ISSN: 2148-9955

International Journal of Research in Education and Science (IJRES)

www.ijres.net

Considering Pedagogical Practices in Higher Education: How Science Methods Instructors Influence Scientific Argumentation Construction

Brent Gilles[1], Gayle Buck[2]
[1]University of West Georgia, USA
[2]Indiana University, USA

To cite this article:

Gilles, B., & Buck, G. (2019). Considering pedagogical practices in higher education: How science methods instructors influence scientific argumentation construction. *International Journal of Research in Education and Science (IJRES)*, *5*(2), 744-757.

IJRES International Journal of Research in Education and Science
Volume 5, Issue 2, Summer 2019 ISSN: 2148-9955

Considering Pedagogical Practices in Higher Education: How Science Methods Instructors Influence Scientific Argumentation Construction

Brent Gilles, Gayle Buck

Article Info

Article History

Received:
28 February 2019

Accepted:
26 July 2019

Keywords

Discourse analysis
Preservice teachers
Scientific argumentation
Teacher educators

Abstract

Fostering students' ability to engage in scientific argumentation is an essential component of science teaching.. Unfortunately, research shows that teachers often lack sufficient prior experiences. As teacher educators, we sought to better understand how to effectively provide such critical experiences. Furthermore, we wanted to understand how the engagement in those activities was shaped by the methods instructor's own discourse. The purpose of this study was to shed light on the discursive practices preservice teachers used as they constructed a series of scientific arguments. Specifically, we sought to understand how argumentation discourse evolved as the preservice teachers went through the sequence of activities. The guiding research questions were: 1) What role does institutional talk play in shaping PSTs' discursive construction of scientific arguments? 2) How does PSTs' use of institutional talk evolve over the course of four argumentation activities? We drew upon discursive psychology and conversation analysis to show how twenty-one preservice teachers' talk functioned to build arguments, as well as how their talk evolved over the course of the four targeted activities. The findings illustrate how the preservice teachers revealed the institutionality within their talk by orienting towards classroom norms. The resulting understandings are used to provide recommendation for science teacher educators.

Introduction

Students' scientific literacy is developed by engaging them in learning the content and engineering and scientific practices (NRC, 2012); thus, including them in authentic science (DeBoer, 2000). Ideally, these authentic science activities involve inquiry-based instruction in which students have opportunities to explore topics that concern them. Such opportunities allow students to internalize scientific knowledge and make it their own (McNeill, Lizotte, & Krajcik, 2006). Authentic activities should allow students to experience the practices in which scientists engage; such as evaluating evidence and making claims. This ability to engage in a scientific discursive practice of which the products are evidence and counterclaims, scientific argumentation (Kuhn & Franklin, 2006), is a vital component of scientific literacy (Driver, Newton, & Osborne, 2000). Teachers' lack of prior experiences with argumentation, however, has negatively affected their abilities in this regard. Thus, providing this experience has become a priorty for teacher educators.

Understandings of how preservice teachers discursively construct arguments in classroom interactions continues to be a gap in our understanding of this practice (Henderson, McNeill, González-Howard, Close, & Evans, 2018). Studies continue to explore the outcomes of the argumentation (e.g., Swanson, Solorza, & Fissore, 2018) or identify that critical aspects of high-level argumentation occurred (Fishman et al., 2017). Current literature on argumentation discourse explores the use of appropriate content knowledge (e.g., Grooms, Sampson, & Enderle, 2018) or the importance of questioning (e.g., Evagorou & Osborne, 2013). However, the classroom space influences the roles that students take on as they engage in authentic activities and interact with their peers and teacher (Wiggins, 2017).

Furthermore, we lack an understanding of how teachers shape the arguments students construct, despite research that suggests their influence (e.g., Fishman et al., 2017; Osborne, Erduran, & Simon, 2004). In regard to our practice of preparing elementary preservice teachers (PSTs), understanding how they engage in scientific argumentation can help us design methods courses in a manner that better shapes practice (Ricketts, 2014). However, we lack an understanding of how the classroom shapes the institutionality of PST discourse and influences the authentic nature of argumentation activities. Furthermore, past research has not provided an understanding of how students incorporate the classroom norm of teacher-as-gatekeeper of content knowledge

in their construction of an argument. It is our contention that PSTs can better engage their future students in the practice if they understand how the instructor shaped the constructor of their arguments.

The purpose of this study was to shed light on the discursive practices PSTs used as they constructed a series of scientific arguments. Specifically, we sought to understand how argumentation discourse evolved as the PSTs went through the sequence of activities. The guiding research questions were: 1) What role does institutional talk play in shaping preservice teachers' discursive construction of scientific arguments? 2) How does preservice teachers' use of institutional talk evolve over the course of four argumentation activities? The findings fill a gap in our understanding of how PSTs discursively build scientific arguments prior to producing the final product.

Literature Review

Given suggested links between teachers' and students' abilities to engage in scientific argumentation, training in argumentation should start with preservice teachers. However, there is little in the literature on preparing preservice teachers to teach argument skills because this area is the least studied in scientific argumentation research. Sadler (2006) examined secondary PSTs' perceptions of and abilities to engage in argumentation and found that while his PSTs could construct scientific explanations and engage in argumentation, they did not view argumentation as a goal of science education, but rather as a classroom strategy. Like Simon et al. (2006), Sadler used the Toulmin argument pattern as a starting point to engage preservice teachers in scientific argumentation and familiarize them with appropriate discourse and found that it improved their ability to analyze arguments, but they used it incorrectly about a fourth of the time. However, this level of incorrect usage was not reported by Simon et al. (2006) for inservice teachers. Though it is reasonable to expect that some inservice teachers would have difficulty using the Toulmin argument pattern, the lack of evidence to support this assumption suggests the need for further research. Sadler (2006) also did not discuss any reasons why his preservice teachers failed to use the Toulmin argument pattern correctly.

Ricketts (2014) examined elementary preservice teachers' beliefs about and understandings of argumentation. She found the PSTs had trouble constructing scientific explanations and they needed content specific support. In the field experience, the elementary teachers did not always implement the planned argumentation. When they did implement it, they expected their students to be able to immediately come up with an explanation for their argument. These PSTs lacked the ability to scaffold their students' development of analysis skills. Ricketts (2014) also considered it an issue that science teacher educators do not always know whether PSTs *understand* the scientific practices they need to implement in their lessons or how to *teach* those practices. For instance, she found that her PSTs would plan activities involving analysis of evidence, but analysis did not actually occur. There was no evidence to suggest whether these PSTs had a pedagogical gap or did not understand what analysis of evidence means. However, with adequate support, PSTs' ability to engage in argumentation can improve (Emig, McDonald, Zembal-Saul, & Strauss, 2014). Furthermore, Debarger et al. (2017) found that purposeful adaption of existing curriculum can support teacher use of the practice.

