'New and Always Improving' - A Case Study On The Development of Discussions Within An Undergraduate Laboratory Classroom With A Novice Teacher Assistant

An Honors Thesis for the Department of Education

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Introduction

Why is discussion important for science education?

Discussions hold a special position in the teaching of science. Teaching in a manner that involves discussion and dialogue has been shown to support better scientific understanding in students (Che & She, 2012; Chi et al., 2016; Mercer et al., 2004). It has even shown to increase motivation to engage in class (Kiemer et al., 2015). However, researchers have argued that just having dialogue in a classroom (dialogic classroom interactions) is not enough and that debate and discussion from varying perspectives are needed (e.g. Henderson et al., 2015). As such, there is a call for the use of argumentation in science classrooms to help students engage with science on a more authentic level, develop the ability in students to reason, and help students develop a deeper understanding of science (Driver et al., 2000; Duschl & Osborne, 2002; Jiménez-Aleixandre & Erduran, 2007; Osborne et al., 2004).

As the field of argumentation research develops, more evidence is available to demonstrate the benefits of argumentation in science classrooms. Argumentation is being shown to promote not only conceptual gains but also better scientific practices in students (Arias et al., 2017; Asterhan & Schwarz, 2007; Aydeniz & Dogan, 2016; Che & She, 2012; Kaya, 2013; Nussbaum & Sinatra, 2003; Venville & Dawson, 2010). With all of this mounting evidence supporting discussions and debate in classrooms, it is now important to observe how this theory can be integrated into the practice of teachers. The transition to a classroom that promotes argumentation can be

difficult for teachers. This is because, despite all of the evidence and research supporting the benefits of discussion and argumentation in science classrooms, most classrooms continue to be monologic (Larrain, et al., 2018). A monologic classroom is in contrast to a dialogic classroom where dialogic classrooms have ongoing dialogues between teachers and students. A monologic classroom is a classroom where one individual, the teacher, is dominating the conversation by just lecturing and presenting to the students. For a teacher who grew up experiencing monologic classrooms, entering a classroom environment that promotes dialogic argumentation is foreign territory that can be hard to adapt to and run smoothly even with training in teaching. It is important to explore the experiences of teachers when they are exposed to or try to develop these new teaching environments in order to help future teachers work in a classroom that promotes discussion and argument.

In this paper, we will explore how a novice teacher assistant, who grew up with monologic science classrooms, approaches discussions and debates within her own lab section. This paper will delve into that teacher assistant's journal reflections in order to access her inner dialogue and analyze her development in thoughts and approaches regarding argumentation. Through analyzing her journal reflections, we will also explore the nuances of introducing argumentation in the classroom. We will also venture into exploring where her motivations for improving her engagement with argumentation come from and see that her genuine caring for her students' ideas drives her to encourage forms of argumentation among her students.

In addition to exploring the case study experience of a novice TA, this paper will also review the literature and history around argumentation to provide context and reasoning for the importance of discussion and debate in a science classroom. Through this we will highlight how discussion benefits students in multiple ways, the limitations of teaching guides, and possible suggestions that current and future TAs can experiment with in facilitating debates and discussions. Firstly though, it is important to explore the history of argumentation in order to gain context for how the understanding around it has evolved and where the motivations for studying it come from.

History of argument as a learning method

For over three decades now there has been extensive discussion in education research circles over the use of argument within a classroom setting as a tool through which students can gain deeper content knowledge and improved thinking skills. Research in argument as it relates to science learning has been of considerable focus. To best understand the current views on the benefits of the use of arguments in the science classroom, this paper will first review the discourse over the past few decades that have surrounded argumentation.

The spark that led many researchers to begin looking at argument as an educational tool within science classrooms may have come from the frustration that researchers were facing regarding how science was being falsely and incompletely portrayed in classrooms. Science in classrooms was widely seen as a field where data led to uncontroversial, universally agreed upon conclusions and

theories. Schwab wrote in 1962 about his frustration with science in schools being, “taught as a nearly unmitigated rhetoric of conclusions in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal and irrevocable truths” (Schwab, 1962, p. 24). This sentiment continued into 1991 with researchers such as Claxton calling the knowledge that science teachers had as being knowledge that is “unequivocal, unquestioned and uncontested” (Claxton, 1991). More researchers claimed that the lack of argument in classrooms gave students a false and confusing view of historical and current controversies between scientists by painting science as just a culmination of unwavering facts about the natural world (Driver et al., 1996; Geddis, 1991). With growing frustration among researchers towards the lack of discourse and challenge going on within science classrooms, things were primed for a new education model to arise.

The idea that learning science is connected intricately to argument was proposed in the 1990's by Duschl (1990) and Kuhn (1993). However, those two were not the only individuals advocating for the use of challenge and argument within science teaching. Not only were psychologists of that time promoting argumentation as a keystone to doing effective science teaching (Kuhn, 1993), but science philosophers (Siegel, 1995) and science education researchers (Kelly et al., 1998; Kelly & Crawford, 1997; Lemke, 1990) were also espousing this position. Thus, a pedagogical approach of incorporating argument into teaching was born in what is referred to as argumentation theory. This argumentation theory consists of three main types of argument; analytical, dialectical, and

rhetorical schemes in order to present and judge claims (van Eemeren et al., 1996). Analytical arguments are based in logic "proceeding inductively or deductively from a set of premises to a conclusion, and include examples such as deduction, material implications, syllogisms, and fallacies." (Jiménez‐Aleixandre et al., 2000). While dialectical arguments spawn from debating and discussions "… involving reasoning with premises that are not evidently true; they are a part of the informal logic domain." (Jiménez‐Aleixandre et al., 2000). Finally, rhetorical arguments revolve around public speaking and aim to sway an audience (Jiménez‐Aleixandre et al., 2000).

Despite those three distinct argument structures having unique properties, researchers have proposed that teachers should incorporate all three styles of argumentation in different areas within a science classroom since the discourse around science includes all three kinds of arguments (Jiménez‐Aleixandre et al., 2000). The pedagogical emphasis on argumentation within classrooms was argued as being very related to general education due to how both argumentation and general education aim to give students the ability to soundly reason and think critically. As Siegel writes, “[e]ducation and argumentation are united...by their mutual concern with rationality and the normative dimensions of reasons and reasoning.” (1995, p. 163)

Argumentation theory had an especially large impact in the field of science as it was argued that scientific inquiry is deeply rooted in justifying and creating claims in order to understand the natural world around us more accurately. Jiménez‐Aleixandre goes on further to explain that, "commitments to

theory, methods, and aims are the outcome of critical evaluation and debates among communities of scientists. Argumentation and argumentation theory are strategies for resolving questions, issues, and disputes." (Jiménez‐Aleixandre et al., 2000). These beliefs led other researchers to call on the need to study argumentation even more in order to support students learning science and scientific thinking better and to have the ability to engage in talks about science at a deeper level (Applebee, 1996; Lemke, 1990).

Since then, there have been numerous studies delving into the analysis of argumentation within the context of education (Driver et al., 2000; Duschl et al., 1999; Jiménez -Aleixandre et al., 2000; Kelly & Takao, 2002). At the same time, studies have been growing in number that show the importance of discussion in learning science and developing scientific habits of mind (e.g. Boulter & Gilbert, 1995; Kuhn, 1992; Schwarz et al., 2003).

As the research field about the use of argumentation developed from the 1990s into the 2000s, more studies surfaced advocating for teaching to shift from recitation and lecture to dialogic discursive practices by highlighting the benefits to learning that come from dialogic classroom interactions (Alexander, 2004; Matusov, 2009; Mercer & Littleton, 2007; Mortimer & Scott, 2003; Nystrand, 1997; Wegerif, 2013; Wells, 1999). Dialogic practices specifically referred to a classroom where students face different perspectives through active participation in discussing and describing their own ideas in authentic interactions (Larrain et al., 2018). The act of dialogic teaching was defined as a "pedagogical approach that involves students in the collaborative construction of meaning and

is characterised by shared control over the key aspects of classroom discourse" (pg. 114) (Reznitskaya & Gregory, 2013). As this definition of dialogic discursive practices developed, the refinement of how argumentation specifically plays into the context of education deepened.

Classroom argumentation fits into dialogic interactions by being a specific kind of dialogic talk. Argumentation itself is seen as a specific kind of dialogic discussion that occurs naturally when individuals bring up pieces of discourse in order to reach an understanding on a given issue (Larrain et al., 2018). It is also a specific kind of dialogue that results in opinions being both formed and justified in a rhetorical context as a response to criticism where one should expect to hear different views (Larrain et al., 2018). This isn't a new view though as Billig (1987) argued that argumentation consists of various positions that are juxtaposed and addressed, thus making argumentation undeniably dialogic. However, a more recent exploration into this view claims that argumentation can occur both between speakers and with just a single speaker as one can present and defend many different kinds of views (Greco, 2016; Leitão, 2009).

This newer view on argumentation also claims that argumentation can be broken up into different categories, but differently from how it was originally divided in the 1990s. One form that argumentation takes is in building and defending a side of an argument through the use of evidence and justification (called "con-sensual argumentation" by Asterhan, 2013 or "coalescent argumentation" by Kuhn, 2015). Another form of argumentation uses counterarguments, challenges, and rebuttals to dispute other sides of an argument

in order to have one side triumph over the others (Larrain et al., 2018). The last form of argumentation in this model is evaluating different perspectives and ideas in a collaborative manner (called deliberative argumentation by Asterhan & Schwarz, 2016).

Looking specifically at the talk that goes on within a classroom, argumentation is a specific dialogic mode of talk where students and teachers cycle in challenging ideas and provide reasoning in a classroom dialogue that incorporates all of the facets of argumentation stated above (Osborne et al., 2013). In this classroom discussion, students have many roles. They help in the construction of classroom meaning (Reznitskaya & Gregory, 2013), talk extensively and build ideas which teachers then recognize and voice (Alexander, 2004), and build arguments to bolster a certain view when approached by a different view (Larrain et al., 2018). As research progresses in this field, we are developing more nuanced looks at classrooms and are tweaking models of argumentation in the classroom to reflect a broader understanding.

