Research Proposal

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**Introduction**

There is broad acknowledgment in the research community that literacy practices such as reading, writing, and oral discourse play a significant role in learning and practicing science (Cervetti & Peason, 2012; Krajcik & Sutherland, 2010). *A Framework for K-12 Science Education* (National Research Council (NRC) 2012) highlights this relationship, noting that “reading, interpreting, and producing text are fundamental practices of science, and they constitute at least half of engineers’ and scientists’ total working time” (pp.3-19). Various scholars (e.g., Lee & Spratley, 2010; Moje, 2008; Pearson, Moje, & Greenleaf, 2010) have argued that without explicit attention to the unique reading and writing practices within subjects such as science, students will leave school with an inadequate understanding of what it means to use literacy as a tool for constructing and evaluating knowledge within the various disciplines.

Two literacy practices essential to producing new knowledge in science are argument and critique (Krajcik & Sutherland, 2010; Osborne, 2010). Argumentation has not only been identified as a core discursive practice of science (Osborne, 2010), but is also the keystone of a democratic society (Allen, Montalbano, & Duke, 2018). The ability to engage in collaborative argumentation is a fundamental skill for success in the 21st century (Osborne, 2010). Research suggests that student participation in argument helps to (a) develop students’ communication skills, (b) enables metacognitive awareness, (3) promotes critical thinking, (4) supports students’ understanding of the culture and practice of science, and (5) fosters scientific literacy (Jimenez-Aleixandre & Erduran, 2007). These abilities are consistent with those characterized as twenty-first century skills necessary for a variety of professions (Zembal-Saul, McNeil, & Hershberger, 2013).
Educational Significance

An emphasis on evidence and argumentation is not only evident within the framework for K-12 science education (NRC, 2012), but is also consistent with national standards and reform documents in education (American Association for the Advancement of Science [AAAS], 2009; National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA & CCSSO], 2010). The focus on argumentation is deeply rooted within each strand of the college and career anchor standards. Students are expected to demonstrate that they can utilize specific textual evidence to support both oral and written claims (NGA & CCSSO, 2010). The Benchmarks for Science Literacy (AAAS, 2009) also include a similar focus on justifying claims with evidence. To achieve this focus, an inquiry-based approach to teaching science has been recommended as a way to improve students’ abilities to read, write, and think like scientists (NRC, 2012).

Problem

Despite the emphasis and the increased attention on argumentation over the last few decades, argument is nearly absent from science education (Osborne, 2010). Previous reviews of literature related to argument in science education (e.g., Cavagnetto, 2010; Driver, Newton, & Osborne, 2000; Sadler, 2004) have found that current classroom practices provide few opportunities for students to develop their ability to construct arguments. While social interaction plays a prominent role in the lives of professional scientists, students in science classrooms often work independently with little opportunity to share ideas, findings, or interpretations (Cavegnatto, 2010). Furthermore, while studies reviewed did provide evidence that students’ argumentation skills can be enhanced through involvement in discursive activities, few teachers have the necessary skills to effectively facilitate argument-based discussions. As a result, the majority of science lessons are dominated by teacher talk. As a result, science is often
presented to students as a set of facts to be transferred from expert (i.e., the teacher) to novice (i.e., the students) (Osborne, 2010). The importance of argumentation for people’s lives, combined with the well-documented lack of argumentation in science classrooms, makes it imperative to help preservice teachers develop the skills necessary to effectively facilitate student engagement in scientific argumentation and explanation.

Among those in most need of this support are preservice elementary teachers, who commonly lack both confidence and proficiency in science (Zembal-Saul, McNeil, & Hershberger, 2013). Research has shown that pre-service elementary teachers often have limited understanding of science, scientific argumentation, the purpose of scientific argumentation, components of argumentation, and the difference between scientific argumentation and scientific explanation (Aydeniz & Ozdilek, 2015). Furthermore, little research currently exists on how to successfully prepare preservice elementary teachers to facilitate student engagement in scientific argumentation and explanation.

