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Promoting Discourse and Argumentation in Science Teacher Education

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Given a sociocultural framework of teaching and learning, argumentation and discourse become central elements of education, particularly in science education because of argumentation's key role in scientific communities. This study documents preservice teachers' perceptions of and aptitudes related to argumentation as they participated in a science methods course designed to promote discourse and argumentation. Data sources consisted of instructor reflections, course documents, and student work. Participants tended to view argumentation as a central element of science and as a means for promoting conceptual development in science classrooms. They were generally adept in the construction of arguments, particularly with respect to the evidentiary support of claims and demonstrated improved practice as the course progressed. Implications for using this course as a model and suggestions for its improvement are discussed.

Introduction

For at least the past 2 decades, calls for reforming science education have centered around fostering scientific literacy among all students (DeBoer, 2000; Laugksch, 2000). Reform advocates have promoted scientific literacy as a multifaceted construct, including "being able to use scientific knowledge and ways of thinking for personal and social purposes" (American Association for the Advancement of Science [AAAS], 1990, pp. xvii–xviii). The National Science Education Standards define a scientifically literate person as someone who is able to "use appropriate scientific processes and principles in making personal decisions" and "engage intelligently in public discourse and debate about matters of scientific and technological concern" (National Research Council [NRC], 1996, p. 13). These statements suggest that science educators must require more of their students than the passive acquisition of knowledge relative to the natural world: The standards imply an active element applicable to the everyday lives of students.

Promoting the active involvement of students has been embraced by the science education community in the form of *inquiry-based instruction*, *discovery learning*, *process skills*, and *hands-on curricula* (Chiappetta & Koballa, 2002). These approaches encourage students to engage in some elements of scientific inquiry, such as the manipulation of variables, experimental design, and the confirmation of hypotheses; but they typically fail to accurately account for the social practice of science or promote skills necessary for the evaluation and defense of scientific theories or findings. An effective science education program not only requires active involvement on the part of students in terms of scientific investigations, but also the development of discursive practices that enable students to apply their understandings of science to personal decision making and engage in public discourse about issues related to science. These discursive practices, which include evaluating evidence, assessing alternatives, establishing the validity of scientific claims, and addressing counterevidence, constitute scientific argumentation (Driver, Newton, & Osborne, 2000).

Classroom science frequently portrays the scientific enterprise as a relatively simple progression from data collection to issue resolution, with little emphasis on the intervening discourse that defines how data are conceptualized, collected, and interpreted. The framework advocated in this paper is summarized effectively by Driver et al., 2000:

> *To provide adequate science education for young people, it is necessary to reconceptualize the practices of science teaching so as to portray scientific knowledge as socially constructed. This change in perspective has major implications for pedagogy, requiring discursive activities, especially argument to be given a greater prominence.... More fundamentally, what is required is a reconsideration of the role of science education, commonly seen as an introductory training in science, emphasizing basic methodological skills and practices, to one that sees its function as an education about science, which seeks to empower young people and develop their scientific literacy. (pp. 289)*

This perspective holds that discourse and argumentation occupy a central role in science and *should* maintain the same centrality in science education. However, classroom discourse is largely dominated by didactic monologues from a teacher, with little opportunity for students to engage in dialogical argumentation (Duschl & Osborne, 2002). If an aim of science education is the promotion of argumentation, then the current state of science classrooms, in which teacher talk is valued and student talk is typically discouraged, or at least heavily curtailed, must be changed. A reasonable place to advocate and promote this kind of change is science teacher preparatory programs. This study explores a secondary science methods course that holds the promotion of argumentation as a major theme.