The literature on argumentation discourse often focuses on the outcomes (e.g., Swanson et al., 2018) or significance of questioning (e.g., Evagorou & Osborne, 2013). However, the process is rarely explored, but when studied examines the components of a high-level argument (e.g. Zembal-Saul, 2009), or more recently, studies examined the relationship between content knowledge and quality of argument development (e.g., Grooms et al., 2018). Furthermore, it is recognized that teachers need to facilitate engagement in argumentation for students by asking open-ended (McNeill & Pimentel, 2010) and probing questions (Shemwell & Furtak, 2010) or to revoice student questions (Chin & Osborne, 2010). Unfortunately, studies do not examine the discursive process of students constructing arguments, which is a gap in our understanding of how teachers can foster an environment that values argumentation (Henderson et al., 2018). However, there is evidence that establishing an environment free from teacher influence can provide students an opportunity to access their own prior knowledge during the cognitively demanding task of developing counter claims in moment to moment discursive interactions with peers (Kuhn, 2015).

Methodology

A discourse analysis approach was taken to enhance our understanding of how PSTs construct scientific arguments. Specifically, this study utilized a discursive psychology (DP) approach in order to reveal what PSTs were trying to do with their discourse (Potter & Wetherell, 1987). We examined how PSTs negotiated the tasks

of knowledge construction, conflict resolution, and argument building through discourse (talk and text). This approach does not view language as neutral or representative of an individual's mental state, but rather as situational (Potter & Wetherell, 1987). Understanding the actions that PSTs were trying to accomplish through discourse provided insight into how they made sense of constructing scientific arguments. DP concerns itself only with what is made visible by the participants through their discourse (Edwards, 1997). Assessing PST discourse through DP provided an opportunity to capture how they were responding to each other as they discussed evidence and its implications within their groups. As the fundamental medium for human action (Potter, 2012), discourse captures how the PSTs performed interactional functions while building arguments (Woofit, 2005). The study also drew on some aspects of conversation analysis (CA) to analyze micro features of PST talk such as sequentiality, how they attended to scientific discourse, their use of talk moves, and the transcription method.

Scientific Argumentation. Given the troubles using the Toulmin argument pattern as reported by Sadler (2006) and others, we adopted a different framework for our study. McNeill and Krajcik (2012) developed an adapted framework of Toulmin's (1958) argument pattern by collapsing the warrants and backings of Toulmin's model into reasoning, so their framework has four components: claim, evidence, reasoning, and rebuttal. Their purpose was to make the framework "more accessible for students" (p.21), but it is more accessible for teachers to use as well. Furthermore, McNeill also argued that even though there is a difference between a scientific explanation and scientific argument they co-occur as individuals work together to build knowledge (Berland & McNeill, 2012). However, argumentation was the preferred method of identification for this study and when used it is referring to McNeill and Krajcik's (2012) framework.

Context and Participants

This study was conducted in an inquiry-based science content course for elementary preservice teachers in a college of education at a large Midwestern university in the United States. The class consisted of 21 female PSTs seated at six laboratory tables. All of the PSTs were elementary education majors. There were thirteen freshman, seven sophomores, and one junior in the class. This inquiry-based course met two times a week for one hour and 55 minutes each meeting. The class was designed to give PSTs exposure to the nature of science and experiences working with the eight scientific and engineering practices outlined in *A Framework for K-12 Science Education* (NRC, 2012).

The PSTs gained experience in these practices through environmental science content. This study examined four targeted activities that required PSTs to engage in scientific argumentation which began four weeks into the course and lasted for five weeks. Prior to these activities the PSTs had experience in using the scientific and engineering practices of asking questions, planning and carrying out an investigation, analyzing and interpreting data, and constructing an explanation. For each activity the PSTs were presented with an introduction, in the form of a presentation, which provided them a basic content background that was relevant to the activity. The PSTs were expected to examine this content at a deeper level during argument construction.

The first targeted course activity was the PSTs' initial experience with argumentation. The instructor presented four empty lots near the university for the class to consider for planting a limited number of new trees. The PSTs were shown pictures and given soil data about each of the sites. They were asked to develop a scientific argument for the best site to put our limited number of trees, as well as the type of trees we should plant. The second targeted activity had the PSTs developing arguments for the source of an oil spill along a beach in Venezuela. They were provided a data table of oil characteristics for this activity and required to graph each set of data to compare the oil found on the beach with the potential culprits. From there, they developed a claim for who they believed was responsible for the oil spill.

The third activity involved the PSTs using biological testing to investigate the water quality of a nearby stream on campus. They went to the nearby stream to count macro-invertebrates and build a data set collectively as a class and across all sections of the course. Based on information provided by all sections of this course, the PSTs made a claim as to the water quality. The last targeted activity built onto the third activity, this time the soil quality and the ability of campus trees to act as carbon storage were investigated. This activity allowed the PSTs to choose the methods with which they investigated the soil. They then combined their evidence from the soil with the water quality evidence to argue the overall health of the campus environment.

Data Collection

Transcripts from small group discussions were the primary source of data that captured the discursive approaches of the PSTs to build arguments collaboratively during each activity. The PSTs were provided an hour or more to work out their argument for each activity. There was approximately 60 hours of audio and video recordings available for transcription. The other types of data collected were written scientific arguments and video recordings of class presentations. Each PST composed three written reports for activities two, three, and four. The video recordings and transcripts of small group discussions were analyzed to investigate PSTs' discourse and embodied behaviors during discussions and to provide context. For example, the video was useful for understanding what was occurring during long pauses in talk. Video was also used in two other instances to capture presentations during the first activity, the first when the students had to build initial arguments of their site, and the second during the next class period when they were presenting the revisions they had made to their initial arguments. The video data was transcribed and analyzed in order to connect this initial experience to the way in which the students built explanations within their groups for the following three activities. Finally, the written argumentation was used to analyze whether and how individual arguments had changed after the group discussion.