**Theoretical Framework**

Argumentation is a fundamental discourse of science, consistent with the epistemological assumptions of cognitive approaches such as social constructivism (Vygotsky, 1978), that describes the process of learning as a “social and communicative process, whereby learners share knowledge and construct understandings in a social context through dialogue, conflict, and negotiation” (Aydeniz, Pabuccu, Seda Cetin, & Kaya, 2012, p. 1303). For young children who are new to constructing scientific arguments, dialogic discussion can serve as an important scaffold. Dialogic discussions provide a social environment in which key discourse skills (e.g., asking questions, providing reasons and evidence) can be acquired through apprenticeship by a more knowledgeable other. As students observe and interact with more knowledgeable others, they are able to engage in cognitive processes beyond their current ability level. Students and
teachers can both act as a more knowledgeable other through modeling and scaffolding.

Through what Croninger, Li, Cameron, and Murphy (2017) refer to as a *discourse apprenticeship*, students gradually internalize higher cognitive functions, such as critical and analytic ways of thinking and reasoning. For this reason, research suggests that a critical component in promoting argument is the need for more student-student dialogical interaction (Driver et al., 2000; Martin & Hand, 2009).

Research has suggested that teacher questioning is a major contributing factor shaping the role of teachers for promoting dialogic interaction in argumentative practice (Chen, Hand, & Norton-Meier, 2017; Chin, 2007, Martin & Hand, 2009). Findings from Chin’s (2007) analysis of teacher-student interactions across six seventh-grade classrooms suggest that different roles of questioning serve different functions for scaffolding student thinking and construction of scientific knowledge. While many previous studies on classroom discourse have simply categorized the types of questions through the dichotomy of closed and open-ended questions (e.g., Martin & Hand, 2009), Chen and colleagues (2017) examined the multi-function and relationship between teacher questions and student cognitive responses. They conceptualized four critical roles of teacher questions: dispenser, moderator, coach, and participant. Results from this multiple case study revealed that as teachers shifted from relying solely on the dispenser role to using multiple roles, higher levels of student cognitive responses were promoted. Similar to Chin’s (2007) findings, Chen and colleagues conclude that teachers must adopt various roles of questioning when establishing dialogic interaction in argumentation.

In order to provide opportunities for students to participate productively in scientific discourse, teachers must transition from their traditional role as sole authoritative voice in the classroom to a new role in which they encourage and support students to have a more active
voice in discussion. For many teachers, engaging students in dialogic discussion for the purpose of constructing scientific arguments is a significant departure from the way they typically teach science (Zembal-Saul, McNeil, & Hershberger, 2013). Research suggests it can take more than a year before significant shifts in classroom discourse patterns are observed. For example, in a longitudinal study that examined the discourse patterns of a fifth-grade teacher, Martin and Hand (2009) found that it took an 18-month period to transition from a teacher-centered, didactic teaching style to an argumentative orientation in which students played a more active role in classroom discussion. As Chen et al. (2017) warn, shifting classroom discourse patterns is not a simple matter of developing a new skill, but instead requires an in-depth understanding of current classroom discourse norms and utilizing instructional strategies that can be used to establish new rules for classroom discourse.

Together, these studies show that teacher questions have the potential to increase student talk and expand classroom discourse beyond the traditional lecture format (McNeil & Pimental, 2009) and that increasing the amount of student-student dialogical interaction within the elementary science classroom is central to promoting argumentation. Thus, the role of the teacher is vital for creating a classroom environment supportive of scientific inquiry and argumentation (McNeil & Knight, 2013). Given the emphasis on argumentation across various science education reform documents, (NGA & CCSSO, 2010; NRC, 2012), there is a critical need to help preservice teachers, especially at the elementary level, develop a deeper understanding of scientific argumentation and ways to promote classroom discourse that is supportive of students’ meaningful science learning in the context of inquiry-based science (Zembal-Saul, 2009). Such understanding is vital in order for elementary teachers to successfully scaffold young students’ efforts to construct evidence-based arguments in science.
Literature Review

Scholars have utilized a variety of research methodologies and approaches to studying scientific argumentation in the context of teacher education. The following is a brief review of research from these various traditions and an explanation of how they informed my approach to studying preservice elementary teachers’ knowledge and beliefs about scientific argumentation.

