting from most beneficial to least beneficial.
    a. Data analysis
    b. Small-group work
    c. Class-wide discussion
6. Please order the phases of the lab meeting from most challenging to least challenging.
    a. Data analysis
    b. Small-group work
    c. Class-wide discussion
7. As the class transitioned to class-wide discussion, did you participate in the discussion?
    a. Yes
    b. No
8. Please indicate which of the following impacted your participation in the class-wide discussion phase of the lab meeting. (IF QUESTION #7 WAS YES)
    a. Likert scale questions on a five-point scale
    b. I had a question for the other research teams
    c. I disagreed with the conclusions of another research team based on the data they cited
    d. I thought of a different conclusion based on the data presented.
    e. Another team's presentation sparked an idea that I wanted to share.
    f. It was required for points.
9. Is there another reason (not listed above) that caused you to participate in the class-wide discussion during the lab meeting? (Open Response)
10. Please indicate which of the following impacted your participation in the class-wide discussion phase of the lab meeting. (IF QUESTION #7 WAS NO)
    a. Likert scale questions on a five-point scale
    b. I was not yet done with the analysis for the lab meeting.
    c. My team did not get a chance to discuss our data prior to the class-wide discussion.
    d. I do not feel confident in my answers to engage in the discussion.
    e. I did not understand the information being presented.
    f. I did not understand what was being asked of me.
    g. I do not feel comfortable speaking up in class-wide discussions.
11. Is there another reason (not listed above) that caused you to not participate in the class-wide discussion during the lab meeting? (Open Response)

12. Thinking specifically about the class-wide discussion portion of the lab meeting please answer the following questions:
    a. Likert scale questions on a five-point scale
    b. The discussion helped me to better understand trends in the data.
    c. Seeing how other students discussed data helped me to think about data.
    d. Engaging in discussion about data helped me to feel more confident supporting my thoughts with data.
    e. Engaging in this discussion helped me apply the skills employed by research scientists.
13. Any additional thought or comments. (Open Response)

Thank you: Lab Meeting #1 - Thank you for completing this survey! Please take a screen capture of this thank you message to upload to Canvas.

Appendix C.2 Student Survey Questions Lab Meeting #2

Introduction: This brief survey collects data on the lab meeting activity, used in Flower Microbiome, for research one of our instructors is doing on class-wide discussion. Lab meetings are used as a means to analyze and communicate scientific data generated in your research. Lab meetings also provide a space for practice with scientific argumentation, which is a vital skill in the sciences but also supports the development of critical thinking.

Please think about the lab meeting you have just engaged in as you answer the following questions.
Thank you!
Sean

Questions:
1. What year are you in your program?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Other
2. I self-identify as...
    a. Female
    b. Male
    c. Non-binary
    d. Prefer not to answer
3. I self-identify as...
    a. American Indian/Alaska Native
    b. Asian/Asian American
    c. Black/African American

    d. Hawaiian/Pacific Islander
    e. Hispanic/Latino
    f. White/European American
    g. Prefer not to answer
4. Do you identify as a first-generation college student (a student whose parents did not complete a 4-year degree)?
    a. Yes
    b. No
    c. Prefer not to answer
5. Please select your section:
    a. Section #1 Monday 11:45 AM
    b. Section #2 Monday 3:00 PM
    c. Section #3 Monday 6:15 PM
    d. Section#4 Tuesday 8:30 AM
    e. Section #5 Tuesday 11:45 AM
    f. Section #6 Tuesday 3:00 PM
    g. Section #7 Tuesday 6:15 PM
    h. Section #8 Wednesday 8:30 AM
    i. Section #9 Wednesday 11:45 AM
    j. Section #10 Wednesday 3:00 PM
    k. Section #11 Wednesday 6:15 PM
    l. Section #12 Thursday 8:30 AM
    m. Section #13 Thursday 11:45 AM
    n. Section #14 Thursday 3:00 PM
    o. Section #15 Thursday 6:15 PM
    p. Section #16 Friday 8:30 AM
6. Thinking generally about class-wide discussion in this course please answer the following questions:
    a. Likert scale questions on a five-point scale
    b. My instructor encourages us to participate in class-wide discussions.
    c. My instructor makes me feel welcome to contribute to the classroom discussion without being fearful of making mistakes.
    d. My peers make me feel welcome to contribute to classroom discussion without being fearful of making mistakes.
    e. My instructor reminds us to listen to each other's ideas and evaluate their arguments.
7. Please order the phases of the lab meeting from most beneficial to least beneficial.
    a. Data analysis
    b. Small-group work
    c. Class-wide discussion
8. Please order the phases of the lab meeting from most challenging to least challenging.
    a. Data analysis
    b. Small-group work
    c. Class-wide discussion
9. Thinking specifically about the most recent lab meeting; as the class transitioned to class-wide discussion, did you participate in the discussion?