Before moving on to a discussion of the course itself and the research that took place throughout the course, further clarification of the terms *discourse* and *argumentation* as they apply to pedagogical practices is warranted. In the preceding paragraphs, a description of argumentation (i.e., evaluating evidence, assessing alternatives, establishing the validity of scientific claims, and addressing counterevidence) consistent with current research frameworks (Driver et al., 2000; Kuhn, 1991; Toulmin, 1958) is presented. However, considering colloquial uses of these terms is also important, especially considering that the aim is for teachers to embrace these constructs as a part of their instruction. The term discourse usually refers to verbal expressions or conversation. As this paper's title suggests, this study explores the promotion of discourse, but the focus is not solely on increasing the amount of conversation in classrooms. The goal is to increase certain kinds of conversation, namely, argumentation among students in science classrooms. In its common use, the term argument usually refers to an oppositional interaction or a contentious dispute. Therefore, a common perception of the suggestion that science teachers should promote argumentation is that this represents a call for debates or other confrontational interactions (Osborne, Erduran, Simon, & Monk, 2001). While debate may be a useful strategy for engaging students, argumentation represents a much broader construct that does not necessarily rely on disagreements or opposition.

Some researchers, including me (Perkins, Farady, & Bushey, 1991; Sadler, 2004; Zohar & Nemet, 2002), have presented a conceptualization of argumentation as primarily the articulation of informal reasoning. In other words, argumentation is the expression of reasoning in the context of ill-structured, controversial, and debatable problems that may possess multiple, plausible solutions and be viewed from a variety of perspectives. This perspective supports a cognitive view of learning, which assumes that thinking and cognition are processes residing in the minds of students and producing outcomes that can then be transmitted verbally. While I certainly would not argue that cognition cannot occur in the minds of students, I believe this view underrepresents the significance of context and interpersonal interactions. In contrast, the sociocultural perspective suggests that learning is distributed across learners and the environment (Greeno, 1998; Lave & Wenger, 1991; Packer & Goicoechea, 2000). This perspective shifts the focus of learning from individual mental operations to interactions among learners, materials, and collective ideas. Viewed from this framework, argumentation is no longer just the expression of reasoning, which implies that reasoning is the significant process and argumentation is just a reporting mechanism. In a sociocultural framework, argumentation assumes a fundamental position in the collective process of making meaning and affecting learning. This perspective, which considers argumentation a necessary aspect of education, grounded the current investigation.

Research Focus

This study is a naturalistic, interpretive investigation of a secondary science methods course focused on the promotion of argumentation as a major theme. The goals of this paper are to describe how argumentation was incorporated into the course and to explore course participants' argumentation skills and perceptions of argumentation.

Methods

Study Design and Data Collection

The study proceeded in two phases that are distinct, but certainly not independent. In the first phase, I functioned as a participant observer with the goal of documenting and describing how argumentation was incorporated as a major theme throughout a secondary methods course. In completing this task, I drew on two primary data sources: my experiences, as the instructor, which were documented through the use of a reflective journal and course documents, including the course syllabus, assignment sheets, presentations, and notes.

The second phase of the project involved the naturalistic investigation of participant perspectives on argumentation and proficiencies in the construction and evaluation of arguments. Several data sources collected throughout the course informed this aspect of the project. To elicit participant perceptions of argumentation, particularly with respect to its place in science education, I asked students to respond in writing to a series of questions pertaining to science education in general and scientific argumentation more explicitly. Participants responded to a question set at the beginning of the semester, as well as a different, but related, question set at the end of the semester (see Appendix A). In addition to the science methods course all participants were taking, they participated in field experiences during which they spent extended amounts of time in a middle or secondary science classroom. (This will be described in greater detail in a later section.) Field experience reflections served as a second data source. The participants were asked to explicitly consider the role of discourse and argumentation as a part of their field-based observations. The final data source contributing to the phenomenological account of participant perceptions of scientific argumentation was a reflective piece individuals wrote after facilitating an in-class teaching activity focused on discourse and argumentation.

The investigation of participant abilities relative to forming and evaluating arguments was based on analyses of four data sets collected at different times throughout the course:

1. As a part of the question set administered at the beginning of the semester, students were asked to create an argument supporting or refuting a scientific theory.
2. Participants completed in-class assignments (before and after a lesson explicitly focused on argumentation) challenging them to construct arguments about scientific controversies.
3. Participants were asked to evaluate two arguments as a part of the summative evaluation for the course.
4. Participants were asked to write an extended argument as a part of the second question set administered at the end of the course.