Difficulties with argument as a learning method

Research into the field of science education has explored how students justify and articulate viewpoints, claims, and explanations (e.g., Bell, 2004; Lawson, 2002; Sandoval & Millwood, 2005; Zohar & Nemet, 2002), as well as how students critique, present, and judge ideas (e.g., Abell et al., 2000; Clark & Sampson, 2006b; Kuhn & Reiser, 2005; Kuhn & Udell, 2003; Osborne et al., 2004; Veerman, 2003). Through this exploration into science education, scientific

inquiry is regularly seen as a process in which knowledge is built through the development of observations and explanations of data, which are then presented to peers for discussing, reviewing, and critiquing (Driver et al., 2000; Duschl, 2000; Passmore & Stewart, 2002; Sandoval & Reiser, 2004; Stewart et al., 2005; Vellom & Anderson, 1999). Therefore, as a vital part of the inquiry process, a student must have the ability to create a persuasive and convincing argument to bolster or counter an explanation (Driver et al., 2000; Duschl & Osborne, 2002; Jimenez-Aleixandre et al., 2000; Kuhn, D., 1993; Kuhn, T. S., 1970; Latour, 1987; Siegel, 1989). Despite that, arguments have to line up with the epistemological criteria that are used by the scientific community as a whole in order to have those arguments be convincing and persuasive (Sampson & Clark, 2008). Four examples of epistemological criteria in the field of science are;

1) The need for evidence to be provided to back up the reasoning for knowledge claims and proposed evaluations of claims (Hogan & Maglienti, 2001).
2) The need for the theoretical frameworks and the observations regarding the phenomena to have coherence (Passmore & Stewart, 2002).
3) The need for evidence credibility (Driver et al., 2000).
4) The need to base arguments on logically sound thinking (Zeidler, 1997).

These are foundations for creating arguments that help refine arguments for the scientific community in order to refine what arguments hold the most, if any sway.

Despite the fact that we know the theoretical criteria to create convincing arguments, some researchers hold the view that it is difficult for students to learn how to defend an argument in practice and thus create effective scientific argumentation. These researchers believe that students have to learn about how scientists make claims, advance claims, provide claims with the best evidence, gather evidence, and interoperate it all (Kelly & Chen, 1999; Osborne, 2002; Sandoval & Reiser, 2004). Duschl (2008) illustrated these points as keys to creating and judging arguments and called them the social, epistemic, cognitive, and conceptual aspects. Many science educators argue that in order to give students a good science education, students require more chances and opportunities to learn how arguments are used to construct knowledge in the scientific community and also that students should be taught what makes for a strong argument (e.g., Bell & Linn, 2000; Driver et al., 2000; Duschl & Osborne, 2002; Kuhn & Reiser, 2005; McNeill et al., 2006; Newton et al., 1999; Sandoval, 2003). It is not impossible to teach children scientific argumentation. Experiments conducted in the classroom have shown that students are fully capable of having more effective discourse when taught and informed about the steps of how to create and critique claims (Herrenkohl & Guerra, 1995).

Despite all of this call and reasoning to bring more argument/dialogic interactions into classrooms, studies show that monologic interactions are still what make up the vast majority of classroom teaching. There are several possible reasons for why this continues. First, despite the benefits argument/dialogic interactions have been shown to provide students, conducting a classroom that

incorporates argumentation can be difficult and sometimes problematic, particularly if the teacher is not experienced in using these methods. Trying to use argument as a teaching technique can be detrimental as Boulter and Gilbert point out that creating an oppositional framework for a class by using polarized language can lead to issues (Boulter & Gilbert, 1995). Framing the students' discourse as inclusive and not confrontational can help shift the talk to one where students can more fluidly work with ideas.

Some researchers have proposed that another issue that can make teaching with argument difficult is that students may have many different difficulties with constructing an argument. Zeidler (1997) draws from numerous pieces of literature regarding science education to highlight five key reasons why students struggle with creating arguments:

1) Students have issues with validity - students are deceived by the converse error and incorrectly infer that a true conditional statement's converse is also true (eg. "If the lamp were broken, then the room would be dark" - true; "The room is dark, so the lamp is broken" - false).
2) Students have an incomplete idea of argument structures - students often fall into the trap of confirmation bias, meaning that students selectively favor information that already fits with their original idea while not giving much thought to information that refutes their original idea.
3) Students are deeply swayed by their core beliefs - students greatly favor and are more convinced by arguments that already are in line with

their beliefs. This weakens a student's ability to rationalize and deal with criticism as well as evidence against their beliefs.

4) Students rely on inadequate amounts of evidence - students are misguided by data and statistics which leads them to come to conclusions before enough data is available or they misuse statistics in collecting evidence.

5) Students misuse what evidence and argument represent - students sometimes go outside the scope of the evidence and infer other things that bias the outcome of what the data is "representing".

Looking at another study taking up that same perspective on the difficulties students face in developing persuasive arguments, we see Chinn and Brewer (1998) argue that when students are faced with anomalous data, there are typically eight responses consisting of:

1) Ignoring the data in its entirety.

2) Rejecting the data.

3) Leaving the anomalous data out by claiming it to be irrelevant.

4) Suspending the data from use by claiming there are uncertainties and not enough data.

5) Shaping the meaning of the data by stating that the causal explanation is different from the scientific explanation.

6) Diminishing the weight of the data by declaring that its impacts are minimal.

7) Expressing doubt about the data as being valid.

And finally, the eighth response is where students changed their view despite the information coming into conflict with their original belief. This eighth response was particularly rare in this study with only 8 of the 168 tests resulting in students changing their view. This highlights to these researchers how difficult it is for students to naturally deal with conflicting data, which impedes them from being able to develop effective and nuanced arguments.

In both studies done by Zeidler (1997) and Chinn and Brewer (1998), they remind the reader that scientific thinking is difficult and messy. Even experienced scientists fall victim to the issues listed above when they try to develop scientific arguments. However, not all researchers believe that the issue of classrooms still being mainly monologic revolves around students having difficulties developing and structuring arguments. Researchers have argued that the structures in which we try to implement argumentation explicitly into classrooms are "not sufficient for allowing students adequate access to the activity systems within which scientific argumentation operates" (Manz, 2015, p. 561). One example of how it is not sufficient is that the explicit teaching of argumentation to students often omits important activities where scientific argumentation operates that are nonverbal, conjectural, or focused on creating a tangible product (Bricker & Bell, 2008; McDonald & Kelly, 2012; Shemwell & Furtak, 2010). Another example of how that kind of implementation of argumentation is not sufficient in teaching students is that students don't have to understand the purpose of scientific argument in order to use the structures of scientific argument. Instead students can just use those structures as a means to finish classes/assignments instead of

actually participating in scientific activity (Berland & Reiser, 2011; De Vries et al., 2002; Kuhn & Pease, 2008). Having the structures and forms of argumentation presented to students can help initiate students into scientific argumentation. However, students may not truly understand the reasons behind these forms if they are just taught the structures of scientific argument. As Manz (2015) summarized, "By developing stable descriptions of argumentation and using them to inform assessments and supports, we risk lifting the practice from the contexts that lend it meaning." (p. 562). This leads to different kinds of argumentation engaged by students versus scientists with students adopting a kind of pseudoargumentation to just excel at a test format or to please a teacher (Berland & Hammer, 2012).

In order to avoid these kinds of pseudoagumentaion from perpetuating in classrooms, argumentation could be approached by ways that are more organic and naturally occurring to a student's experience and regular activity. Argumentation isn't something foreign to students or that can be only engaged with when students are older. Students have been shown to be able to identify uncertainty, participate in meaningful discussions around uncertainty, and construct ways to handle uncertainty in scientific activates from a young age (e.g., Ford, 2005; Lehrer et al., 2008; Passmore & Svoboda, 2012). Children have also been shown to have argumentation as a naturally occurring central part to their out-of-school concerns which include; debating social order, creating identity, and getting what they desire (Goodwin & Goodwin, 1987; Kyratzis, 2004). These out-of-school situations illuminate activity systems where students

skillfully argue using intonation, format-tying, attacking character, treats, inquiring about justifications, telling stories, and discerning alternative reasoning and cause-effect logic (Bricker & Bell, 2012; Goodwin & Goodwin, 1987; Ochs & Taylor, 1992). Although these arguments may not be scientific, they display to us that students have the tools to engage in argument and demonstrate students naturally having some of the tools necessary for argumentation. In this example we see that students can alter their argumentation strategies depending on the situation of the argument and whom they are arguing against or with. We also see that students try and convince others by drawing on a wide range of resources. We also see students constructing social organization by agonistic arguments. Through this, we can see that classrooms can tap into the naturally occurring abilities of students to engage with argumentation without having to express explicit structures. This will then allow students to better understand the rationales behind the forms of scientific argumentation.

As shown above, there are two approaches by which researches have suggested argumentation could be approached in the classroom. One approach calls for explicitly introducing argumentation structures to students so that students can be shown how knowledge is developed in science while scaffolding students' argumentation performances until they can create arguments on their own (Berland & Reiser, 2011; McNeill et al., 2006). Another approach taps into the natural processes and activities students already engage with in other settings to convince and discuss with other students in ways such as telling what and why they are thinking and demonstrating if they agree or disagree (Hudicourt-Barnes,

2003; Varelas et al., 2007). It may be tempting to provide students with a scaffold for argumentation and explicitly tell students about the forms of scientific argumentation so that students are presented with clear information. However, it is likely that the continual issues of students performing towards a test or to please a teacher without digesting the meaning behind the forms of argumentation will continue to persist. Students are capable of venturing into argumentation without explicitly having the forms laid out for them so tapping into the naturally occurring ways in which students argue is an effective way to engage students within argumentation. However, further research is still needed to see how to integrate these practices into the classroom.

Why the public needs to know about scientific argument

It has already been shown in studies that argument is integral in handling scientific controversies (Fuller, 1997; Taylor, 1996). However, scientific controversies and issues don't exist only in the classroom and in laboratories. Scientific issues surround all of us in our daily lives and students are limited in their ability to analyze and reason through arguments and claims generated by these socio-scientific controversies in part due to how little students get to practice proper arguing within science classrooms (Norris & Phillips, 1994; Solomon, 1991). These youth are already a part of the public and they will grow up to become even more central parts in society. Educating them to be able to reason with data and arguments to come up with an independent, informed view on topics is a crucial empowering factor that should be given to everybody.

With so many scientific controversies facing the modern world such as global warming, traffic management, genetic engineering, food content, genetic information rights, fuel usage, animal testing, anti-vaccination, and conservation, it's crucial that individuals be able to logically reason through these issues in order to come to an informed opinion to act upon. Studies have shown that the public can come to reasoned conclusions about socio-scientific controversies when given the chance to carefully examine information (Doble, 1995) and it's important to foster the ability in students to naturally be able to reason through these controversies. This is because although the public may be able to come to reasoned conclusions naturally, they need to learn to take the time to do so and not jump to conclusions.