    a. Yes
    b. No
10. Please indicate which of the following impacted your participation in the class-wide discussion phase of the lab meeting. (IF QUESTION #9 WAS YES)
    a. Likert scale questions on a five-point scale
    b. I had a question for the other research teams
    c. I disagreed with the conclusions of another research team based on the data they cited
    d. I thought of a different conclusion based on the data presented.
    e. Another team's presentation sparked an idea that I wanted to share.
    f. It was required for points.
11. Is there another reason (not listed above) that caused you to participate in the class-wide discussion during the lab meeting? (Open Response)
12. Please indicate which of the following impacted your participation in the class-wide discussion phase of the lab meeting. (IF QUESTION #9 WAS NO)
    a. Likert scale questions on a five-point scale
    b. I was not yet done with the analysis for the lab meeting.
    c. My team did not get a chance to discuss our data prior to the class-wide discussion.
    d. I do not feel confident in my answers to engage in the discussion.
    e. I did not understand the information being presented.
    f. I did not understand what was being asked of me.
    g. I do not feel comfortable speaking up in class-wide discussions.
13. Is there another reason (not listed above) that caused you to not participate in the class-wide discussion during the lab meeting? (Open Response)
14. Thinking specifically about the class-wide discussion portion of the lab meeting please answer the following questions:
    a. Likert scale questions on a five-point scale
    b. The discussion helped me to better understand trends in the data.
    c. Seeing how other students discussed data helped me to think about data.
    d. Engaging in discussion about data helped me to feel more confident supporting my thoughts with data.
    e. Engaging in this discussion helped me apply the skills employed by research scientists.
15. Any additional thought or comments. (Open Response)

Thank you: Lab Meeting #2 - Thank for taking the time to share your responses. Please be sure to take a screen capture of this message to upload to Canvas.

Appendix C.3 Student Survey Questions Lab Meeting #3

Introduction: This brief survey collects data on the lab meeting activity, used in Flower Microbiome, for research one of the instructors is doing on class-wide discussion. Lab meetings are used as a means to analyze and communicate scientific data generated in your research. Lab meetings also provide a space for practice with scientific argumentation, which is a vital skill in the sciences but also supports the development of critical thinking.

Please think about the lab meeting you have just engaged in as you answer the following questions.
Thank you!
Sean

Questions:

1. What year are you in your program?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Other
2. I self-identify as...
    a. Female
    b. Male
    c. Non-binary
    d. Prefer not to answer
3. I self-identify as...
    a. American Indian/Alaska Native
    b. Asian/Asian American
    c. Black/African American
    d. Hawaiian/Pacific Islander
    e. Hispanic/Latino
    f. White/European American
    g. Prefer not to answer
4. Do you identify as a first-generation college student (a student whose parents did not complete a 4-year degree)?
    a. Yes
    b. No
    c. Prefer not to answer
5. Please select your section:
    a. Section #1 Monday 11:45 AM
    b. Section #2 Monday 3:00 PM
    c. Section #3 Monday 6:15 PM
    d. Section#4 Tuesday 8:30 AM
    e. Section #5 Tuesday 11:45 AM
    f. Section #6 Tuesday 3:00 PM
    g. Section #7 Tuesday 6:15 PM
    h. Section #8 Wednesday 8:30 AM
    i. Section #9 Wednesday 11:45 AM
    j. Section #10 Wednesday 3:00 PM
    k. Section #11 Wednesday 6:15 PM

l. Section #12 Thursday 8:30 AM
m. Section #13 Thursday 11:45 AM
n. Section #14 Thursday 3:00 PM
o. Section #15 Thursday 6:15 PM
p. Section #16 Friday 8:30 AM