Data Analysis

The data was analyzed through an open coding process by which the data explored was guided by what the PSTs revealed and not by predetermined categories (Edwards, 1997). A "first pass" was conducted of the data, which included making a verbatim transcription of all audio and video collected. This "first pass" was a critical first step in forming ideas about the data due to the amount of data collected (Potter, 2012). During this "first pass," notes and memos were made about the talk used to construct each argument so excerpts could be identified for further transcription using a modified Jeffersonian technique (Jefferson, 2004). To analyze the data for the first research question we wanted to identify some micro-talk features that were revealed during our "first pass" and considered typical behaviors associated with argumentation construction in this course, such as language explicitly identifying the instructor, which would provide an indication of how the PSTs were using the information he provided. This process began by exploring these questions: "How are the PSTs referring to the instructor during their discussions?" "How are the PSTs using discourse to construct an argument?" and "How does the institution shape their talk?" We looked across all of the memos that were made after multiple passes through the data to understand the features of institutional talk that were consistent across all four activities (research question 1) and what features of the talk evolved from the first activity to the last (research question 2).

The second research question was analyzed by comparing the progression of the discourse from the first activity through the last activity. However, a shift in the talk occurred between the second and third activities. The analysis focused on understanding how the PSTs' talk shifted over the course of the last two activities from the first two. This analysis involved examining how the PSTs were rhetorically constructing their discourse (Edwards & Potter, 1993). The way we identified changes in the talk was to pay careful attention to what the PSTs indicated as important in an interaction (Edwards, 2006). Discursive actions across activities were noted and presented along with argumentation outcomes for those activities to provide evidence for the patterns found in the data (Wood & Kroger, 2000). Based on the codes assigned, profiles were built of how the PSTs constructed arguments from the features that occurred most often.

Trustworthiness and Warranting Claims

Presenting findings in discourse analysis tends to increase the variability rather than achieve the triangulation of evidence characteristic of other qualitative designs (Wood & Kroger, 2000). Triangulation of data tends to support the single version of the evidence as fact (Potter & Wetherell, 1987), which leads to all evidence pointing to one interpretation to strengthen that claim (Anfara, Brown, & Mangione, 2003). Claims in this study were warranted by creating an audit trail, making the analysis visible for the comment and critique of others, and searching for analytic shortcomings within the analysis. Discourse analysis relies on the lens with which we viewed the data. We present as much raw data as possible to allow readers to make their own judgements about our conclusions (Potter, 2012).

Findings

What Role Does Institutional Talk Play in Shaping PSTs' Discursive Construction of Scientific Arguments?

Institutional Talk

The dominate influence on PST talk was how they marked the space as a classroom. Institutional spaces, such as classrooms, are marked by the discursive moves of the people interacting within them (Drew & Heritage, 1997). For example, it is customary in a classroom to raise one's hand and wait to be called on before talking, whereas in a social situation raising one's hand to signal the wish to speak is not customary (Heritage, 1984). The identities that the PSTs took up in the classroom space in this study were related to the goals and purposes of the classroom (Drew & Heritage, 1997). The structure of turns, turn-taking, and sequence organization of the institutional talk within the classroom was different from that of everyday (mundane) talk in which PSTs participated outside the classroom (Heritage, 2015). The analysis revealed the ways PSTs' talk in the classroom shaped their approaches to analyzing data and forming claim(s).

***The Role of the Instructor*.** The first way that the PSTs marked their discourse as institutional was by referring to the instructor while analyzing data. Referencing him in this manner was a mark of the group doing "being a good student" by prioritizing the data that the instructor had identified as important. Engaging in the role of "being a good student" is described as PSTs whom perform the institutional norms expected of them in order to achieve a certain score (Stokoe & Benwell, 2006).

Excerpt 1: Group 4, Activity 4

1 PST 13: soil moisture depends on temperature (0.2)
2 PST 14: yeah:: and I thought he told me on temperature >like it's relevant<
3 cause we're talking about like (.) the [change]
4 PST 13: [and it] just cooled down (0.3) so like (.) our
5 numbers are naturally going to be lower

In excerpt one the talk is marked by a reference to "he" (i.e., the instructor) in line two. Instead of doing background research to make sense of the data they had collected, these group members were referring back to information that the instructor had given them. This suggests they positioned him as an expert on their data as substantiated by the statement "like it's relevant" in line two. PST 14 used this phrase to restate what the instructor had said earlier about the importance of the temperature. PST 13 offered further explanation for the change in soil moisture values in lines four and five. This is an example of trying to further validate a claim the instructor had made that PST 14 referenced in line two. What PSTs 13 and 14 did not offer was a source for their position. They were simply offering up further explanation as to why the change in the soil moisture occurred. Interestingly, PSTs across groups never challenged the information that the instructor gave them, pointing to the institutional norm that typically precludes students from questioning the instructor's knowledge (Kapellidi, 2013). This is another example of the PSTs playing the role of "being a good student" instead of "being a good scientist" by finding corroborating evidence for the instructor's statements (Stokoe & Benwell, 2006). The PSTs simply oriented themselves to the norms of the classroom, such as completing work according to expectations, which were ways that they enacted "being a good student." This suggests that they were oriented to the task as one that needed to be completed, but not one that required the necessary background information to validate evidence as a scientist would in a similar situation.

The PSTs had to collect their own data for activities three and four. During that time, PST 1 repeatedly justified her claims by repeating information the instructor had given to them. This demonstrated a version of argumentation through expert testimony (Walton, 2013); a common strategy for defending a claim. By referencing information given to the group during data collection, PST 1 reasoned that the instructor had given them the correct answer to their question, which would strengthen the claim for her group's argument.

Excerpt 2: Group 1, Activity 3

1 PST 3: erosion was (0.2) not bad where we were ↑<right> (.)
2 PST 1: no it was good >cause you remember< when he said <the plants> (.)

In line one of excerpt two, PST 3 made a claim about the state of erosion found along the creek where they collected data. However, she hedged on whether she was correct by posing the question at the end. This was indicated by her rising intonation. PST 1 validated this claim in line two, without supporting evidence, citing a statement the instructor made during data collection. PST 1 did not expand on this statement beyond saying, "when he said the plants," which is an indication that she believed her group understood what she was saying.

This statement perhaps points to PST 1's alignment with the traditional view of a teacher as a gatekeeper of information (McNeill & Knight, 2013). PST 1's lack of explanation suggests that she might not know a scientific reason for why plants limit erosion (what they term to as "good"). This explanation is further supported by what PST 1 wrote in her report:

> When looking at erosion to depict if a river is healthy it needs to be able to have a steady ground and have a slope of some sort with a variety of vegetation to keep the river from over flowing into the grounds surrounding the river.