Scientific Argumentation in Teacher Education

Scholars have conducted research on both in-service and pre-service teachers’ skills and understandings of scientific argumentation. For example, Sampson and Blanchard (2012) examined how 30 middle and high school teachers evaluate explanations and construct scientific arguments and their views about using scientific argumentation in the classroom. The researchers found that while the teachers seemed to value argumentation as a way to improve the quality of teaching and learning in science, they generally held naïve understandings about scientific argumentation. For example, teachers in the study often relied on their own personal ideas or content knowledge to assess the validity of an explanation rather available data. Furthermore, few teachers in the study constructed written arguments with sufficient evidence to support their claim. Lastly, participants mentioned several potential barriers to student engagement in argumentation in the classroom, including students’ ability levels, lack of time, and limited knowledge of how to successfully engage students in argumentation.

McNeil and Knight (2013) explored the impact of a professional development series on K-12 in-service teachers’ (N=70) pedagogical content knowledge (PCK) for scientific argumentation. Overall, they found that the professional development workshops supported teachers in developing understanding of the structural components of argumentation (i.e., claim, evidence, and reasoning) to assess students’ writing, but the application of argumentation to
classroom discussion continued to be difficult. For example, teachers exhibited a limited understanding of argumentation for both the structural components and dialogic interactions when analyzing student talk. Furthermore, teachers had difficulty designing argumentation questions.

Zembal-Saul and her colleagues have conducted several studies focused on supporting pre-service teachers in learning to teach argumentation in the science classroom. For example, in an earlier study, Zembal-Saul, Munford, Crawford, Friedrichsen, and Land (2002) conducted a qualitative case study to explore the nature and development of pre-service teachers’ argument construction. Participants included undergraduate secondary science majors enrolled in their advanced methods course. These preservice teachers engaged in a technology-enhanced investigation of natural selection that required them to construct an evidence-based argument. Two pairs of preservice teachers were purposefully selected for in-depth analysis. Analysis of data revealed that while participants consistently used evidence from the investigation to support their claims, their arguments still exhibited several limitations. For example, participants tended not to include alternative explanations or justification for the relevance of evidence.

More recently, Zembal-Saul (2009) synthesized findings from three related studies (Zembal-Saul, 2004; 2005; 2007) that are part of a design-based research and development project known as TESSA: Teaching Elementary School Science as Argument. This project investigated the use of a conceptual framework focused on evidence and argument in a science methods course for elementary preservice teachers. Findings across all three studies suggest that the use of a coherent conceptual framework for teaching science as argument can help preservice teachers improve their science teaching in various ways such as greater focus on classroom discourse and increased attention to monitoring and assessing students’ thinking.
Sadler (2006) also investigated the impact of integrating scientific argumentation on preservice teachers’ skills and understandings of argumentation. Participants included 17 middle and secondary science preservice teachers all enrolled in the same methods course. During the semester, argumentation was incorporated as a major focus throughout the course. Overall, he found that the majority of participants improved the structure of their arguments over the course of the semester. However, when evaluating arguments, participants often had difficulty distinguishing among data and warrants.

Scholars have also explored the impact of argumentation on pre-service teachers’ conceptual understandings in science. For example, Aydeniz and colleagues (2012) conducted a quasi-experimental study with a sample of 108 undergraduate PSTs drawn from two sections of a general chemistry course taught by the same instructor. The study explored the impact of argumentation on students’ conceptual understanding of properties and behaviors of gases. They exposed one group of students \( n = 56 \) to two hours of argumentation-based pedagogy while the comparison group students \( n = 52 \) spent the same amount of time solving chemistry problems in preparation for the post-test. The results of their study show that the participants in the intervention group performed significantly better than the participants in the control group on the post-test that measured students’ conceptual understanding of the properties and behaviors of gases.