6. Thinking generally about class-wide discussion in this course please answer the following questions:
    a. Likert scale questions on a five-point scale
    b. My instructor encourages us to participate in class-wide discussions.
    c. My instructor makes me feel welcome to contribute to the classroom discussion without being fearful of making mistakes.
    d. My peers make me feel welcome to contribute to classroom discussion without being fearful of making mistakes.
    e. My instructor reminds us to listen to each other's ideas and evaluate their arguments.
    f. My instructor is a partner and supports me as I engage in this authentic research.
7. Please order the phases of the lab meeting from most beneficial to least beneficial.
    a. Data analysis
    b. Small-group work
    c. Class-wide discussion
8. Please order the phases of the lab meeting from most challenging to least challenging.
    a. Data analysis
    b. Small-group work
    c. Class-wide discussion
9. Thinking specifically about the most recent lab meeting; as the class transitioned to class-wide discussion, did you participate in the discussion?
    a. Yes
    b. No
10. Please indicate which of the following impacted your participation in the class-wide discussion phase of the lab meeting. (IF QUESTION #9 WAS YES)
    a. Likert scale questions on a five-point scale
    b. I had a question for the other research teams
    c. I disagreed with the conclusions of another research team based on the data they cited
    d. I thought of a different conclusion based on the data presented.
    e. Another team's presentation sparked an idea that I wanted to share.
    f. It was required for points.
11. Is there another reason (not listed above) that caused you to participate in the class-wide discussion during the lab meeting? (Open Response)
12. Please indicate which of the following impacted your participation in the class-wide discussion phase of the lab meeting. (IF QUESTION #9 WAS NO)
    a. Likert scale questions on a five-point scale
    b. I was not yet done with the analysis for the lab meeting.
    c. My team did not get a chance to discuss our data prior to the class-wide discussion.
    d. I do not feel confident in my answers to engage in the discussion.

e. I did not understand the information being presented.
f. I did not understand what was being asked of me.
g. I do not feel comfortable speaking up in class-wide discussions.

13. Is there another reason (not listed above) that caused you to not participate in the class-wide discussion during the lab meeting? (Open Response)
14. Thinking specifically about the class-wide discussion portion of the lab meeting please answer the following questions:
    a. Likert scale questions on a five-point scale
    b. The discussion helped me to better understand trends in the data.
    c. Seeing how other students discussed data helped me to think about data.
    d. Engaging in discussion about data helped me to feel more confident supporting my thoughts with data.
    e. Engaging in this discussion helped me apply the skills employed by research scientists.
    f. Engaging with the lab meetings throughout the semester has helped me to feel more confident in using scientific argumentation.
15. Any additional thought or comments. (Open Response)

Thank you: Lab Meeting #3 - Thank for taking the time to share your responses! This data will be insightful for use in a dissertation. Please be sure to take a screen capture of this message to upload to Canvas.

Appendix D Focus Group Interview Questions

Focus group interviews were conducted in the instructor meeting following the lab meeting. These questions served as general guides to help navigate the focus group interview but did not exactly match the transcripts as I allowed the conversations to flow organically.

Appendix D.1 Focus Group Interview Questions Lab Meeting #1

<u>Introduction:</u>

Thank you all for your time and supporting me in my dissertation work. I appreciate the extra time and effort as we engage in this focus group meeting, I will ask several questions that I hope will prompt discussion. I plan to mostly listen and at times may attempt to guide the conversation. I would also like to note that I will be recording this meeting and have the transcription tool active to create a transcript of this recording that I plan to use in my research moving forward.

This lab meeting was framed with explicit instruction to help better explain to student why we use the lab meeting format and its associated goals in both the research and their education.

<u>Guiding Questions:</u>

1. Please briefly share your feelings about the lab meeting format used in Flower Microbiome.
2. I would like you to share your perspectives on the intervention employed for this lab meeting.
    a. How did this intervention influence class-wide discussion?
    b. How did the intervention change the dynamics of the class-wide discussion (i.e. Did you find yourself directing the conversation or did students direct)?

c. What are your thoughts on the intervention? Can improvements be made? Should it be dropped?

d. Did the intervention impact your ability to conduct the lab meeting? Were there issues (i.e. time constraints, etc.)

e. Overall, how do you feel this intervention led to any potential improvement in class-wide discussion?

3. Do you feel that students understand the rationale for the lab meeting format?
4. Do you feel this activity is equitable (all students feel welcome to engage)?
5. Do you feel this intervention inspired you to engage in larger practice changes?