Rather than explaining how the roots hold the soil in place to prevent erosion, PST 1 simply repeated the information the instructor gave to the class. Positioning him as the gatekeeper of information may have kept her from exploring the implications of the presence of plants. Likewise, PSTs across the groups would often privilege the information the instructor gave them. This illustrates they were directly using the information to support their claims without verifying or extending the information from other sources.

Activity Requirements. The second way that PSTs marked the institutionality of their talk was through identification of the need for certain requirements of a project. The PSTs did not always attribute their reasons for completing projects directly to the instructor's requirements, but also to a "need" in order to meet the requirements. Once PSTs had collected data for an activity, the group's first task was to analyze the data to construct a claim. Once the claim had been constructed, they conducted background research to justify why their evidence fit the claim. Thus, the conversations during this time should have been about how their data supported their claim and the confirming evidence in the literature. Excerpt three is drawn from the discussion of the data they collected to fulfill the project's requirement that they calculate the amount of carbon sequestration for the trees in the area:

Excerpt 3: Group 6, Activity 4

1 PST 19: did somebody measure the diameters of the trees that we (.) did for
2 the (.) garden app (.)
3 PST 21: I don't think we needed to do that one (.)
4 PST 20: yeah we have to (.) enter it (.) into the website

The institutionality of the talk is marked by the word "needed." The "need" is established by the fact that they were required to collect the data, which PST 21 references in line three. The discussion between PSTs 19 and 21 in lines one through three was followed by PST 20's comment in line four that they "have" to do the task of measuring tree diameters, which supported initiation of the question posed in line one that this task was required. An activity that "needs" to be done marks the classroom space because the structure of talk identifies the task as not being optional, but required (Heritage, 2015). Their identification of a project need suggests that they were doing the activity not because they saw it as important to their claim; but, because they considered it a requirement for constructing their argument. That is, referring to need suggests that they did not view the activity as authentic but as a series of tasks that needed to be accomplished to meet the expectations of the project. The construction of the claim became more about meeting the expectations of the rubric than about exercising reason and building knowledge.

How Does PSTs' Use of Institutional Talk Evolve over the Course of Four Argumentation Activities?

The findings revealed the PSTs displayed an increased reliance on the instructor once they had to collect their own data. This was evident in the class talk. During the early activities, the PST-instructor talk centered on the parts of an argument, and in activities three and four, it was more about logistical and content support. This is explained and supported below.

Talk about Argument Components

During the first two activities, when PSTs were learning how to construct scientific arguments, their questions typically concerned the type of information that went into each component of an argument. Their interest in discussing the components of claim, evidence, reasoning, and rebuttal is not surprising because this way of talking about science was new to the PSTs. Also they did not have to collect their own data, because the instructional goal was for them to focus on the construction of their argument. This is illustrated in excerpt four.

Excerpt 4: Group 1, Activity 1

1 PST 1: I have a ↓question

2 Instructor: okay
3 PST 1: okay (.) so::: for like (.) I don't (.) I think we can't like (.) pick which of
4 these:: evidence still and then reasoning (.) because like (.) we want to saying
5 something about like there's good (.) it fits the project because it says that there's
6 good like car traffic and:: like (.) walking traffic
7 Instructor: m↑hm
8 PST 1: but wouldn't that be like reasoning because that's (.) it's not like saying
9 something specific
10 Instructor: so yeah (.) here's the thing (0.6) um (.) evidence can be its a high traffic
11 area and then reasoning you can say (.) well part of the project was that it wanted
12 to be in a location where it would be used and this area is a high traffic area so
13 therefore (.) that makes it a good spot
14 PST 4: ↓okay (.) I think
15 Instructor: does that make ↑sense
16 PST 1: ↓yeah (.) thank you
17 Instructor: yep (.) you are welcome

PST 1's pause and use of the filler "like" (lines three through six) as she asked the instructor a question exemplified the PSTs' uncertainty about what information went into the evidence and what went into the reasoning. She continued to hedge in the sequence using the phrase "wouldn't that be like" (line eight) and "I think" in (line fourteen) (Laserna et al., 2014). Interestingly, although the latter phrase "I think," was a display of unknowing, when the instructor asked, "does that make sense" in the following turn, the PST responded with a downward intonation of "yeah," which suggested she did. This and the PST's utterance of "thank you" (line sixteen) served to close the sequence, which the instructor acknowledged with "yep" (line seventeen). PSTs across all groups displayed this type of talk when interacting with the instructor during the first two activities. They wanted to know that they were constructing their argument correctly but were not necessarily concerned about content.

Once they became more familiar with the process of constructing an argument and what type of information went into each component, the PSTs started to focus their questions on their data. Not surprisingly, this increased when they started to collect their own data and had to decide which pieces were relevant to their investigation. Excerpt 5 is an example of how the PSTs' questions centered on how much evidence was needed to adequately support their claim.

Excerpt 5: Group 2, Activity 3

1 PST 6: so how are we supposed to like ↑mark (.) just=
2 Instructor: =just put like a star or something on it (.) yeah so usually what I do so I
3 just was doing this the other ↓day (.) so I just insert shape and then I (.) I did like a
4 star (.) but you can do whatever shape you want
5 PST 6: well (.) we took pictures like <u>literally</u> everywhere
6 Instructor: ↓okay
7 PST 5: you're going to pick one that you are going to use=
8 Instructor: =well (.) so well (.) you're gonna pick not just one (.) you're gonna pick
9 multiple=
10 PST 5: =well ↓yeah
11 Instructor: but you don't have to give me every single picture that you took
12 PST 6: ↓okay
13 Instructor: give me enough that you think paints a picture
14 PST 8: do we need to mark like where we picked up our ↑rocks
15 Instructor: ↓<u>no</u>
16 PST 6: okay that's what I thought it ↓said
17 Instructor: no no ((walks away from group))

The sequence began with PST 6 asking the instructor a question about logistics (line one). However, after the instructor answered, her utterance transitioned the sequence from a logistical question to a statement about her evidence (line five). She asked a clarifying question (line seven) about the number of pictures they were going to use, and the instructor quickly latched onto her turn and used filler words such as "well" and paused to hold his turn (line eight). Once the instructor stated, "you're gonna pick multiple" PST 5 latched onto his turn and used "well" as a filler to hold the turn, and acknowledged this piece of information with a downward intonation "yeah." This response suggests that PST 5 had more to say during her turn in line seven and already knew the

information in his utterance in lines eight and nine. The instructor quickly did repair (line eleven) to finish his turn from line nine, which completed the response to PST 6's utterance in line five.