It is important to note that the goal of the project's second phase was to document participant beliefs and abilities relative to argumentation as they emerged throughout the methods course. The study provides a naturalistic interpretation of how argumentation as a pedagogical theme was situated in a secondary science methods course and how students responded to this focus. Given that data were collected at multiple times throughout the course, it was possible to document changes over time. However, these data were used to build a description of the course context and outcomes. Causal declarations and generalizable results are not appropriate outcomes, given these data and methods.

Data Analysis

Analysis of these data sources was consistent with inductive analytic procedures described by Lincoln and Guba (1985). In short, this entailed reading through data sources, noting patterns and trends relative to the research foci (viz., participant perceptions of and proficiencies with argumentation). I then engaged in a process of refining and consolidating the emergent taxonomy in several iterations, constantly comparing revised analytic structures with the actual data. This approach was consistent with the constant comparative method as described by Glaser and Strauss (1967). The trustworthiness of these analyses and results were built through a variety of mechanisms, including triangulation of multiple data sources, presentation of thick description to enable readers to assess applicability, peer debriefing, and an audit log (Lincoln & Guba).

Participants and Context

The course serving as the subject of this investigation was a methods course specifically designed for preservice middle and secondary science teachers. It was offered as a part of a middle and secondary science teacher preparation program at a large Midwestern public university. The course served as the last requirement before students began their student teaching, which was the final component preceding graduation, licensure, or both. Twenty-six students completed the course in the semester during which this investigation took place, and I served as the instructor. Seventeen students completed human subject consent forms, so, although 27 of us formed the classroom community, analysis of individual participants' products was limited to the 17 who consented. Because of Institutional Review Board guidelines, the informed consent forms had to be mailed to participants following the course. Had the study been described and the informed consent forms had been distributed in person, I suspect that the response rate would have been much higher. I have no reason to believe that the sampling procedures introduced systemic bias that might compromise the conclusions drawn.

Although all of the students enrolled in the class were preparing for careers in science teaching, they came to the class from a variety of backgrounds and degree programs. Their disciplinary emphases and licensing plans spanned all of the major science areas, including biology, chemistry, earth science, and physics. Some of the students were undergraduate seniors seeking Bachelors degrees in science education. These students had completed extensive coursework in at least two of the traditional science disciplines. The other students had already earned undergraduate degrees in a science content area and were seeking Master's degrees and teaching licenses. Regardless of the track, all participants had completed coursework in educational foundations, technology, psychology, multiculturalism, and content-area literacy. In addition, they had completed an introductory methods course specific to middle and high school science instruction. This class, a prerequisite to the course under investigation, was accompanied by a field experience during which students spent a minimum of 30 hr in a local middle or high school.

The class that provided the context for this study possessed a unique structure relative to typical teacher education programs: It was an intensive course carried out in 6 weeks, and it met every weekday for 3.5 hr each day. In addition to the daily coursework, students spent a minimum of 40 hr engaged in a classroom-based field experience throughout the 6 weeks. For the field experience, students observed and participated in a middle or secondary science classroom. Directly following the methods course and field experience, students began a 10-week student-teaching placement in their field experience classrooms.

Argumentation Focus

This section documents how argumentation and discourse were incorporated as important themes throughout the 6-week course. The presentation is divided into four subsections: instructional themes, classroom environment, explicit instruction, and facilitating argumentation.

Instructional Themes

Early in the course (but after the beginning-of-semester question set), I presented a framework for science teaching; argumentation was one of four fundamental elements of this framework. The other elements, all of which—including argumentation—are interdependent, were constructivist epistemology, inquiry, and critical thinking. I made the case that, from my perspective, a best possible science education would be one in which a constructivist theory of learning guided instructional decisions, students were challenged to engage in critical thinking and argumentation, and science was experienced as inquiry as opposed to a static collection of facts. Given the focus of this study, it is important to emphasize that, while argumentation and discourse were central themes, other significant aspects of science pedagogy were also stressed. Other themes around which instruction and assignments were designed included inquiry, nature of science, learning cycles, standards, misconceptions, safety, and instructional planning.

Classroom Environment

Throughout the course, I tried to model the development of a classroom community that could support argumentation instruction. Students were physically organized into groups of four or five, and they were encouraged to share ideas and collaborate. From the very beginning of the course, I made students aware of my expectation for active participation of all members of the class. Regardless of a particular class period's topics, student groups had the opportunity (and responsibility) to engage one another in discourse during every class meeting. Many of these opportunities did not require students to engage in argumentation as described earlier; but they did involve discourse that encouraged the development of interpersonal relationships, trust, and a sense of accountability to one another.