Appendix D.2 Focus Group Interview Questions Lab Meeting #2

Introduction:

Thank you all for once again supporting me in my dissertation work. I appreciate all the extra time and effort you are putting in to help me with my interventions and data collection regarding class-wide discussion.

As we engage in this focus group meeting, I will ask several questions that I hope will prompt discussion. I plan to mostly listen and will at times attempt to guide the conversation. Just a quick reminder there are no predetermined answers that I am fishing for, but rather would like to collect differing points of view. I welcome you to share even if it differs from what others have said or what you think I am looking for. Divergent points that emerge may potentially be of extraordinary value.

I would also like to note that I will be recording this meeting and have the transcription tool active to create a transcript of this recording that I plan to use in my research moving forward.

As you may recall I am focused on two aspects to foster richer, student-centered discussion: explicit instruction and fostering authority. This second lab meeting focused on fostering authority by utilizing teacher noticing. Specifically, when we elicit students to respond and then recognize their contributions by working them into our teaching. This practice in theory should help foster students' recognition of their authority in the learning process. I would like to begin briefly at this idea.

Guiding Questions:

1. How do you understand or recognize your authority in teaching? Is this an issue you've previously thought about or addressed, why/why not?
2. I would like to discuss your perspectives on the intervention employed for this lab meeting: teacher noticing. (The subset of recognizing student contributions and using their names when you rephrase or discuss the idea/concept later).
    a. How well do you feel you did at teacher noticing? Was it easy or difficult to implement why/why not?
    b. How did the intervention change the dynamics within your classroom?
        i. How did it influence the class-wide discussion during the lab meeting?
        ii. What changes did you observe between lab meeting #1 and #2? Do you believe it was due to the intervention or something else? Please explain.
    c. What are your thoughts on the intervention? Can improvements be made? Should it be dropped?
    d. Did the intervention impact your ability to conduct class? What were some issues/observations you noticed while utilizing this technique?
    e. Overall, how do you feel this intervention led to an improvement in class-wide discussion?
3. How do you perceive equity in your classroom/class-wide discussion while employing teacher noticing? Do you feel this practice is equitable (all students feel welcome to engage)?
4. Do you feel this intervention inspired you to engage in larger practice changes?

Appendix D.3 Focus Group Interview Questions Lab Meeting #3

Introduction:

Thank you all for once again supporting me in my dissertation work. I appreciate all the extra time and effort you are putting in to help me with my interventions and data collection regarding class-wide discussion.

As we engage in this focus group meeting, I will ask several questions that I hope will prompt discussion. I plan to mostly listen and will at times attempt to guide the conversation. Just a quick reminder there are no predetermined answers that I am fishing for but rather would like to collect differing points of view. I welcome you to share even if it differs from what others have said or what you think I am looking for. Divergent points that emerge may potentially be of extraordinary value.

I would also like to note that I will be recording this meeting and have the transcription tool active to create a transcript of this recording that I plan to use in my research moving forward.

As you may recall I am focused on two aspects to foster richer, student-centered discussion, explicit instruction and fostering authority. This third lab meeting focused on fostering authority by utilizing teacher-as-partner. Specifically, by yielding our authority and fostering theirs by engaging as a partner or equal in the research. This can be signified by the use of intentional "we" pronoun usage.

Guiding Questions:

1. How have your thoughts on authority in the classroom shifted after these interventions (teacher noticing/teacher-as-partner)?
2. I would like to discuss your perspectives on the invention employed for this lab meeting, teacher-as-partner. (The subset of we, us pronoun usage).
    a. How well do you feel you did at teacher-as-partner language? Was it easy or difficult to implement why/why not?
    b. How did the intervention change the dynamics within your classroom?
        i. How did it influence the class-wide discussion during the lab meeting?
        ii. What changes did you observe between lab meeting #2 and #3? Do you believe it was due to the intervention or something else? Please explain.
    c. What are your thoughts on the intervention? Can improvements be made? Should it be dropped?
    d. Did the intervention impact your ability to conduct class? What were some issues/observations you noticed while utilizing this technique?
    e. Overall, how do you feel this intervention led to an improvement in class-wide discussion?
3. How do you perceive equity in your classroom/class-wide discussion while employing teacher-as-partner language? Do you feel this practice is equitable (all students feel welcome to engage)?
4. Do you feel this intervention inspired you to engage in larger practice changes?

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