Interestingly, the instructor changed his interactions with the PSTs after the first two activities by engaging them over longer sequences and providing more detail (lines eight, nine, eleven, and thirteen). However, he marked questions as not being relevant through quick responses, like the one in line fifteen. PST 6 interpreted the downward intonation and emphasis the instructor put on the utterance in line fifteen to mean trouble in the talk because she did repair (line sixteen), providing a justification for why she asked the question in line fourteen. The instructor then ended the sequence by walking away, an embodiment move meant to show the answer is no (Goodwin, 1981), which denied PST 6's spatial privilege. Giving spatial privilege means gazing and positioning one's body towards another to convey granting attention (Goodwin, 1981). As the PSTs sought more help in determining the amount of evidence they needed to support their claim, the instructor began to modify his approach to helping them. The instructor spent more time on questions he apparently deemed appropriate through longer turns and sequences but displayed his unwillingness to answer questions through moves such as walking away as at the end of this sequence, though he was also leaving to help another group.

Desire for Correct Answer

The increase in PST questions that centered on the data collected during the last two activities created situations in which the instructor was holding longer turns with PSTs to provide content support in addition to the logistical support in the earlier activities. The PSTs came to rely on the instructor to help them make sense of their data and decide which pieces to prioritize and use to build a claim. This was not surprising in light of research showing that teacher facilitation of small groups often fosters PST dependence on the teacher (Chiu, 2004). The following excerpt is an example of how the instructor's turns became increasingly longer as he provided content support to group one during activity three.

Excerpt 6: Group 1, Activity 3

1 PST 2: okay (.) is that same the ↑thing it's just um (.) I don't understand how
2 the number of macroinvertebrates in the water is the same as the pollution index
3 ↓rating
4 Instructor: ↓okay (.) so:: (.) remember last week we calculated (.) here ((looking at
5 PST 2's computer screen)) (.) if you'll go to our canvas folder (.) and I'll show
6 you how we calculated that (1.2) so basically what they do is based on different
7 kinds (.) all the different kinds uh [state] river watch protocol (4.6) so scroll down
8 a little bit right (6.4) here (.) okay so what you did is you had all these numbers
9 and it had you count up how many different kinds did you find (.) and so (.)
10 basically what it is doing is saying okay here are all these different kinds and
11 these kinds are in different groups and so that is intolerant and that means if there
12 is any pollution in the water they'll <u>die</u> (.) they can't survive in that and then
13 moderately tolerant all the way to very tolerant which are ones that doesn't really
14 matter they are going to survive no matter what (.) and then so based on all those
15 kinds right then you (.) wrote down oops (.) wrote down the taxas so that's
16 the number of different kinds so now (.) raw numbers and then you multiply it
17 Instaructor: [based on]
18 PST 2: [yeah we] have it figured (.) so what does that ↑mean
19 Instructor: yeah (.) so that's what you need to figure out (.) what does that ↓mean (.)
20 what does that fair rating ↓mean

PST 2 began the sequence by asking how the amount of macroinvertebrates found in the creek related to the pollution tolerance index. Once PST 2 marked the end of her turn with the downward intonation of "rating" (line three) the instructor was selected by the PST to start his turn, which the instructor did by first making a connection to prior information given to the PSTs (line four). The instructor then showed PST 2 how that was calculated from the resources on her computer (lines five to eight) and explained how the pollution categories work (lines eight to seventeen). However, PST 2 overlapped his speech in line eighteen to end his turn so she could state that, "yeah we have it figured" meaning that that was not the information she was seeking. After a brief pause she restated her question, "what does that mean," (line eighteen) as identified by the rising intonation of "mean." The instructor acknowledged understanding her question by uttering "yeah" (line nineteen) but declined to give the answer saying, "that's what you need to figure out." The instructor signaled the closure of the sequence by declining to answer the question and through the downward intonation of the word "mean" (line twenty). This sequence suggests that PST 2 wanted the instructor to interpret their data. His refusal to do so

for this or any group was intended to foster the PSTs' autonomy and initiative to find their own answers (Cohen, 1994), but it resulted in some displays of frustration. Not surprising, this was because institutional norms had led PSTs to expect the instructor to give evaluative feedback (Edwards & Mercer, 1987).

Some scholars have argued that dogmatic approaches to science education have encouraged PSTs to focus on seeking correct answers in their investigations (Osborne et al., 2012). In the case of this study, the frustration they experienced in the absence of a specific target answer led to longer sequences of question-response patterns among PSTs and some anxiety when confronted by the instructor about their progress. The following excerpt shows the difficulties group five had constructing their claim on activity three because of conflicting data.

Excerpt 7: Group 5, Activity 3

1 PST 17: erosion ↓factors (2.1) p value=
2 PST 18: =he's gonna ask ↓us
3 PST 17: p where they equal estimated average (1.4) oh wait (.) hold on (.) how
4 to correctly interpret p values (2.2) this is like talking about statistics (.) is this
5 ↑statistics (.) I have no ↓idea
6 PST 18: the quality is <↓okay> (.) but like ↓why (.) you know like the erosion
7 was really bad in a lot of ↓places
8 PST 17: but <overall::> the quality was good (.) is that what you are ↑saying
9 PST 16: NO (.) I just don't know how the erosion being bad would
10 PST 16: [incorporate into]
11 PST 17: [what is a]
12 PST 17:p score what is the ↑p=
13 PST 18: =pollution (.) tolerance (.)
14 PST 16: index
15 (2.1)
16 PST 17: ↓oh (.) and that's how is that ↑test (.) that's a water quality is the actual
17 ↑water (.) and the erosion is the stuff around it ↑right (.) like it was the trees
18 falling over in the pictures=
19 PST 16: =but it would be due to <the water>
20 PST 17: <to the ↑water>
21 PST 16: I don't know how (.) I just DON'T=
22 PST 17: =>so it's<=
23 PST 16: =I'm not saying like include it (.) I just don't know <HOW I would>
24 (.) that's I guess what I'm saying (.) so I'm gonna look up like what erosion
25 (14.1)
26 PST 18: oh ↓god
27 PST 17: ah:::
28 Instructor: ladies do you have a ↑claim
29 PST 16: we just need to figure out like (0.3) why (.) what the erosion has (.)
30 <to do> with the overall picture and p score (1.5) (hhh)
31 PST 18: yeah we are just researching it right ↓now
32 Instructor: ↓okay