This notion that students should take the time to practice scientific reasoning and engage productively with scientific arguments isn't new. For decades it has been stated that in a democratic society, youth must be given an education that fosters their ability to analyze and construct sound arguments around science and the societal impacts of science (Dewey, 1916; European Commission, 1995). It is crucial that students have the capability to skillfully digest and critique arguments that they will come across in daily life, particularly arguments that come from the media. They need to understand what makes for a sound argument and a trustworthy viewpoint so as to not be deceived by more nefarious or ignorant individuals.

There is also another reason why argumentation is crucial for the public's understanding of science. That reason is that argumentation helps individuals

understand what truly develops in the process of scientific inquiry. Numerous studies have pointed out that most people view scientific knowledge as being unwavering and static once derived from observation and experimentation (Driver et al., 1996; Larochelle & Desautels, 1991; Lederman, 1992). However, in reality, scientific knowledge is very often debated and argued over, especially socio-scientific topics. This then leads us to a problem of how the general public views and understands why scientists have disagreements about issues. The public may speculate that scientists are biased due to external or personal factors. The public could also speculate that some scientists are inept. These views from the public don't cast a good light onto the scientific community, but as Gregory and Millar (1998) pointed out:

> *". . . while science is in-the-making, the 'right answer' is unavailable to everyone including the scientists, and anyone who claims to know it deserves public skepticism if not distrust. In such cases, the scientific literacy enterprise, in terms of knowledge or understanding is beside the point."* (p. 243)

What this quote is pointing out and what the public doesn't always understand is that conflict, argument, and debate are at the core of science and are integral parts to the process of understanding the world. As Driver summarizes about the role of argument in the realm of science,

> *"For it is through the process of exposing different interpretations and checking them against available evidence that scientists, and eventually the public, gain confidence in the knowledge claims that are made. Argument is thus the mechanism of quality control in the scientific community. Understanding argument, as used in science, is therefore central to any education about science."* (Driver, et al., 2000)

Problems with limited perspectives on argumentation

With research coming out that calls for and supports more use of argument and discussion within science classrooms as a method for learning, researchers have been wondering why the amount of discussions in science classroom isn't increasing. Driver et al., (2000) argued based on their preliminary study that there is," a general lack of pedagogical expertise among science teachers in organizing activities in which students are given a voice." So, with this absence of pedagogical knowledge within teachers, institutions and researchers have been exploring the pedagogical side of teaching with the use of arguments to help better the skills of teachers.

However, with the rise in institutions looking to help teachers utilize argumentation in the science classroom, more and more teacher-targeted handbooks or guides are being published that have narrowly viewed approaches to facilitating argumentation. In trying to streamline research on argumentation and develop manuals for teachers, much of the nuance around argumentation has been lost.

A significant example of this is the U.S. National Research Council's book, *Ready, Set, SCIENCE! Putting Research to Work in K-8 Science Classrooms*, which was published in 2008. This book overlooks or ignores many points of nuance that would be extremely beneficial for a teacher to consider. One area of discussion in the classroom that the book doesn't provide a nuanced view for can be seen when the book explores how language and terminology is used by students:

> *"First, the language of science can be very particular. Certain words have precise, specialized definitions. It is quite common, however, for children and adults alike to confuse specialized science definitions with the more familiar definitions commonly associated with those words."* (National Research Council, 2008, p. 88)

This is an overgeneralization of the issue with scientific language in regards to the misuse of scientific terms. Students may confuse scientific terms with colloquial terms, but students may also use terms in order to sound more scientific because they know they should be speaking "science" in a science environment. In this case, students may not understand the meaning and background of the scientific term but are taught to just say those words in a given context.

The cultural backgrounds of students may also influence how language is used as different areas around the world use terms differently. Although it may be tempting to have a unified definition of complex terms, insisting on "correctness" being defined by a singular use of words can also serve to limit the discussions the students are capable of having. Getting caught up in the semantics of a language doesn't serve the students when the deeper ideas and thought processes are crucial to the overall development of their scientific abilities. Vocabulary and definitions are important, but writers of guides for teachers shouldn't have that be the main focus of what to tell teachers since it serves to propagate all of the issues previously mentioned when not observed in a nuanced manner.

A second example of poor nuance of discussions in classrooms can be seen when the authors acknowledge cultural differences within the student body of a classroom. As I said previously, it is important to consider the cultural backgrounds of students in a classroom, so it is pleasing that the book attempts to

cover this topic, but the solution to cultural differences proposed by the book is quite lackluster and doesn't truly appreciate diversity:

> *"One way for teachers to overcome cultural and linguistic differences in students is to treat them as if they were highly intelligent foreign diplomats... An assumption of competence makes it easier to build on and promote student's contributions, even if those contributions are incomplete, not entirely explicit, or are expressed in a nonstandard dialect. Once students are invited into the conversation, are given opportunities to engage in coherent instructional tasks, are able to hear and build on the contributions of their peers, and have scientific reasoning modeled for them by teachers and peers, they gradually take on the language and forms of competence that are valued in science."* (p. 99-100)

I find this solution to cultural differences to be quite rude towards students of other cultures. This "solution" is basically calling for an assumption, not even confidence, but an assumption that students from other cultures and languages can contribute. If the primary tactic here is to convince teachers that students from other language and cultures can have good contributions, then there are deeper issues here about understanding people who are different from you. In addition to that, the most shocking thing from this section is that this section of the book is calling for assimilation as the way to have discussions with other cultures. This passage doesn't incite respect for varied student cultures; this passage is encouraging only tolerating a student's culture until they are assimilated into the dominant culture. The "forms of competence" that are valued in science in this scenario are based on one culture's ideals about the forms of competence, but there are different ways to have competence in science that can vary culture to culture. Different cultures can add valuable and diverse perspectives, which can challenge ways of thinking about science and scientific questions (Rosebery et al., 2010). However, the tactic presented by this book serves to slowly eliminate those

backgrounds and dialogues. This is a shining example of how a lack of perspective and nuance into discussions and student culture can lead to propagation of well-intentioned actions that ultimately fail to serve students.

A final problem with can emerge with some handbooks is that the way authors define argumentation can be at odds with other definitions in the literature. When this book attempted to talk about argumentation, it started off with an immediate deviation from what some literature has said about how argumentation relates to the field of science. The book describes argumentation as have different forms, but declares that the kind of argumentation that happens in science is different from, *"the common forms or argumentation in which people engage in daily life"* (p. 89). The book goes on further to claim that,

> *"In science, the goals of argumentation are to promote as much understanding of a situation as possible and to persuade colleagues of the validity of a specific idea. Rather than trying to win an argument, as people often do in nonscience contexts, scientific argumentation is ideally about sharing, processing, and learning about ideas."* (p. 89).

However, this book is presenting a limited perspective on argumentation. Researches have stated that the argumentation that occurs in a science classroom should include all forms of argumentation in the right contexts since they all hold a facet of what the field of science encompasses (Jiménez‐Aleixandre et al., 2000; Osborne et al., 2013).

By considering this case of a handbook attempting to teach teachers how to better use argumentation in the classroom, we can see that a simple approach with little nuance in understanding argumentation and classroom cultures is not effective at preparing teachers to use argumentation in their classroom in a

manner that would serve to benefit all students. In order to best prepare teachers to teach using argumentation, teachers have to understand the logic of why argumentation is important and be able to analyze the nuances that surround having argumentation in the classroom. They also need active practice to see how theory works in practice and how they can hone their own techniques. The case study in this paper will demonstrate some of those nuances that can occur in a classroom focused around discussion and discourse. In addition to that, this paper will circle back to highlight the crucial need for teachers to practice, reflect, ponder, and analyze in order to better their teaching.

About the Study

Motivation for a case study approach

The rationale behind using a case study approach in this paper to contribute to the discourse around the use of argumentation in science classrooms is that a case study will focus on the experience of one teacher's teaching, which will allow a greater exploration into the nuances of how teaching argumentation can be handled and developed. The successes, failures, realizations, reasoning, and general thoughts are looked at to provide both researchers and other teachers a look into situations that may affect a classroom and can provide a better understanding of how to deal with implementing argumentation into science classrooms.

Objectives

The goals of presenting this case study are to:

1) present examples and discussion of a development in a novice teacher's pedagogical approach to facilitating science discussions as well as the results of those shifts in pedagogy and practice.
2) provide educators with a novel case to reflect upon and consider against their own growth and exploration with science discussions in the unique dynamics and contexts of their own classrooms.
3) explore the nuances with implementing argumentation into a science classroom when a teacher doesn't have a background in argumentation yet is reflective and driven.

Study Context

This study takes place at a private university in Massachusetts, United States of America in an undergraduate biology lab that is focused around discussions. The course that this lab is a part of is one of the introductory biology courses at this university. There are three units in this lab section of this biology course; bacteria, plants, and beetles. The individuals teaching the lab sections of this course are graduate students that are referred to as teaching assistants (also known as a 'TA'). Each lab section of this course is assigned to one graduate teaching assistant and one undergraduate lab assistant ('LA') who teach their lab section for nine labs that take place over four months. During the months of teaching, weekly lab prep meetings are held where the pedagogy of the biology

labs is discussed and TAs and LAs perform that week's entire lab so that they understand and have done the lab before teaching it to their class. The TA of this case study was also participating in a class that was designed to help teach TAs about the pedagogy of teaching this lab (BIO 196). The professor of that class was also the laboratory coordinator of the biology course that the TA was teaching.

Data Collection

To understand how a novice teacher develops in facilitating and fostering discussions, a novice TA's lab classes and reflections about her experience in those lab classes were recorded by a research team during the spring of 2018. The TA consented to the collection of videos of her lab section as well as the collection of the reflection journals she wrote regarding these labs. Students were also asked to give consent to be recorded with the option to be omitted from recording if they desired. The TA also had two interviews over the semester. For this paper, I examined her interviews, classroom videos, and reflection journals. However, I focused most heavily on analyzing the journals as they provided the most direct link to the TA's thoughts.

Classroom Videos

Every week of the course the laboratory was recorded from multiple video angles and with audio recorders placed on each table. These videos ranged in length but were more than an hour each time. There was one whole classroom camera set up along with three cameras that focused on the three large lab tables

that students sat at. Conversations can be heard through the video feed, but separate audio recorders were also set up on the tables to help capture discussions more clearly.