Explicit Instruction

During the 3rd week of the course, two full class periods (about 7 hr) were devoted to argumentation and discourse. This instruction began with a discussion of excerpts from an article related to strategies for enhancing argument in school science (Osborne et al., 2001). Building from the information presented in the article, we further examined argument structure by exploring a simplified version of Toulmin's Argumentation Pattern (TAP; Toulmin, 1958). This argumentation format highlighted claims and evidence necessary for supporting claims. Evidence was defined to include both data and warrants that serve to link or explain how data support claims. The students then analyzed a series of excerpts taken from secondary science textbooks to identify argument patterns (see Figure 1 for an example). The students also worked through a series of practice exercises based on examples provided by Osborne et al. These exercises challenged students to evaluate evidence used to support competing claims and theories, select lines of evidence that best supported claims, and construct arguments with the given data and warrants.

Once students had the chance to explore and work with simple arguments consisting of claims, data, and warrants, we discussed how an argument's effectiveness can be improved with the inclusion of counterpositions and rebuttals. Counterpositions represent opposing perspectives to a claim that has been presented. By

Excerpt:
While there are many things to appreciate and celebrate about the world in which we live, many pressing environmental problems cry out for our attention. Human populations have grown at alarming rates in this century, creating many environmental stresses. Nearly 6 billion people now occupy the earth, and we are adding about 90 million more each year. (Cunningham & Saigo, 1999, p. 9)

Analysis:

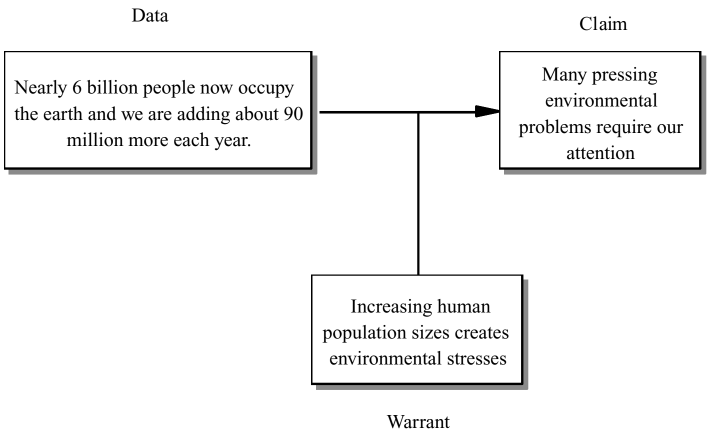

Figure 1. *A sample argument analyzed by students using Toulmin's Argument Pattern.*

attending to possible counterpositions and supplying plausible rebuttals, an individual enhances his or her own argument. Students practiced forming their own arguments—complete with claims, data, warrants, counterpositions, and rebuttals—based on their reading of a brief summary of a controversial environmental policy. I then spent some time presenting common reasoning fallacies that can undermine argumentation. Zeidler (1997) identified and described many fallacies that can affect student discourse and reasoning. From this inventory, I selected five on which to focus, based on their prevalence among middle and secondary students. I presented the following modes of fallacious reasoning as points to help students avoid: ad hominem attacks, circular reasoning, hasty generalizations, appeals to authority, and altering the representation of an argument. Table 1 provides a description and an example of each fallacy.

During the instruction explicitly focused on argumentation, I provided specific suggestions for enhancing the quality of argumentation in classrooms. These suggestions stemmed from my own experiences as a science teacher and teacher educator and general texts relative to classroom communication (Chesebro & McCroskey, 2002; Cooper & Simonds, 2003). The suggestions are outlined below:

– create an environment in which student comments and opinions are valued;
– create an environment in which students feel safe and comfortable in terms of expressing themselves;

Table 1
Common Fallacies to Avoid in Argumentation

Fallacy	Description	Example
Ad hominem attack	Attacking the speaker rather than the legitimacy of his/her argument	"His objection to the power plant should be dismissed because he never knows what he is talking about."
Circular reasoning	Supporting a claim with the claim	"The power plant should be built because it will be beneficial."
Hasty generalizations	Making a conclusion based on limited information	"I'm not going to use the learning cycle because I saw Ms. Gonzalez use it and it failed miserably."
Appeal to authority	Using an authority figure as the primary means of supporting an argument	"Evolutionary theory must be well supported because S. J. Gould wrote of it often."
Altering representation of the argument	Responding to an argument in a way that changes the nature of the argument	"Should human cloning be legalized?" "I certainly wouldn't want to be a clone."