The sequence began with PST 17 trying to determine what the meaning of p value, a common indicator of stream health (and statistics term), which was used to determine the health of the creek in terms of the amount of macroinvertebrates the PSTs found in it. PST 18 latched onto PST 17's turn (line two) to state that, "he's gonna ask us" while she was observing the instructor asking other groups if they had determined a claim. PST 18 then ignored PST 17's utterance (lines three through five), which, based on the upward intonation of "statistics" and following pause, she could have interpreted as a question needing a response. Instead PST 18 self-initiated a turn to discuss the conflicting evidence (lines six and seven), which was a continuation of her utterance in line two. PST 16 also deflected from making a declarative statement (line nine) about the health of the creek when asked by PST 17 (line eight). The emphasis that she placed on "no" (line nine), on "don't" (line twenty-one), and on "how" (line twenty-three) suggested her frustration because the other PSTs were pressing her to make a declarative statement (Goodwin & Goodwin, 2000). The long pause in line twenty-five ended when PST 18 self-selected a turn to signal that the instructor was coming to their group through the utterance "oh god." These displays of anxiety toward the instructor are examples of the discomfort the PSTs experienced with analyzing conflicting data. Being provided answers by the instructor is a characteristic of traditional classrooms, which the PSTs had been conditioned to expect. PST 18's utterances in lines two and twenty-six were displays of anxiety concerning the instructor's expectations, and PST 16's frustration was overt in her hedging and loud emphasis on certain words (lines nine, twenty-one, and twenty-three). Such frustrations did not surface until PSTs had to

negotiate conflicting or ambiguous data in activities three and four, which they did not have to do during the first two activities.

Discussion

The PSTs had to negotiate the processes of analyzing complex data and arguing to support a claim. The institutional environment that they occupied, however, shaped that argument. The orientation towards doing "being a good student" was prevalent in their talk as they attempted to fulfill the expectations of each activity. Taking up the role of "being a good student" meant that the activity was not authentic for them. They viewed the task of arguing as a means to meet expectations instead of as a way to gain useful knowledge. This was evidenced by their frequent references to the role of the instructor and to the requirements of the project as justifications for their claims and how they were constructing their arguments. The number of questions that the PSTs asked was not surprising because they were learning a new scientific practice. The information they sought and the way they used it, however, revealed their focus on the product rather than the process of shaping their arguments. The PSTs relied uncritically on information the instructor relayed during multiple stages of the construction of their arguments without scrutiny or corroborating evidence. This indicates the extent to which the instructor influenced their arguments. Previous research has suggested that the teacher's ability to argue is associated with his/her students' abilities to construct arguments (Fishman et al., 2017; Osborne et al., 2004). Therefore, it stands to reason that if students uncritically incorporate the information they receive from their teacher, they are not cognitively engaging in the practice, but benefitting from their teacher's abilities to construct an argument while not developing their own. Teachers must be aware of the type and amount of information they provide students because that information is likely to be used in their arguments. In this case, the PSTs' talk revealed the instructor's role in their construction of arguments in two distinct ways.

The first way was that the PSTs used any information the instructor provided to justify the construction of a particular claim. The instructor's talk became a source of justification to help strengthen or counter a claim. Even though the instructor used his talk largely to resist the PST's efforts to obtain answers, he provided enough of the information they sought to become relevant to the construction of their claims. The use of sources to justify claims is an important aspect of argumentation. The literature, however, provides no evidence on how teachers act as the sources that shape their students' arguments. Instead, research on teachers typically analyzes their role in scaffolding or facilitating a practice (e.g., Christodoulou & Osborne, 2014) and developing appropriate classroom norms (Berland, 2011). Argumentation requires students to think about and engage in knowledge building in a way with which they are not familiar (Driver et al., 2000). The PSTs approached the practice of knowledge construction by using all sources of information available to them, including the instructor, whom they viewed as a content expert. Thus, they used the information he had provided as evidence from an expert (Walton, 2013). Moreover, their talk revealed that they used the information that the instructor had provided without discussion. Thus it can be inferred that revealing too much information to the students only reinforces traditional classroom views of the teacher as the gate keeper of knowledge.

The second way that the instructor influenced the construction of PST arguments was through the institutional talk they used to analyze the data provided. During the first two activities, the PSTs were given data that they used to construct arguments, while for the last two activities they collected their own data. Studies have suggested that argumentation does not help build content knowledge, but only helps deepen existing knowledge (Von Aufschnaiter et al., 2008). Perhaps, activities that provide pre-selected data are a symptom of this finding because of their focused attention on the process of argument construction and not knowledge building. Furthermore, the institutional norms to which most PSTs are conditioned constrained activities from being authentic because by enacting the familiar role of doing "being a good student" the PSTs focused only on what was required. Their talk did not reveal on-task conversations about data that fell outside the parameters of the project. However, they repeatedly talked about what was needed for the project as a way to justify certain actions. Discussing project needs suggests that the PSTs were concerned with meeting the expectations of each project, not building knowledge. Additionally, the design of the activities did not allow them to make a connection between projects but instead to concentrate on the needs of each activity individually, which would indicate knowledge building. Because argumentation was not the only focus of the course, the possibility exists that the PSTs will view argumentation as a strategy for teaching content and not in itself a primary aim of science education (Beyer & Davis, 2008; Laius et al., 2009; Sadler, 2006).

The role of institutional norms was an important factor as the PSTs constructed arguments. Their talk moves revealed their comfort with traditional teacher-centered approaches, not the inquiry-based approach used to engage them in argumentation. They were trying to perform "being a good student". But, their talk displayed

frustration due to the fact they were engaging in activities that did not have a correct outcome. The classroom norms in an inquiry-oriented classroom are different from those of a traditional classroom. The PSTs revealed their expectations for how they wanted the class to be run. Those expectations were different from the instructor's intentions.

The first way that the PSTs revealed their expectations for classroom norms was through their treatment of the instructor as a gatekeeper of information. In a traditional classroom, the teacher can be counted on to provide correct answers. Because of widespread familiarity with such classrooms, teachers have often cited a departure from traditional classroom procedures as a reason for not engaging students in argumentation (Laius et al., 2009; McDonald & Heck, 2012; McNeill & Knight, 2013). The questions that the PSTs asked the instructor revealed that they expected him to provide them with correct answers. However, providing answers would only reinforce a traditional view of science as a set body of facts and not as a system of tentative explanations (Khifshe, 2012). Despite his best efforts to not interfere in the PSTs' construction of their arguments, however, he did provide some information to them in the course. As noted, they used this information without scrutiny or discussion.