TA Journals

Each week as part of the pedagogy course that the TA engaged in, she wrote a journal that was a reflection of the lab she taught that week. She was asked to reflect on specific moments from the lab that stuck out to her as well as her general thoughts prevailing around how the lab went. I analyzed these journals through reading them and then locating the moments referred to with the use of the classroom videos. In doing so I was able to compare her internal thoughts and dialogue to the reality that was being presented during that instance. She submitted only seven journals, one for each of the first seven weeks of lab. As a note about confidentiality, in the journal excerpts that will be shown below, the names of teachers, students, and researchers were changed to "[Student X]", "[Researcher X]", or "[The Laboratory Coordinator]" in order to maintain confidentiality of individuals.

Research Interviews

A researcher also interviewed the TA in this case study and had that interview recorded for later analysis. I watched her interviews to further examine the TA's thought processes.

Selection and description of case study participants

During the Fall of 2018, the Biology Learning Lab research team led by Professor Julia Gouvea met to discuss the TAs that had engaged in that series of biology laboratories the previous Spring. We discussed moments from those labs that stuck out to us and reviewed the difficulties and successes that were brought to light. We then started going over the journals and interviews of these TAs to get a better understanding of the thought processes these TAs were having. During this time, one TA stood out to me as particularly intriguing. This individual was given the codename "Susan" by the research group.

Susan is a novice TA who has no experience with teaching and who didn't go to school in the US. She was educated in China and talked about the difference in how education is approached in the United States versus where she grew up in China. In particular, she talked about how she didn't grow up in an education environment where discussion happened; the teacher's single answer was the only acceptable answer. The teacher lectured and told her what was right or wrong. Susan was particularly intriguing to me because she was a novice TA from a background totally different to the use of argumentation in teaching and she had plenty of motivation to teach as best as she could and continually tried to better her teaching ability. Her motivation to implement and encourage argumentation forms into her classroom seemed to stem from a genuine care about her student's ideas, which made her case even more interesting to explore from the perspective of teachers caring being a factor to the success of argumentation. Some TAs don't put much effort into being a better teacher since they don't believe they will ever

go into teaching, but Susan was willing to try her hardest. This attitude coupled with her background led to a very fascinating case to study and analyze.

Case Analysis of Susan's Development in Teaching Using Discussions

Week 1 (A Focus on Semantics and Technical Knowledge)

During the first week of teaching, Susan appeared to focus her efforts on attending to technical misconceptions and overarching technicalities the students had. The most memorable moments that she chose to reflect upon in her journal were ones that didn't dive into the deeper understandings or thought processes that students had. Unsurprisingly, upon reflecting about the first week of class that she taught, Susan wrote about the lack of discussion present in her class:

> *"My first week doesn't have too much to talk about. Most of the students were the first time having a discussion-based lab, and they were not getting used to it. When I brought up a question, they were not reactive, and only a few were willing to answering questions. It's the first lab and students are not familiar with each other yet, and many of them didn't have a chance to read the pre-lab reading, so that they don't have a good background and don't know what to say. I believe that the following labs will be better."*

In this reflection, Susan attributed the lack of discussion in her class to the lack of experience students had with "discussion-based lab[s]", the lack of familiarity students had with each other, and the lack of background knowledge students had due to not completing the pre-lab reading. This is an observation to take note of, as Susan will begin to consider other factors influencing discussions in later classes.

In addition to that first instance of Susan focusing on the students for not creating a large amount of discussion, there were also other points during the

reflection of the first week in which Susan attributed blame to the students for the mishaps in the lab. In this next segment, we see an example of Susan reflecting upon a misinterpretation that a group of students had:

> *"I walked around and asked each group for their thinking. One group was thinking about UV lights. They misread the question and said: "When you are exposed under environment with stronger UV lights, you have more chance to get cancer because your genetic repair mechanism has a higher chance to mutate and becomes dysfunctional. That's how you end up with a higher mutation." I realized that they were taking the word 'favor' as 'cause' but I did not know a good way to correct that. So I simply said: 'The question stands for 'under what condition an organism a higher or lower mutation will have better fitness'. They suggested that the word 'favor' was misleading and it would be better to rephrase the question."*

This moment is a case of a rather common misinterpretation that students can have. However, what is more interesting is that this was a big enough moment about discussions for Susan that she wanted to write about the whole moment. This general correction of a group's confusion about phrasing isn't demonstrating any real depth of a discussion and is a very surface level, semantic issue, yet this issue stood out to Susan. This focus on correcting semantics and around the general knowledge/experience of students points towards Susan having an attitude of attending to just the surface level of teaching through discussions during this first week. On this level, she is focused on the technical understandings instead of the mechanisms and depth of the substance that the discussion is exploring. This point is further supported by the next moment Susan wrote about where she once again corrects a misconception a student had:

> *"The other moment I want to share is that when I asked the class what they would expect on two antibiotic plates. One student said the mutator strain would have colonies on rif+ plate but the other wouldn't. Then I asked him to further explain, and he said that only mutator strain could mutate but standard strain couldn't mutate, because standard strain had a*

functional repair mechanism that could recognize errors and fixed them. I realized that he misunderstood the definition of repair mechanism, so I told him that even a fully functional repair mechanism also made mistakes, just fewer. And he changed his mind saying that mutator strain would have more colonies than standard strain on antibiotic plates."

Here again, we see Susan focusing on correcting technical definitions and attending to facts instead of focusing on deeper discussions and student ideas. During this first introduction into teaching with discussions and argumentation, Susan seemed to be thinking much more about the technical correctness of facts and semantics instead of looking at more in-depth student thinking and teaching through discussions. Susan wasn't struck much by thinking about how students are generating ideas and supporting their claims. Overall, we see that in week one, Susan took a very surface level approach to discussions and demonstrated a focus on correcting technical knowledge due to how those moments stood out to her.

Week 2 (An Experiment in Fostering Argumentation)

The second week of lab had unexpected circumstances surrounding it as there was a failure in the previous week's experiment on bacteria which gave Susan's class unexpected results all around. The layout of the curriculum for the lab asked the TA to lead a discussion on the results from the previous week. Interestingly, since the results obtained were unexpected, this led to an interesting discussion that Susan seemed to be excited about and that also created more discussion among the students:

"This week was a little bit messy for the experimental design section, which I will talk about later on. However, I feel like the discussion worked better than last week, and students were more active and willing to talk!

They brought up many valuable thoughts and made discussion more interesting than the first week."

In this section of Susan's reflection about the second week of her lab, Susan noticed more engagement and discussion happening that also led to more interesting discussion overall. It is possible that having a failed experiment with anomalous data where the reason for the mishap or possible implications isn't known actually helped Susan have better discussions. This could be due to the possibility that Susan wasn't focused on correcting the technical knowledge of students and instead let them explore different answers as to what went wrong. This second week's discussion is quite different from the first week's since Susan can't really correct the students too much since she doesn't know the true answer of what is happening with the experiment, opening up the class to a broader discussion. Susan goes on further in her reflection to lead us through the thought process she had when trying to help facilitate the classroom discussion around the anomalous results:

"The first discussion we made was around the result from last week. Instead of having 0-1 colonies on the low mutator rif+ plate, the whole class ended up with nothing. I was worried that they would simply consider that low mutator strain is unable to survive in such an antibiotic environment at all. So I asked, 'Does that mean that there will be no mutation happens for the low mutator strain? Is there any other explanations for no colonies on the rif plate?' "

From this part of her reflection, we can see that Susan clearly wants to foster a discussion and is worried about the most obvious answer being the only one presented. So she opens up the floor to a wider discussion by inviting other explanations to be presented. Seeing data or a situation from multiple perspectives is part of good argumentation practices so Susan has ventured into developing

argumentation in her classroom through an effective step in trying to avoid a single answer being given and the discussion ending there. Susan then goes on in her journal to reflect upon how the use of outliers and even more anomalies can push a discussion down further paths:

> *"Since there was one group that didn't have any colony on the high mutator rif+ plate, I thought it would be an alternate way to consider. I then asked, 'Most groups have several colonies on the high mutator rif+ plate, while one group doesn't. Does anyone have thoughts on that?' I discussed with the group before so one of they answered, 'Maybe it was a technical issue. When we planted, maybe we didn't mix the culture quite well, and only took a few or even non cells to plate. It is a rif plate so the majority would die, and we left with nothing.' "*

Susan demonstrated that she was attempting to engage the class in thinking through a situation from a different perspective to try and develop more discussion. Anomalous data was once again used to introduce argumentation into the class by providing novel data to consider against other pieces of data. Susan tried to encourage students to consider other perspectives by throwing a wrench into a single mode of understanding. Through anomalous data, a more nuanced perspective on the overall data and experiment can be developed. Susan also performed an interesting move in this case by approaching the groups individually when they were talking in smaller groups. By doing so she was able to assist the groups in considering their data thoroughly and help them come up with a perspective to share with the class. However, not everything was going smoothly for Susan. Susan also reflected upon an instance where she shared her ideas to the class only to have little response and discussion emerge:

> *"I believed that this explanation could also be applied to the low mutator strain, so I kept on saying that, 'Is it possible that no colonies left for the low mutator can also be explained by this? Low mutator needs longer time*

> *that high mutator to generate rif assistance mutation. If you culture your cells for a longer time, will low mutator also have a rif assistance mutation?' Several students noded. I feel like if sometimes students have no ideas on what's going on, or they have a rough thoughts but don't know how to purify it to a solid one, it is important to throw questions on them and see how do they react."*

During this segment Susan presented a leading question to her students but she presented it as a "yes/no" question. This question is different from the previous questions we looked back upon during this second week of Susan's teaching. In the previous two moments, Susan presented more open-ended questions by asking students "*Does anyone have thoughts on that?"* or "*Is there any other explanations for no colonies on the rif plate?".* However, during this moment, Susan asked a "yes/no" question which just had students nodding their heads. Susan reflected upon how she isn't convinced that the students have thought through the question fully. This shows that Susan is starting to pay attention to and consider what she can actually tell about a student's understanding.

What is more interesting in this moment though is the fact that Susan doesn't push the students to provide a more in-depth answer but instead just continues once she sees heads nodding. Susan wanted to try and guide the students to a broader understanding by providing a new perspective for the class to consider, but she doesn't go beyond having the students just nod their heads after hearing her nuanced idea. She shows dissatisfaction with just seeing nodding and flirts with the idea of asking follow up questions or just posing more questions to her students. Near the end of this passage, she considers wanting to "throw questions" at students in order to see how the students react in answering

those questions. Susan seems to be thinking now that posing questions to students can help her better understand the thinking of students more so than just relying on students nodding.