The authors attribute these reported gains in participants’ conceptual understanding to several factors. For example, they argue that argumentation might have given participants a chance to elaborate on their pre-existing ideas and become aware of any gaps in their knowledge related to the topic of gases. These results are consistent with other studies that have found
scientific argumentation to have a positive impact on student learning in other contexts (Jimenez-Aleixandre, Bugallo-Rodriguez, & Duschl, 2000; Zohar & Nemet, 2002).

While studies have focused on supporting pre-service teachers’ understandings of scientific argumentation, most have focused on secondary science. Studies exploring how to support elementary pre-service teachers’ understanding of scientific argumentation are limited. Other than Zembal-Saul’s (2009) work, I found only one study that explored pre-service elementary teachers’ understanding of scientific argumentation and explanation. Aydeniz and Ozdilek (2015) employed a mixed method case study design to explore pre-service science teachers’ understanding of science, scientific argumentation and the difference between scientific argumentation and scientific explanation. Participants included 40 pre-service elementary science teachers purposefully sampled from an elementary teacher program in Turkey. Data was collected using an open-ended questionnaire that consisted of five questions. Findings revealed that the majority of participants lacked an informed understanding of science, science argumentation, and various aspects of scientific argumentation, including the difference between argumentation and explanation. While participants scored poorly across nearly all categories, their understanding of science received the lowest score. The second lowest scores were related to the elements of scientific argumentation and scientific explanation.

Methodology

Table 1 describes the overall methodologies of the identified studies, including research design, primary focus, participants, sample selection, sample size, instruments (as apply), data sources, duration, and methodological limitations.
Table 1

Methodology Overview of Identified Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Research Design</th>
<th>Focus</th>
<th>Participants</th>
<th>Data Sources</th>
<th>Duration</th>
<th>Limitations</th>
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</thead>
<tbody>
<tr>
<td>Aydeniz et al. (2012)</td>
<td>Quasi-experimental</td>
<td>Impact of argumentation-based pedagogy on secondary preservice teachers’ conceptual understanding in science</td>
<td>108 preservice teachers (52 in the control group and 56 in the intervention group) selected from 2 general chemistry college courses taught by the same instructor</td>
<td>Pre- and posttests</td>
<td>One semester</td>
<td>Positive results may have been the result of other factors that were not controlled for.</td>
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<tr>
<td>Aydeniz &amp; Ozdilek (2015)</td>
<td>Case Study</td>
<td>Pre-service elementary teachers’ understanding of science, scientific argumentation and the difference between scientific argumentation and scientific explanation</td>
<td>40 pre-service elementary teachers purposefully sampled from an elementary teacher program</td>
<td>Open-ended questionnaires</td>
<td>One semester</td>
<td>Data many not have been sufficient enough to fully capture participants’ understandings.</td>
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<tr>
<td>McNeil &amp; Knight (2013)</td>
<td>Case Study</td>
<td>Impact of professional development on K-12 teachers’ pedagogical content knowledge of scientific argumentation</td>
<td>70 elementary, middle and high school in-service teachers (recruited through the school district e-mail and online professional development Web site)</td>
<td>Pre- and postsurveys, videotapes of the workshops, artifacts produced by the teachers, and samples of student writing</td>
<td>Three months</td>
<td>Study did not examine impact on teacher practice or student learning</td>
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<tr>
<td>Sadler (2006)</td>
<td>Case Study</td>
<td>Preservice teachers’ argumentation skills and perceptions of argumentation</td>
<td>17 middle and secondary science preservice teachers (all students in one science methods course)</td>
<td>Instructor reflections, course documents, and student work samples</td>
<td>One semester</td>
<td>Positive results may have been the result of other factors that were not controlled for.</td>
</tr>
<tr>
<td>Sampson &amp; Blanchard (2012)</td>
<td>Case Study</td>
<td>In-service teachers’ skills, knowledge, and views in regard to scientific argumentation</td>
<td>30 middle and high school science teachers purposefully sampled from a large school district</td>
<td>Interview transcripts, written arguments by teachers, and field notes</td>
<td>Each teacher interview lasted about 40 minutes.</td>
<td>Potential of biased responses due to self-report data</td>
</tr>
<tr>
<td>Zembal-Saul et al. (2002)</td>
<td>Case Study</td>
<td>The nature of scientific arguments generated by secondary</td>
<td>Two pairs of preservice science teachers (purposefully</td>
<td>Electronic artifacts and videotaped interactions of both pairs</td>
<td>One semester</td>
<td>Results are not generalizable.</td>
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</table>
Discussion