The PSTs' expectation that the instructor would adhere to their notion of classroom norms is likely linked to the constraints inservice teachers cite for not teaching argumentation. Specifically, the difficulties involved in first learning to construct arguments are likely to reinforce the belief that argumentation is for high level achievers only (McNeill & Knight, 2013; Sampson & Blanchard, 2012). Also teachers often fall back on their own experiences as students, which is typically a traditional classroom where the activities are teacher-centered (Laius et al., 2009). There were times that the PSTs appealed to the instructor for a correct answer and were frustrated when he did not provide one. They also voiced frustration about expectations to each other when the instructor was not present. Their frustration was an indication that they were out of their comfort zone as students. These experiences are likely to influence them as they design argumentation activities in a science methods course (Ricketts, 2014). However, it is unknown exactly how they will be influenced.

Implications

This study has implications for science teacher educators and professional developers. The ways in which these PSTs engaged in the process of argument construction from evidence to claim suggest a distinct recommendation. When facilitating argumentation, the facilitator must be aware of the nature and amount of information that s/he provides to the participants. That information will be used because of the traditional institutional norm of classroom settings that the teacher is a gatekeeper of information. Teacher-as-gatekeeper is a view that is rooted in the experiences of most PSTs during their science education prior to becoming an education major. Inadvertently, the instructor provided information that kept participants from engaging in the critical processes of discussing evidence and implications of that evidence because they simply took what he said as correct. In this way, the PSTs used an argument tactic known as "arguing from expert" (Walton, 2013). Using the teacher-as-expert short-circuited the PSTs' science experience as tentative and not an established body of facts. Unfortunately, traditional K-12 science education has conditioned PSTs to uncritically accept evidence sanctioned in classroom sources. However, regardless of their level of frustration, they should be required to question, critique, and remain open to new evidence. Science educators and professional developers need to be aware and highlight the importance of allowing PSTs the space to analyze their own data without providing answers.

This study has prompted two questions that need to be researched further. The first area that needs further study is how different levels of teacher content support shapes PST arguments. This study suggested that the PSTs came to rely on the instructor's content knowledge to develop their arguments. However, would this be the same level of content support that secondary education PSTs, who have taken more content courses, require, or would they develop a different reliance on their instructor? Scholars have pointed out that a difference between elementary and high school PSTs is that the former needs content support, while the latter does not (e.g., McNeill & Knight, 2013; Sadler, 2006). However, assuming that they do not need content support, what supports do secondary PSTs need from their methods instructors? This information would help science teacher educators provide science methods supports specific to elementary and high school levels. Secondly, the shift in reliance on the teacher seemed to occur when the preservice teachers started collecting their own data. They also began to display more frequent signs of frustration during the construction of their arguments when they were managing their own data, and the source of that frustration should be investigated. The institutional expectation of being provided a correct solution is part of the explanation (Chiu, 2004), but there are likely to be other factors. For instance, it is true that the PSTs lacked practice in analyzing data (Gilbert, 2008), but the frustration did not begin until the third activity. Given the delay in frustration, the question becomes: To what extent did

the additional steps of designing the data collection and organizing the data interfere with the PSTs' abilities to engage in argumentation, and how can activities be sequenced to provide support during this challenging transition from more to less structured activities?

References

Anfara, V. A., Brown, K. M., & Mangione, T. L. (2002). Qualitative analysis on stage: Making the research process more public. *Educational Researcher, 31*, 28-38.

Berland, L. K. (2011). Explaining variation in how classroom communities adapt the practice of scientific argumentation. *Journal of the Learning Sciences, 20*(4), 625-664.

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education, 94*(5), 765-793.

Beyer, C. J., & Davis, E. A. (2008). Fostering second graders' scientific explanations: A beginning elementary teacher's knowledge, beliefs, and practice. *The Journal of the Learning Sciences, 17*(3), 381-414.

Chin, C., & Osborne, J. (2010). Students' questions and discursive interaction: Their impact on argumentation during collaborative group discussions in science. *Journal of Research in Science Teaching, 47*(7), 883-908.

Chiu, M.M. (2004). "Adapting teacher interventions to student needs during cooperative learning: How to improve student problem solving and time on-task." *American Educational Research Journal 41*(2), 365-399.

Cohen, E.G. (1994). "Restructuring the classroom: Conditions for productive small groups." *Review of Educational Research, 64*(1), 1-35.

Debarger, A. H., Penuel, W. R., Moorthy, S., Beauvineau, Y., Kennedy, C. A., & Boscardin, C. K. (2017). Investigating purposeful science curriculum adaptation as a strategy to improve teaching and learning. *Science Education, 101*(1), 66-98.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of research in science teaching, 37*(6), 582-601.

Drew, P., & Heritage, J. (Eds.). (1992). Talk at work: Interaction in institutional settings.

Cambridge: Cambridge University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science education, 84*(3), 287-312.

Edwards, D. (1997). *Discourse and cognition*. London, UK: Sage.

Edwards, D. (2006). Discourse, cognition and social practices: the rich surface of language and social interaction. *Discourse Studies, 8*, 41-49. doi: 10.1177/1461445606059551

Edwards, D., & Mercer, N. (1987). *Common knowledge: The development of understanding in the classroom.* London: Routledge.

Edwards, D. & Potter, J. (1993). Language and causation: A discursive action model of description and attribution. *Psychological Review, 100*, 23-41.

Emig, B. R., McDonald, S., Zembal-Saul, C., & Strauss, S. G. (2014). Inviting argument by analogy: Analogical-mapping-based comparison activities as a scaffold for small-group argumentation. *Science Education, 98*(2), 243-268.

Evagorou, M., & Osborne, J. (2013). Exploring young students' collaborative argumentation within a socioscientific issue. *Journal of Research in Science Teaching, 50*(2), 209-237.

Fishman, E. J., Borko, H., Osborne, J., Gomez, F., Rafanelli, S., Reigh, E., Tseng, A., Million, S., & Berson, E. (2017). A practice-based professional development program to support scientific argumentation from evidence in the elementary classroom. *Journal of science teacher education, 28*(3), 222-249.