A final important realization that Susan is picking up on during this moment is the idea of students having "rough thoughts" or ideas that aren't completely finished. Susan seems to realize something about these half thoughts and "rough ideas" as being important but her solution is to "throw questions" at the ideas and just see what happens. Throwing questions at students seems to be a method in which Susan believes she can help her students transition from "rough thoughts" into "solid" thoughts. Through this we can see that Susan is thinking about how she can help her students with their ideas in discussions. With Susan reflecting upon all of these moments of discussions in the lab, she also starts reflecting on how she is approaching the ideas in these discussions herself:

> *"However, I feel like sometimes my mind is solid too. In the first assignment, most students talked about how changing environments favor high mutators while stagnant environments favor low mutators. In the first lab students were not so active and their response to this question was quite limited. Moving forward, I need to promote them to think diversely.. (to be continued…)"*

This is a fascinating and constructive critical thought that Susan is having. The wording of her mind being "solid" is in reference to her believing that she has a limited and restricted perspective on these topics and questions. (This idea will be supported later on in a more in-depth interview where Susan explores her own background she is bringing to the classroom). At this moment, Susan is considering the perspective she has and is bringing to the classes/discussions. She is lamenting about the issue of limited ideas being brought up in discussions, but

she isn't just putting the blame onto students. Susan is considering herself as a limitation to the discussions and is empathizing with the students having difficultly engaging in discussions by admitting that sometimes her "mind is solid too". At the end of this moment, we see her reiterate that she wants students to have a broader discussion and think from diverse perspectives. She clearly wants to promote discussion and foster diverse ideas, which is leading her to consider factors about how argumentation and discussion are being framed and executed within her classroom. Through this, she is not only considering what the students are bringing to the table in terms of ideas and participation, but also, she is considering what she as a TA is bringing to the table in terms of framing the discussion and fostering diverse ideas.

Overall, this week we see that Susan has shifted from focusing on the technical points and ideas about questions and student background understanding to start thinking about how students have ideas and how those ideas can come out in discussions. A problem with a lab led to this more open discussion, which is evidence that mistakes or unexpected results can be more beneficial to discussions of a topic than if the lab went smoothly. This event may have helped Susan's understanding and awareness of many facets that contribute to effective and deep discussions within a lab. We even see Susan take purposeful actions to try and facilitate argumentation and discussions by opening up a broader discussion about an unexpected issue and also by presenting different lenses of understanding for the class to discuss. However, one of the most interesting observations Susan had in this week's journal is the observation she had about her own perspective that

she brings to the classroom discussions. In this next section, we will analyze an interview where Susan reflects upon this idea further.

February Interview (Susan's "Solid" Mind)

During the month of February 2018, a researcher interviewed Susan about her experience teaching a lab and what she thought about the pedagogy course she was taking. Near the end of the interview, a fascinating moment arose in which Susan reflected upon a concern she had regarding why her lab was not having as many ideas brought up in discussion when compared to labs taught by other TAs:

> *"Because I'm… my education background is in China so which is really different from here. So I just, like sometimes because in China we are basically like 'We have the right answer', instead of like diverse answers as long as you can explain it. So I just ummm I don't want to… blow up the students with my personal experience before. So I just trying to think like more. Because for actually for the first lab for the mutation rate like because we have discussion like 'Why mutation rates are different?' like 'What different conditions will favor different mutation rates?' and I because I saw other TAs like they posted their… because they just write down the answers from the students on the white board and then just took a picture and upload it to their folders. I kind of I look at some and I feel like their discussion has more answers than my class. I don't know if the TA are kind of like helping the students to get the answers or just the students like bring up the answers by themselves. But I just think, because I actually don't have that many ideas on that, so I don't know if it is my problem that my students doesn't have enough thinking about that or it just like basically they are not that talkative in the first class. So I just don't… because… because I think my education background kind of constrained my thinking to a smaller perspective. But I just don't want to... because of my personal experience to constrain my student's thinking. So that's the think that I want to improve."*

This is a more fleshed out version of the concern Susan briefly mentioned in her week 2 journal about her mind being "solid". Susan is concerned that her education background she received in China is limiting her ability to help her lab

generate more ideas and have discussions around ideas in class. According to Susan, she was brought up in an educational environment that did not encourage discussion about answers; the focus was on which one was the deemed technically correct answer. Susan grew up in very monologic classrooms and appears to be considering how that is affecting her now. It is an impressive step for Susan to have this metacognitive ability to consider how her own past educational experiences may be affecting her current ability to think about diverse ideas and foster a broad discussion. Through this metacognition, she is showing a deep reflectiveness and intense willingness to help her students. She is exploring where she might have a weakness in facilitating discussions and engaging in argumentation. Most importantly though, in this interview we see Susan stating that she wants to improve herself in those areas in order to help her students. She shows here that she truly cares about her students thinking and the ideas they are able to generate. She has the drive to improve her discussion/argumentation facilitating abilities and we will see where that takes her over the semester.

Week 3 (An Introspection Into Her Actions And Herself)

During the third week of labs, Susan attempted to begin a discussion around the most common misunderstandings she came across in the students' assignments. She reflected upon the success of this endeavor:

> *"I made a list of misunderstandings that I encountered from their assignments and started with the most common mistake of 'can environment promote mutations to happen and change mutation rate of a species'. Nobody answer this question so I just talked about my opinion on that."*

In this moment that Susan is reflecting on, we can see that Susan doesn't get a response from students. However, what is more interesting is that Susan doesn't push for a discussion to happen and instead starts to state her own opinions. Just moving on to talk about her ideas puts the classroom back into a monologic classroom instead of a dialogic classroom, which is something this lab was trying to avoid. Susan does seem to realize that she was creating a monologic classroom though and goes on to reflect upon a suggested tactic to foster more discussion that a fellow TA shared with her outside of lab:

> *"On Wednesday I chatted with [Teaching Assistant X] and she suggested that when students are quite, I can always ask them to turn to their own groups to discuss the question. I think it would be very efficient so that I don't need to talk a lot myself. Actually I'm sometimes worried that if I say something wrong that I don't mean it, especially when I'm talking a lot with nobody to interrupt. Also it is always easier to input than output, and listening doesn't require any thinking (if you don't want to). The same idea will leave a deeper memory if it comes from your own thinking than comes from others saying. I think I will definitely try this method next week."*

During this reflection, we see that Susan is trying to keep herself open to different ideas about how to help discussions develop. She has taken on advice from a fellow peer and has resolved to try a new approach to help discussions during her lab the following week. She has kept herself open to her peer's ideas since a collective experience and diverse perspectives on teaching can help Susan deal with a diverse set of situations she may face when trying to foster argumentation and discussions. However, what is more fascinating in this segment is the introspective look Susan is having into her own actions that she is taking as a teacher and how her actions are being absorbed by students. This introspective look can be seen when she shows concern over talking too much in

lab or saying something wrong. This internal dialogue over her approach to dealing with ideas continues as Susan reflects upon a question a student posed to her:

> *"I would like to talk about the question that raised by a student, 'Can mutation take place on MacConkey plate? It is not as lethal as Rifampicin and cells won't die immediately when being plated.' I didn't think about that question before but I think it is a valuable point to bring up. At that moment I answered that question based on my own knowledge, but now I feel like it would be better if I introduced the question to the whole class and let students think about that themselves."*

In this part of her reflection, Susan is wrestling with herself over what would have been the best way for her to handle a valuable question brought up by a student. She answered the question "based on her knowledge" but laments over the missed opportunity to pose the question for the whole class. This wrestling is all in hindsight, but it is interesting to see Susan thinking about how to handle ideas brought up in lab. She is beginning to appreciate more and more ways in which she can help a discussion form in her classroom. In this case, she is considering a unique question posed by a student as the launching point for a whole class discussion. This wasn't the only instance of Susan wrestling with herself over how she should have handled situations better in lab. She reflects upon another moment from the lab where students were confused:

> *"Then I walked around and asked students what did they get from their results and whether their results met with their expectations. Since we didn't discuss the purpose of broths in week 2, some of them were confused with their results. I want to commit myself that I didn't do a good job that week and didn't provide the students with sufficient introduction of materials that were provided. Although the information is also provided in the handout from week 2, I still think that I should take a great responsibility for those misunderstanding (I don't know if I can blame myself here haha). In the future I would read through the handouts more*

carefully and take more notes from prep to make sure the same situation won't happen again!"

Here we can see Susan blaming herself for confusion among students and considers how to best help prevent this kind of confusion in the future. This is a fascinating transition of thinking for Susan since in week 1 of labs she originally attributed blame to the students for the errors in technical knowledge. However, now in week 3, she is blaming herself for not helping to provide the technical knowledge about broths. This may be a result of the general introspection she had been doing over the prior weeks with regards to how she is affecting the students' understandings and discussions. She shouldn't be too worried about this though since background information was given to the students (as she mentions). But Susan is continuing to show drive for improving herself as a teacher and doing more to ensure that she can help her students as best as she can. As Susan continues to work on bettering herself and the discussion in her lab, she has a key realization about teaching:

"I believe that teaching is also a process of learning - not only learning how to teach, but also building my own knowledge based on students' questions and feedbacks. I think it would be ok to say 'I don't know', ask for opinions from experts (I asked [Teaching Assistant Y] with many bacteria and mutation questions), and return the answer back to students."

We can see Susan start to have some large revelations about teaching as she wraps up the first lab unit around bacteria. She now sees that teaching is deeply connected with learning beyond just technical teaching skills. She is beginning to see the value of not only having students learn from her, but also having herself learn from students to expand her own knowledge of the subject that is being taught. Through the experience of teaching and the reflection process

she has been engaging with, Susan has also become more comfortable with the idea of saying "I don't know" and admitting that she doesn't hold all of the answers. In fact, she is beginning to want to seek out answers with her students instead of worrying that she has to be able to answer each and every question that comes her way.

Week 4 (Considering The Class)

During the fourth week of lab, a new unit on touch sensitive plants began. Susan reflects on how this new study organism will be received by the students:

> *"Shifting to a plant unit! I'm anticipating more active students during these three weeks - they might know more about plants than bacteria so that students might have more things to talk about. Comparing to the first lab of bacteria, when students almost had no idea on what would affect mutation rate, they have a better sense on what would affect animal foraging behaviors."*

In this reflection we see Susan considering how a student's or class' background can really impact the amount of conversation that can be generated around a given topic. Susan is considering the foundation of knowledge as something that should be considered when she is teaching with argumentation and discussions. In this case, she reflects on how students will likely know more about plants than bacteria so she is more likely to get discussions in her class during a plants unit. Susan appears to have a greater focus on students this week because she goes on to reflect upon herself noticing the responses some students are having when facing a difficult discussion:

> *"I saw one problem from the group at the front of the middle table - those three girls were on their phones during most of discussions. When questions are too difficult to answer, some students might easily give up*

and turn to their phones; however, when questions are relatively simple, some students are also likely to come up with one or two ideas and then turn to their phones. For both situations I think I can provide some hints and encourage students to think more, but I feel like under the latter circumstance, they might think me annoying - 'we've already have some thoughts but why she keeps pushing us'. I'll join their discussion next class to see if my participation would keep them from their phones and be more engaged."