- establish ground rules for classroom discourse, including respect for one another and no personal attacks;
- expect student contributions to classroom discourse;
- provide ample opportunities for students to practice argumentation skills;
- provide opportunities for students to evaluate arguments; and
- explicitly discuss the nature of high-quality argumentation.

The first four suggestions, all of which relate to the classroom environment, are not as concrete as some of the others; and, yet, they are every bit as important. Successfully engaging students in argumentation relative to scientific claims and controversial issues is not the kind of thing that a teacher can just do by selecting a certain activity. It takes time to establish a sense of community conducive to this approach. As a class, we discussed how I had tried to model some of the steps necessary to establish this kind of community throughout our own course (viz., grouping strategies, discourse strategies and expectations, and the gradual establishment of discourse norms in the class). The final suggestion listed above begs the question: What constitutes high-quality argumentation? I responded by suggesting that consistently supporting claims with data and warrants was a mark of high-quality argumentation. Careful evaluation of evidence and competing inferences based on that evidence is important for argumentation. Recognizing multiple perspectives, as is necessary in offering counterpositions and rebuttals, is related to high-quality argumentation. Avoiding fallacious reasoning and recognizing the differences between ethical or moral beliefs and data-driven claims are also central to argumentation.

Students were challenged to construct arguments on a variety of scientific issues (see Appendix B), and we discussed various strategies for structuring and encouraging student discourse within the science classroom. Topics included directing class discussions, avoiding teacher-dominated classroom discourse, setting up role plays, managing debates, and encouraging participation by as many students as possible. The class also explored how argumentation and discourse could be used in the context of science—technology—society or socioscientific issues (Zeidler, Sadler, Simmons, & Howes, 2005). During this segment, we discussed the uses and limitations of data and evidence, as well as how values contribute to some argumentation contexts. To gain a firsthand account of using argumentation in the classroom, the students also participated in a jigsaw activity related to gene therapy designed for high school biology classes. This activity, which is described elsewhere (Sadler & Zeidler, 2004), challenges participants to analyze evidence and interpretations from a variety of perspectives en route to formulating a group position statement related to the regulation of gene therapy.

Facilitating Argumentation

During the week following the two class periods focused specifically on argumentation, pairs of students presented sample lessons designed to highlight discourse and argumentation. The presentations, which took place over 2 days, ranged in formats from small-group discussions to full-class debates to exercises in persuasive writing. Some of the topics explored included the endosymbiont theory of mitochondrial evolution, human space travel to Mars, evolutionary biology, the overuse of antibiotics, local environmental issues, and genetically modified foods. In addition to these class activities that directed focus on discourse and argumentation, the topics were incorporated in less formal ways throughout the course. For instance, students prepared a series of lesson plans, an assessment rubric, and a unit plan—all of which could have possessed an argumentation focus.

Participant Perspectives on Argumentation

Preinstruction Views

Prior to any course interventions or activities, the students responded to a series of questions (see Appendix A) that revealed some of their ideas relative to the place of argumentation in science. Only 2 of the 17 participants referred to discourse or argumentation in response to the question: "What, in your view, is science?" The quote below was one of these responses:

> *Science is an attempt to investigate, understand, and explain natural phenomena. Although this can be done by a variety of methods, observation and collection of evidence is the primary method. . . . The evidence is analyzed, discussed, and debated in order to draw the best, most accurate conclusions possible. (P1)*

This individual, along with one other participant, explicitly acknowledged the role of discourse in science before the topic emerged as a part of the class. Others did not make this specific reference, but many (14) did discuss the significance of data and evidence, which are fundamental to argumentation as the construct has been operationalized in this study. For example, P2 stated, "Science creates explanations that are based on evidence: Science can be tested and observed."