Gilbert, J. (2008). *Catching the knowledge wave? The knowledge society and the future of education.* Wellington, New Zealand: NZCER Press.

Goodwin, C. (1981). *Conversational organization: Interaction between speakers and hearers.* Academic Press.

Goodwin, M.H., & Goodwin, C. (2000). Emotion within situated activity. In: Budwig, N., Uzgiris, I.C., Wertsch, J. (Eds.), *Communication: An arena of development* (pp. 33–53). Ablex Publishing: Stamford.

Grooms, J., Sampson, V., & Enderle, P. (2018). How concept familiarity and experience with scientific argumentation are related to the way groups participate in an episode of argumentation. *Journal of Research in Science Teaching, 55*(9), 1264-1286.

Henderson, J. B., McNeill, K. L., González-Howard, M., Close, K., & Evans, M. (2018). Key challenges and future directions for educational research on scientific argumentation. *Journal of Research in Science Teaching, 55*(1), 5-18.

Heritage, J. (1984). *Garfinkel and ethnomethodology*. Cambridge, UK: Polity Press.

Heritage, J. (2015). Well-prefaced turns in English conversation: A conversation analytic perspective. *Journal of Pragmatics*, *88*, 88-104.

Jefferson, G. (2004). Glossary of transcript symbols with an introduction. In G. H. Lerner(Ed.), *Conversation analysis: Studies from the first generation* (pp. 13–31). Amsterdam, The Netherlands: John Benjamins. doi:10.1075/pbns.125.02jef

Kapellidi, C. (2013). The organization of talk in school interaction. *Discourse Studies*, *15*(2), 185-204.

Khishfe, R. (2012). Relationship between nature of science understandings and argumentation skills: A role for counterargument and contextual factors. *Journal of Research in Science Teaching*, *49*(4), 489-514.

Kuhn, D. (2015). Thinking together and alone. *Educational Researcher*, *44*(1), 46-53.

Kuhn, D., & Franklin, S. (2006). The second decade: What develops (and how)? In W. Damon & Richard M. Lerner (Series Eds.), D. Kuhn & R. Siegler (Vol. Eds.), Handbook of child psychology: Vol. 2, Cognition, perception, and language (6th ed., pp. 953-993). Hoboken, NJ: Wiley.

Laius, A., Kask, K., & Rannimäe, M. (2009). Comparing outcomes from two case studies on chemistry teachers' readiness to change. *Chemistry Education Research and Practice*, *10*(2), 142-153.

Laserna, C. M., Seih, Y. T., & Pennebaker, J. W. (2014). Um... who like says you know: Filler word use as a function of age, gender, and personality. *Journal of Language and Social Psychology*, *33*(3), 328-338.

McDonald, C. V., & Heck, D. (2012). "How do we teach argumentation in the new Australian curriculum?" Secondary science teachers' experiences in an argumentation- based professional development program. *Teaching Science*, *58*(3), 22-28.

McNeill, K.L., & Knight, A.M. (2013). Teachers' pedagogical content knowledge of scientific argumentation: The impact of professional development on k–12 teachers. *Science Education*, *97*(6), 936-972.

McNeill, K. L., & Krajcik, J. S. (2012). Supporting Grade 5-8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talk and Writing. *Pearson*.

McNeill, K. L., Lizotte, D. J., & Krajcik, J. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences*, *15*(2), 153-191.

McNeill, K. L., & Pimentel, D. S. (2010). Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation. *Science Education*, *94*(2), 203-229.

National Research Council (U.S.) (2012). Committee on a Conceptual Framework for New K-12 Science Education Standards., & ebrary, I. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C.: National Academies Press.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, *41*(10), 994-1020.

Osborne, J., MacPherson, A., Patterson, A., & Szu, E. (2012). Chapter 1 Introduction. *Perspectives on scientific argumentation, Theory, practice and design. London/New York: Springer Dordrecht Heidelberg*.

Potter, J. (2012). Discourse analysis and discursive psychology. In Cooper, H. (Editor-in-Chief). *APA handbook of research methods in psychology: Vol. 2. Quantitative, qualitative, neuropsychological, and biological* (pp. 111-130). Washington: American Psychological Association Press.

Potter, J., & Wetherell, M. (1987). *Discourse and social psychology*. London, UK: Sage.

Ricketts, A. (2014). Preservice elementary teachers' ideas about scientific practices. *Science & Education*, *23*(10), 2119-2135.

Robertshaw, B., & Campbell, T. (2013). Constructing arguments: Investigating pre-service science teachers' argumentation skills in a socio-scientific context. *Science Education International*, *24*(2), 195-211.

Sadler, T. D. (2006). Promoting discourse and argumentation in science teacher education. *Journal of Science Teacher Education*, *17*(4), 323-346.

Sampson, V., & Blanchard, M. R. (2012). Science teachers and scientific argumentation: Trends in views and practice. *Journal of Research in Science Teaching*, *49*(9), 1122-1148.

Shemwell, J. T., & Furtak, E. M. (2010). Science classroom discussion as scientific argumentation: A study of conceptually rich (and poor) student talk. *Educational Assessment*, *15*(3-4), 222-250.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, *28*(2-3), 235-260.

Stokoe, E., & Benwell, B. (2006). *Discourse and identity*. Edinburgh, UK: Edinburgh University Press.

Swanson, L., Solorza, R., & Fissore, C. (2018). Providing Opportunities for Argumentation in Science Exam Settings. *Journal of College Science Teaching*, *47*(3).

Toulmin, S. (1958). The Uses of Argument. Cambridge University Press. *Cambridge, England*.

Von Aufschnaiter, C., Erduran, S., Osborne, J., & Simon, S. (2008). Arguing to learn and learning to argue: Case studies of how students' argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching*, *45*(1), 101-131.

Walton, D. (2013). *Methods of argumentation*. Cambridge University Press.

Wiggins, S. (2017). *Discursive psychology: theory, method and applications*. Los Angeles: Sage.

Wood, L. & Kroger, R. (2000). *Doing discourse analysis: Methods for studying actions in talk and text*. London: Sage.

Woofit, R. (2005). *Conversation analysis and discourse analysis: A comparative and critical introduction*. London, UK: Sage.

Zembal Saul, C. (2009). Learning to teach elementary school science as argument. *Science Education*, *93*(4), 687-719.

Author Information

Brent Gilles
University of West Georgia
USA
Contact e-mail: *bgilles@westga.edu*

Gayle Buck
Indiana University
USA