Susan notices how some students are disengaging themselves during discussions and begins to speculate on reasons why these students are not willing to engage in a discussion. This is a critical thought for Susan to have and ponder on since there are a multitude of potential reasons why a student may not want to engage in discussions. In this reflection, Susan proposes two possible reasons for her students' disengagement; the questions are too difficult or the questions are too easy.

Susan does seem to want to keep all of her students engaged and contributing to discussions but is not certain how to do that. She states that she doesn't want to badger students to come up with more ideas just for her. She wants those ideas to come more organically from encouragement and gentle directing. She frets over questions being too hard for students and wants to solve that issue by providing seeds of ideas or directions of thoughts in order to facilitate more discussion. In the case of the three girls on their phones, she declares that she wants to try another new method of facilitating discussion by joining in on their discussion as a way to solve the issue of their disengagement from discussions. Susan is doing her best here to try a new way to get everyone in class engaged in discussions. Experimentation can go wrong but that is also a learning aid. For example, in later weeks Susan will begin to think about how her

action of sitting in on a group's discussion impacts the rest of the class. For now, though, Susan reflects in her journal about another moment from the week 4 lab where there was difficulty in getting groups to voice disagreements to the whole class:

> *"An interesting situation is that, on the question of 'which plants, long day or short day, would re-open faster after they receive stimulus and close', the whole class agreed that short day plants would re-open faster because they 'want' more energy during more limited daytime than long day plants. I know the group at the front close to the door had disagreement or confusions because they were not certain of either answer**,** and I believe that there should be some other groups or students confused too, but they didn't want to share their thoughts in front of the class. Since this question is tightly related to assignment 2.1, I'm afraid that they might have trouble explaining the class result if it is the opposite (I still don't have the result at this point because not all of them update their data to spreadsheet). I should promote their thinking by asking 'how would you explain if the long day plants actually re-open faster', or saying 'if I claim that long day plants would re-open faster, how would you persuade me'."*

Here Susan is struggling with the situation where students don't propose ideas that are contrary to the general trend of ideas that are happening in class. It's completely valid to voice uncertainty or confusion in class even if you don't have a complete alternative idea to propose. However, voicing uncertainty can also be scary to present to a whole classroom of your peers due to the reasons already stated. Despite all of that, voicing different ideas and conflicting ideas is crucial in creating argumentation, deep discussions, and better understandings of issues. Those different ideas are what need to be considered weighed, and evaluated against each other in order to create a nuanced perspective and better reasoning skills within students. In this case, Susan has taken note of what she heard groups discussing and where confusion seems to be arising, but she doesn't push groups to share ideas that are different.

Despite not pushing groups to share different ideas, Susan does realize the importance of students being able to consider and debate alternative viewpoints and ideas. So she reflects on some ways she could have gotten students to consider and talk about a different perspective. She proposes a tactic of pretending she believes in the opposite of what has been said in class to be true. She is thinking of playing the "devil's advocate" role to aid the discussion and push students to think about a different side. This allows those students who believe in this viewpoint to defend it while also getting those who believe in other viewpoints to consider this argument. However, every tactic can have downsides that need to be addressed and weighed in the unique situation it is going to be applied in and trial and error is important to the process of figuring out what works best in a given situation.

Overall, this week we see Susan thinking more and more about the students in her classroom as having their own background and personalities when engaging in discussions. Through considering student engagement in discussion, Susan also reflected on how she can better foster argumentation when there is resistance from students to present opposing ideas.

Week 5 (Taking In Input From Students and Peers)

When reflecting about teaching during her fifth week of labs, Susan begins to take in more feedback and ideas from her students and peers. In regards to taking in feedback and ideas from her students, Susan reflects upon how her

students chose to have a discussion over a challenging question that was deemed too complicated for students to discuss during the TAs' lab prep:

> *"However, I won't consider this week's discussion as 'easier' than previous ones, since I think making sense from existing data is actually harder than raising potential analysis, especially the question about how to explain the difference between afternoon and evening plants. I remember that during prep [The Laboratory Coordinator] said we could skip that question because it might be too complicated. I'm surprised that my students provided convincing explanations on that. The idea [Student X] proposed on selective pressure is really great, but I feel like my reaction was not professional enough to help him build up that thinking. He said: 'Short day plants have limited resources so that they're selected into one direction, while long day plants do not have such a limit.' I was obsessed with the idea brought up from prep about plasticity so I tried to lead him into that, but I felt that it was not what he meant, that he further explained: 'Selective pressures force selection for one consistent trait.' I think his explanation for short-day plants is quite sufficient, and I could push his thinking by asking more specifically on long-day plants, that if there's no selective pressure at all, or selective pressure varies."*

In this case that Susan points out, her students willingly decided to discuss a difficult question and, to Susan's surprise, they generated convincing reasoning. Susan seemed to be quite excited that her students were generating ideas from this question and she pushed one student to try and develop his idea further. She tried to lead him into considering nuances to help build this idea even more. However, she regrets that she was unable to get him to go further with his idea. She claims that she is "not professional enough" to help this student develop this idea which could mean that she doesn't believe she is an experienced enough teacher to have helped this discussion dive deeper. Later in this journal, Susan mulled over the successes and problems with her class' discussions:

> *"It is nice to have students really engaged and talkative. I'm thinking if different discussion manner should be applied to different class, because comparing to previously when I let students talk in small groups first and then share their thoughts with the whole class, this time when only class*

discussion took place, they did better. No group discussion also keep some of them from their phones. Group discussion is still helpful because it can help individuals refine their ideas from others' opinions, IF they have unclear thoughts. At least in my lab, more often I saw only one student talking while others nodding or echoing, which I think is not the purpose to have small group discussion."

In this moment that Susan is writing about, her class demonstrated that they had a better discussion when they immediately jumped into a whole class discussion. Smaller group discussions usually preceded the larger group discussions to help ideas generate and for more dialogue to have a chance to emerge. However, in this moment, Susan has learned about the situational nature of teaching and how she can approach discussions. In this case, the class voted to go straight into a class discussion and it ended up being a good discussion. From this, Susan is realizing that using one style of leading discussions may not be the best way to facilitate and increase classroom involvement in all discussions. Susan listened to her class and that paid off with a better discussion. Susan shows an understanding now that listening, reflecting, and then adapting approaches to discussions based on each class is a possible way to make sure students engage in productive argumentation and discussion. Further on in her journal, Susan reflects on different methods to promote discussions even further as she talks about another suggestion brought up by a friend:

"When I talk with my friend who took this class years ago, she said that in her lab, after her TA asked a question but nobody answered, her TA just waited until someone was about to talk, simply because students wanted to end this discussion as soon as possible. For me I would feel awkward if I'm standing while all students are looking at me… but I have to admit that it could work sometimes because students might have thoughts but refuse to talk. I don't know if I'll try it - probably not; I'd rather give them some hints, or like what [Teach Assistant X] suggested earlier, to put them back in small groups again."

In this case, Susan is approached by a peer with another suggestion on how to facilitate more discussion in her lab classroom. The idea presented is that she could just wait for a student to talk when she poses a question to the class. Susan understands the logic behind how this tactic would work on some students since some students just want to get on with the class while some other students don't want to talk right away. This is a new tool that has been given to Susan to help her promote more discussions and students engagement. However, in this moment, Susan feels too embarrassed to just stand and wait for an answer. Despite that, Susan seems to be frequently considering and reflecting upon new approaches to discussions from input she receives from peers and other TAs. Susan seems to want to do the best she can do to foster engaging discussions in her lab. Susan does seem to be reflecting more and more about her teaching but she also seems to be more confident and happy with how she has been running her lab as she reflects upon a comment from a student that she liked:

> *"Overall, I think this week is pretty good! I also heard one girl saying that 'I think this lab is more interesting than others'. Hooray!"*

That exclamation of "Hooray!" at the end of her journal and the pleased nature she has with this lab's week being "pretty good" shows growing confidence in Susan in regards to her teaching ability. This is a positive contrast to her first few reflections where she seemed more worried and anxious about her teaching. Overall, Susan is gaining confidence and experience with teaching and has now shifted to absorbing more and more feedback and ideas from her students and peers to further improve her teaching.

Week 6 (Revisiting Ideas and Issues with Discussions)

In the sixth week of teaching lab and promoting discussions among students, Susan continued to think about how she can better approach discussions by attending to students' ideas more deeply when they are brought up. A large reflection she had this week revolved around the depth of ideas that students bring up and the steps she should take to further student thinking:

> *"When I'm talking to them or grading their assignments, I don't have any anticipation in my mind, that I'm not looking for any specific answer. I'll take whatever thoughts the students come up with, and as long as they explain themselves clearly, I'd consider it as good response. Some students just don't bother to think deeper and apply one explanation to several circumstances. At that moment I think I should push them thinking by asking: 'So how does this behavior affect plants in the whole population, within several generations?' In addition to asking for clarification on their answer, I should also ask question that help them expand their thinking. I'll try to ask higher-level questions in the following weeks!"*

In this reflection, Susan is considering what approach she has been taking to processing and responding to students' ideas. She is accepting of a variety of answers as long as a student can explain their answer and perspective. However, she goes on further to show an issue she has come across with some students not considering how other circumstances might change an answer or being willing to add nuance to an answer. This is an important moment for Susan to show concern because this issue arrives at the crux of what argumentation is trying to teach students. Practicing argumentation gives students the ability to consider more nuanced answers and think deeper about a particular issue. These students Susan is talking about don't appear to be providing nuanced answers that tackle various circumstances and complications. Susan not only points out how some students

should be providing more nuanced answers, but also, Susan goes on to present argumentation facilitating questions that she thinks would help the students think more broadly and deeper in their answers. In her words, she wants to not only ask these students clarifying questions, but also ask questions that "help them expand their thinking" or that are "higher-level" questions. This is a much more focused response to the issue of student ideas being rather one-dimensional. This also is another example showing how Susan cares for the kind of thinking and ideas her students are coming up with. During her second week of journals, Susan responded to this issue by just wanting to "throw questions" at students. But now in the sixth week of journals we see that Susan has refined her ideas and understanding of how to get students to explore nuances and different perspectives. In this week, we see growth in Susan as Susan is seeing more clearly how she needs to attend to student ideas in order to promote deeper thinking among students and she has presented some great argumentation ideas as to how she will approach those students.