Together, these studies show that most preservice teachers have limited understanding of scientific argumentation and call for call for a more concentrated effort to help preservice teachers to develop more sophisticated understanding of this vital scientific inquiry practice. For example, the literature shows that most teachers do not understand the structural components of an argument (McNeil & Knight, 2013), have difficulty supporting their arguments with sufficient evidence (Sampson & Blanchard, 2012), fail to include alternative explanations or justification for the relevance of evidence (Zembal-Saul et al., 2012), and do not recognize the difference between scientific argumentation and scientific explanation (Aydeniz & Ozdilek, 2015). Therefore, the challenges reported in the literature should be considered in the design of future teacher education experiences. As Zembal-Saul et al. (2002) warn, “it is unrealistic to expect teachers to adopt argumentation as a pedagogical practice to teach science if they do not themselves develop more elaborated understandings of argumentation in the context of science learning” (p. 440). In order to develop such understanding, teacher education must include opportunities for preservice to engage in classroom experiences that reflect contemporary reform.
efforts in science education. Such instruction should include an explicit focus on the structural components of argumentation, how to evaluate arguments for strengths and weaknesses, and how to design learning tasks and promote classroom discourse that is supportive of students’ engagement in argumentation.

Next Steps

Given the influence of teachers’ views about the role of scientific argumentation on their pedagogical decisions, (Sampson & Blanchard, 2012) research efforts to support pre-service elementary teachers in developing a rich understanding of scientific argumentation should be continued. Science methods courses for preservice elementary teachers offers one possible vehicle for promoting argumentation in elementary science education. In order to address the call above and the identified gap in the literature, I intend to conduct an intervention study to explore the impact of explicit instruction on scientific argumentation within a science methods course on preservice elementary teachers’ knowledge and beliefs about scientific argumentation.

This study will utilize a mixed method research design in which pre and post quantitative and qualitative data are utilized to examine the extent to which pre-service teachers receiving explicit instruction in scientific argumentation in one section of an elementary science methods course differ in their understanding of scientific argumentation from those receiving instruction in a comparison section. The rationale for utilizing this design is that the in-depth qualitative data will offer different, but complimentary data to the quantitative pre/post quantitative data.

The treatment and comparison groups will be similar in terms of the main goals and pedagogical methods used. Meetings and discussions between the instructors will ensure that both sections cover similar content. There will be distinguishing features and experiences for preservice teachers participating in the treatment group as related to the goals of the study. For
example, various course components will be specifically embedded in the treatment section. These components will be designed to allow participants to develop and apply their developing knowledge of scientific argumentation and explanation over the course of one semester and will include (a) explicit argumentation instruction using Toulmin’s (1958) framework, (b) opportunities for participants to engage in argumentation using data collected during in-class investigations, and (c) practice facilitating participants’ engagement in scientific argumentation in a mixed-reality teaching environment (i.e., TeachLivE). I plan to use a pre/post assessment of participants’ knowledge, beliefs, and attitudes about science in the elementary classroom at the start and end of the semester. I also plan to conduct observations (using an observation protocol), and interviews (with randomly selected participants).

The findings of this study are meant to contribute to the emerging body of research exploring elementary preservice teachers’ knowledge and beliefs of scientific argumentation and explanation. Given the influence of teachers’ beliefs and knowledge on their pedagogical decisions (Bandura, 1997), developing pre-service elementary teachers’ understanding of scientific argumentation and explanation is critical if teachers are to effectively facilitate elementary student engagement in scientific reasoning, as called for by recent education initiatives in both science and literacy.
References