Week 7 (Considering the Class and the Individuals)

For the final week of her journals, Susan showed a considerable shift in the focus of her writing to focusing on individuals in her class and the unique dynamics they brought to the classroom. However, the first discussion moment Susan brought up in her journal this week was a surprise she came across when she asked groups to create a representation on a whiteboard of what they think

would happen to the behavior of beetles in regards to differences in resource quality:

> *"I'm actually surprised for the result of first discussion. In prep we all came up with a line graph that indicating the relationship between female's choice and resource quality, while in my lab almost all groups (only one group had a line graph) ended up with a cartoon that represented the several scenarios provided on the handout. I couldn't remember if in prep [The Laboratory Coordinator] asked us for a line graph specifically or introduced the question in a different way, but I think it might be better if I could clarify this question more specific so that students wouldn't misunderstand. (I really don't know why they simply 'visualized' the sample provided for the model… what's the point of drawing cartoons?)"*

Here Susan is surprised that students just drew visual representations of models provided to them instead of drawing graphs. However, on a deeper level, Susan is actually struggling to understand how students had a very different interpretation of a prompt than what was interpreted by the prep lab section. In this reflection, we see Susan realizing the possibility of a lack of clarity on her part and the need to take steps to clarify what may have been obvious to her. However, she still shows confusion over how students could have interpreted something differently. She also shows confusion about why the students did what they did. As Susan reflects more on this discussion about beetles and behaviors being represented, she praises a particular student in her class:

> *"After I drew a x- and y-axis on board and asked them to create a line representing the model, [Student Y] (she is the most active student in my lab and I'm SO appreciated) offered her suggestion on how to make the line. After I asked them to consider how did lines intercept with x- and y-axis mean, she said: 'Line intercepts with y-axis may imply a harsh environmental condition where female maximizes her fitness by laying eggs in spite of resource quality. Line intercepts with x-axis may imply a good condition when female maximizes her fitness by comparing resource quality and doesn't lay eggs until she finds a resource with certain level of quality.' Those are not her exact word but what I extract built on my own*

understanding of her idea, for which I also asked her several questions for further clarification. Her idea based on environmental condition is not raised in prep, and I think it is a valuable point to consider and a reasonable representation to the two lines."

Through her writing, we can see that Susan is really appreciative of Student Y, who is a frequent contributor to discussions and who seems to be confident in sharing her ideas and starting discussions. It is important that Susan has begun to see patterns in who is engaging in and starting discussions since each student has a different personality and comfort zone. However, Susan does not seem to have fully realized the issues that can arise with students who continually kick-start discussions, but she does recognize the issue of students who are completely disengaged with discussions as we see from Susan's reflection upon a specific group of students in her class:

"While they were waiting for the beetles and working on the handout, I noticed that the group at the front in the middle table were on their phones. ([Researcher X] I believe you're also familiar with this group… it is the one I always want to keep an eye on to make sure they're doing their work) I simply walked to them and asked them about their thinking, and I highly doubt that they only glanced through the handout (or maybe not at all) without discussed the questions. I went through each single question with them, and they said that they thought the inconsistency of the result might because the model evaluated bean quality with bean mass. They believed bean surface area would be a better representative than bean biomass in terms of evaluating bean quality because there'll be more eggs laid on beans with more surface area instead of more biomass. (I was like '???') I asked: 'But I think larger beans would have a greater surface area than smaller beans.' They explained that: 'Yes there'll be a positive correlation, but surface area would still be better.' I really should ask them to clarify their thoughts further by asking 'under what circumstances would you expect a lighter bean has more surface area or a heavier bean has less surface are' or similar questions."

The group of students that Susan is talking about in this section of her journal is a group of students who seem to be on Susan's radar as being not

engaged in class. Just as how she had praise for Student Y, Susan seemed to have suspicions of this group. This example further highlights the development Susan is having in noticing differences between how different students are engaging in discussions and in class. Susan doesn't shirk away from this group though. She appears to tackle this group head on by engaging herself directly in their discussion to try to analyze what ideas they are generating and how they support those ideas. Through her interactions with this group, she seems to be confused by their ideas and declared that she needs to ask more clarifying questions with this group. Susan seems to be suspicious of this group already, which may affect her judgment of the group's discussion. With this suspicion, it is possible that she is giving them less benefit of the doubt than she normally would. However, what it clear though is that Susan is having a hard time understanding them but still cares about their ideas and engagement in the class so she is spending time trying to understand and help them. As Susan goes on to explain, she continues to spend more and more time with that specific group to push them to think more. However, she also expresses a tension she feels with stereotyping students and a tension she feels with the amount of time she was spending on that one group that she thinks may not be having effective discussions:

> *"I know it is wrong as a TA to have stereotype on student, but this group always shows a tendency of being lazy or willing to leave earlier (when I was doing the calculation on the class data they walked away to grab their bags until I said 'class is not done yet'). This week I discussed the whole handout with them to make sure they were working, and I didn't have time to talk to other groups. Is that worthy, spending time on groups that are not willing to learn, or I should devote my time evenly to each group regardless of the 'personality' of each group? I think I would definitely have a more interesting conversation with groups that are more active, but*

I don't want to simply give them up and watch them do nothing but playing phones."

In this moment, Susan is expressing two large conundrums she is having. Firstly, she is expressing regret that she has slotted a group of students under a stereotype. This is an issue Susan is fretting over because it can be easy to accidentally fall into the trap of stereotyping individuals. Not every student will be a perfect contributor to class. There are students who adamantly don't want to participate in discussions. However, the larger conundrum Susan is struggling with is the debate over how much time she should spend on each student. There is no easy answer. This is a heavy issue Susan is considering that shows her commitment to reflecting deeply on some of the most difficult questions in education. This drive to tackle the hard questions of teaching is an attitude Susan has that is pushing her to do her best in teaching and helping her students learn.

During this final week of journals, we see Susan pondering some of the hardest questions about using discussions as a learning technique, including how time is best used among students and how her perception of students is affecting her attitudes and actions towards them and their discussions. We also see Susan continue to do even more to better her discussion facilitation ability by reflecting on the technical aspect of the need for prompt clarity in prompts and instructions.

As an exercise for you, the reader, how would you divide up your time among students in your class? Can you think of any situations that might change how you would allocate your time?

Discussion

In this case study, I analyzed the weekly journal of a novice TA as she reflected on her attempts to have positive engagement with her lab students and implement discussion and argumentation in a classroom. The objective was to provide an example of how a reflective TA's perspective about discussions in the classroom develops and changes as the TA aims to better herself as a teacher and also the discussion in her classroom. Through this exploration we see that Susan caring about her students' ideas drives Susan to value argumentation and seek to implement it within her class discussions. Concrete excerpts from the TA's weekly journal reflections and an interview with the TA were used to analyze what stood out to the TA and to hear the TAs internal dialogue about the experience and challenges of teaching with discussions.

Where Susan's Growth Stems From

During her week 3 journal, Susan made a very profound statement, "*I believe that teaching is also a process of learning - not only learning how to teach, but also building my own knowledge based on students' questions and feedbacks.*" This is a very powerful belief that is at the core of Susan's growth in her teaching ability. Teaching is about learning on multiple levels. Susan learned tricks and tactics to help her facilitate discussions in class, however, she also learned more herself through her experience as a teacher. She learned both about teaching and science by listening and absorbing the questions and responses students gave her. Through listening and processing these inputs students gave

her, Susan not only learned about the class, but she also learned about how her own teaching actions were received by the students.

This segues into another cornerstone of Susan's growth, which is all of the reflections she has been having. Throughout the journals, we see Susan ponder and consider how her teaching is going and we also see her ponder more and more aspects around teaching. She reflects about her students, their answers, their personalities, and their dynamics. However, she also turns the observational lens on herself to ponder about how she is affecting the class. She contemplates her own background, approaches, and responses to students to see how she can better herself for her students. Susan is very reflective through these journals, which may have resulted from her being made to write journals as part of a class. Regardless, Susan reflects rather deeply about her class, herself, and also what her peers are doing in order to do the best job she can at facilitating discussions and arguments in the classroom. This is a crux of what I believe made Susan progress in her teaching ability. Her willingness to ponder things over and reflect led her to consider tough issues with education and brainstorm possible solutions, which she then experimented with to try and push argumentation in her classroom.

Susan's reflection and experimentation with different ideas may have been important to her improvement in promoting argumentation and development as a teacher, but there is another underlying force that seemed to drive her throughout this teaching experience. She seems to genuinely care for her students' growth in scientific thinking and wants to do her best for them. During the February interview with Susan, she explained how she had a drive to improve herself

because she is worried that her personal background might be hindering her students, *"So I just don't… because… because I think my education background kind of constrained my thinking to a smaller perspective. But I just don't want to... because of my personal experience to constrain my student's thinking. So that's the think that I want to improve."* This is a very genuine admission from Susan. She doesn't want to constrain her student's thinking and is worried that she might be a hindrance to them. She genuinely wants the students in her class to have a broad range of thinking so she resolves to improve her own breadth of thinking in order to be better for her students. Even the structure of her journals shows us that she is being genuine about her caring towards student ideas as she openly reflects deeply on specific moments that don't show her in a faltering light but highlight key moments in her progress towards implementing argumentation into her classroom. This genuine care Susan has about her students' growth and ideas is a key driving force for Susan's growth in teaching and implementing argumentation in the classroom. This pushes her to be reflective and to experiment with different ways to engage students and encourage argumentation practices. Willingness and drive to better oneself is a crucial ingredient in improving oneself and is a vital feature for teachers to better implement argumentation into their classrooms.

Teachers Caring About Students and Wanting to Better Themselves

As just mentioned, willingness and drive to better oneself are crucial aspects for a teacher to have in order to improve themselves. In addition to that, caring for students and their ideas are also important facets in getting genuine

growth for a teacher. These ingredients help motivate and push teachers to reflect upon their own teaching, absorb feedback from students, and work to try new methods and approaches to their teaching.

This may seem like a “no-brainer” when it comes to teaching, but it seems to be underappreciated in science education with not many papers mentioning these aspects as important in seeing improvements in the ability for a teacher to implement argumentation in their classroom. Dozens, even hundreds of different strategies may arise around how to best implement argumentation into a classroom. However, with so many competing strategies and ideas, one can lose focus of what core ingredients can push teachers and lead teachers to seek better ways to implement argumentation into their classroom even when they know that students and classrooms are constantly changing. The core ingredients of teachers caring about student ideas and having the drive to better their implementation of argumentation leads teachers to continually consider more methods instead of just relying on a limited pool of methods. It's important to understand what motivates and drives teachers to consider more methods as one method to implement argumentation may work fantastically within the construct of a given class in a given school in a given country in a given time. However, that method will most likely not work for every classroom everywhere. Each classroom has a varied dynamics with changing student bodies and student cultures. As time goes on students change, teachers change, resources change, and cultures change. Simple tricks to encourage discussions like waiting for students to talk, playing devil's advocate, or having different sized group discussions may work but they also may

not work and they are not the true core of what drives better implementation of argumentation in the classroom. To claim that simple tricks are the core and all-encompassing answer to good argumentation practice is to ignore the vastly different classrooms that exist around the globe with different dynamics, resources, and individuals. It also ignores the likelihood of their strategy becoming obsolete as we progress into a technological age where we can not even predict how classrooms will look or behave in 10 years from now.

It is important to not get blinded into thinking that all of the tips, tricks, and methods to implementing argumentation are what drive the implementation of argumentation because there are deeper motivations and driving forces to appreciate that push teachers to experiment with and shape these methods to their unique classroom. Having care for students by valuing their ideas and thinking while also having the drive to seek ways to support and encourage the generation, presentation, and debating of students' ideas in class are driving factors that can help push teachers through the struggle of implementing argumentation. We also realize that a large challenge with argumentation comes with how much time and energy has to be spent on implementing it into the classroom. Having in-class discussions takes up time and takes time away from lecturing, which can reduce the overall amount of content being presented in a class. With all of that being said, we do see the clear benefits to argumentation and know some basic points about how to implement argumentation. Challenging students to think and consider different perspectives is crucial for helping to implement argumentation and some strategies to do that include asking open-ended questions instead of

yes/no questions, playing "devil's advocate" to constructively challenge responses, and mixing up groups.

What is perhaps the most important factor for argumentation as a teaching tool to be effective is for teachers to have the drive and willingness to better themselves and their own teaching and for that to be coupled with care for students to see them be the best they can be. These cornerstones will ensure that a teacher will step up to the challenge of implementing argumentation and will work with the changing classroom to find effective ways to implement argumentation in the context of their own classroom. Without this drive pushing teachers, there will not be experimentation performed by teachers to try to find the best way to engage their class in argumentation and there will be a tendency to fall back to narrow teaching strategies and "tricks" that likely don't account for their unique classroom environment.

Teachers Reflecting

There is something else that needs to be discussed in regards to helping a teacher better themselves and find effective ways for them to implement argumentation into their own classroom. That is the reflection aspect of teaching. As we saw from Susan's use of her journal, she reflected upon moments, issues, successes, and failures that happened in her lab. This allowed her to consider what did and didn't work with regards to engaging her class in argumentation. It also allowed her to brainstorm other approaches to implementing argumentation and dealing with issues surrounding argumentation. For teachers who want to improve

their teaching and implement argumentation, using a reflective journal can be a useful tool to record issues they come across and contemplate how different approaches may be used to address issues they face with their class. Those recorded ideas, issues, thoughts, and responses from the class can be tailored into better and better approaches on how to implement argumentation into that specific classroom.

Implications For Teachers

This entire thesis has the potential to be used as training material for teachers who are looking to implement more discussion and argumentation in their classrooms. In particular, novice TAs can use this background research on argumentation to prepare themselves to understand the reasoning and history behind implementing argumentation in the classroom. Understanding the history of argumentation and discussions in the realm of science education gives teachers a nuanced perspective into why science education researchers are encouraging science teachers to increase the amount of discourse and argumentation in their classrooms.

This thesis does more than just provide knowledge around argumentation. Through reading about a case study of a novice TA who is keen on improving her teaching ability and creating effective discussions within her classroom, teachers and other TAs can reflect on the difficulties and successes put forward by this case. The questioning, struggles, successes, and failures the teaching assistant

faced provides a reflective case to consider with regards to how teachers can implement argumentation into their classroom.

Implications For Researchers

This case study highlights the underlying rationale of certain pedagogical shifts that have been observed when a teacher attempts to implement more argumentation into classroom discussions. Hopefully, this will broaden the perspective around teachers attempting to use argumentation in their classroom. Through looking at the rationale and internal dialogue of a novice TA attempting to incorporate more argumentation into her classroom, the importance for teachers to reflect on their own teaching and class feedback in order to effectively adapt argumentation into their own unique class is reinforced.

This thesis provides another resource to compare against and use when unpacking how a teacher's experience in the classroom and reflection in journals plays into the picture of argumentation in the classroom. However, it also opens up questions about how to explore deeper thinking of teachers and how different a teacher's internal dialogue might be different from that of another teacher. This thesis also shows just how strongly the teacher's own background and culture can impact how they approach discussions and using argumentation. Furthermore, Susan's caring attitude towards her students' ideas begs the question if this motivating factor can or can not be instilled within teachers.

Limitations

A large limitation with this case study analysis is that it is a single case study. As such, it is of a unique situation with a unique individual, unique class, and unique university. While there may be similarities to this case study that arise in the classrooms of other teachers, this case study and analysis here is not a step-by-step instructive guide for teachers on how to deal with these issues. Instead, this is a reflective piece meant to spark thinking and contemplation. The results of the actions taken by Susan in this case study may lead to different results in a different classroom. As such, each classroom environment, context, class culture, and student body has to be considered when choosing actions while teaching.

While it is advised to not just blindly follow the suggestions and actions reflected upon in this case study, with consideration, a teacher may find themselves using some of the tactics and ideas that have been presented here. These ideas and tactics presented in this thesis are certainly usable in the right situation. However, that situation should be thought about first before using these ideas as they could be modified. As mentioned, reflection on one's own classroom, one's self, and one's students is a large part of what can help improve a teacher's ability to implement discussion effectively into their classroom.

Another limitation with this case study is that Susan's internal dialogue from her classroom experience may be different from the internal dialogue she expressed in her journal. With time between writing those journals and being in the classroom, certain important thoughts may not have stuck. On the flipside, certain important ideas presented in the journal may have arisen outside of the

classroom but Susan believed they happened while she was teaching. This is something to consider when looking at journals and reflections. For future studies intended to delve into a person's internal dialogue, thoughts, and reflections it may be better to have TAs write a journal directly after teaching and then write another journal about the same lab a few days later. The first journal right after lab will illustrate a clearer image of what the TA was truly thinking during class time. The second journal will give the TA some time to reflect upon what happened in the lab so that a more fully thought out reflection with contemplated thoughts can be expressed. Both kinds of journals have their own benefits and hindrances to fully understanding the thoughts of an individual. However, there is also the practical issue of time needed to write these journals.

A final limitation to this case study is in the data gathered for this case study. The data gathered for this case study may have been influenced by the recording equipment placed in the classroom. By having cameras and recording devices in the classroom, students may have been more nervous to participate in discussions, which then gives the appearance of Susan struggling with facilitating discussions when she may not have had as much difficulty if there were no cameras in the classroom. The cameras and recording devices have to be considered when analyzing the classroom environment and classroom culture that is impacting the amount of discussion.

Further Research Suggestions

There are several further research suggestions and directions that can be taken from this case study analysis. First, since Susan was not the only individual whose journals were recorded in this larger research group. A further study could analyze more individuals of this larger research group study. In doing so, we could see if similarities in the developments of thoughts and ways of implementing better discussions exist. By analyzing the successes, difficulties, and failures of a larger number of TAs, patterns may be identified. Another route that can be taken with this research group is to analyze Susan's experience against an experienced TA's experience to see how each deals with facilitating discussions. Comparing their developing thoughts as well as the successes and failures they have could be enlightening to see how experience with teaching using discussions affects a teacher's thought process and amount of success in getting argumentation into the classroom.

Another suggestion for further research is to see how journals affect a TAs ability to implement argumentation in a classroom when compared to TAs who do not keep journals. Keeping a journal may help a TA reflect on their own teaching which can translate into improvements with facilitating discussions. The results of this experiment can be measured by having a few students in the classes keep journals about their perception of how the teacher is teaching in general, how the teacher is using argumentation, and how the discussions within class are going. Then those student journals can be compared against each other to see which class best engaged the students in argumentation and why that happened. Having

student journals about the discussions in class is a useful tool as it could give more insight into how the teaching is being taken up by the students. It could also concretely highlight reasons behind why certain methods to implement argumentation are successes or failures. Case studies can be run using student journals as a method to understand argumentation but student journals can also be a way to analyze how teachers are implementing argumentation into the class and if students are taking up and internalizing the argumentation practices.

Finally, another suggestion for further research is to see how reading this thesis and considering this case study impacts a TA's ability to implement argumentation and discussion effectively into their classroom. I don't believe that enough teachers understand the history and theory behind argumentation so learning about that in itself may help teachers (and TAs) improve their ability to understand and implement argumentation. That background information coupled with a case study of a novice TA attempting to implement argumentation into her classroom should provide assistance to teachers in reflecting upon how they can implement argumentation into their classroom effectively. So further research could look into the effectiveness of this thesis as a teacher development tool to see if it does or doesn't have an impact. The more tools for implementing argumentation teachers have at their disposal, the more hope there is that argumentation will become a regular part of science classrooms.

Conclusion

The degree to which argumentation is used as an effective teaching technique in a classroom varies from teacher to teacher and from classroom to classroom. It is a complex issue that doesn't have a single resolution for the best way to implement argumentation into the classroom. Through observing the case study of Susan, we see an example of a teacher learning and pondering the nuances and complexities of trying to implement argumentation in the classroom. Through looking at her journals, we get to observe her internal thoughts as she works to navigate the complexities of classroom culture, individual student personalities, her own background influence, and wording in her efforts to establish more argumentation in her classroom discussions to help bring differing ideas to a classroom discussion. We also illuminated an important driving factor for Susan's use of argumentation in her classroom. Her genuine care and concern for her students' ideas and thinking motivated her to seek out more ways to build discussions, generate ideas, and have students present opposing ideas to one another within her classroom. This case study can be an effective teaching device to help other teachers consider the nuances of implementing argumentation in their classroom. This case study also highlights the importance of teachers reflecting on their own teaching and being genuinely invested in student learning in order to create the best classroom discussion dynamic.

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