When prompted to consider the role of discourse in science, a majority of the participants (10) expressed ideas similar to that expressed above by Participant 1. In other words, discourse was a normal part of the scientific process. The following quotation illustrates this pattern: "Discourse helps generate phenomenon for study . . . helps widen the approaches to studying a phenomenon . . . invigorates the scrutiny of evidence and proposed explanations, and . . . helps push the field of endeavor outwards" (P3). When asked to go further and consider the place of discourse in the context of science classrooms, participants cited several ideas, including discourse reflects the true character of science, promotes critical thinking, helps students develop social skills, and connects science to everyday lives. No more than three individuals mentioned any of these themes. The only themes discussed by several participants (more than 5) related to discourse as a pedagogical tool for enhancing content understanding and personalized learning. These quotes exemplify these themes: "Conversations and debates that occur in middle or high school classrooms should occur as a means to help the students better understand new concepts" (P4), and "Discourse can let them [middle and secondary students] be involved and see that science is not merely a set of facts and figures that they need to regurgitate later" (P5). In response to the question of what science teaching should look like in a best case scenario, all of the participants mentioned student-centered approaches, including inquiry and hands-on activities. Only 2 individuals suggested that discourse was fundamental to an ideal science education. The quote below provides an example:

> *Students can work together as fellow scientists and then present their findings to the teacher and other students. Constructive criticism and discourse/dialog throughout the classroom facilitated by the instructor makes the science education classroom an interactive and engaging forum for learning. (P3)*

Postinstruction Views

At the end of the semester, which corresponded to the conclusion of the participants' student-teaching experience approximately 10 weeks beyond the end of the methods course, participants responded to another set of questions. They were asked to reflect on how their ideas about science teaching had changed. Not surprisingly, most participants focused on the practical issues with which they struggled throughout their student-teaching placements. They talked about classroom management, the difficulty of incorporating inquiry, how busy a teacher's day is, and the complexities of adolescent students. One participant also discussed his take on classroom discourse:

> *I learned throughout the semester the importance of discourse and conversations in the classroom. More often than not, some students had valuable input on the topic that we were covering in class. Whether it was in the form of a story, question, or remark, the ideas that they brought up usually helped contribute to the understanding of the subject matter (P4).*

In preparing the question set, I did not expect many participants to discuss discourse and argumentation with this general question, so I included a more targeted prompt: "How did you use (or not use) discourse/argumentation in your student-teaching classroom(s)?" Of the 17 participants, 8 reported having tried one or two lessons focused on argumentation. Participant 6 briefly describes her experience below:

> *I did two activities . . . that really did a great job of bringing discourse into the classroom. The first activity was based on cancer. I gave the students some articles from two newspaper sources . . . I would say that discourse works really well with the right topics and give students a chance to share their thoughts.*

Three other participants, represented by the excerpt below, reported a more systematic approach to incorporating discourse and argumentation:

> *I prepared several lessons that were meant to encourage discourse and argumentation. One lesson provided information and roles to guide students in discussion about a variety of large-scale energy production methods.... Another activity involved genetic engineering in agriculture. (P2)*

A few individuals from these two groups talked about how they had used lesson ideas seen in class from both me and their peers during the sample lesson presentations.

Of the six participants who reported not using discourse or argumentation, four suggested the prescribed content did not lend itself to this approach. At least one of these participants, quoted below, came to this conclusion because he perceived argumentation from its colloquial use as necessarily oppositional: “I did not incorporate discourse or argumentation because I never saw an opportunity to fit it in. Most of the standards I covered were argument free” (P7). He seems to suggest that because something is not controversial, argumentation cannot be employed—a view that is consistent with most colloquial accounts of the construct. This perspective ignores the fact that argumentation can involve evidence and claims, and does not necessarily have to be controversial. One other participant did not try classroom argumentation because she felt that she did not have the time to develop community characteristics necessary for productive discourse. The final participant reported that she felt unprepared to manage this approach: “I do not feel very comfortable about trying something like that [argumentation], and I am not sure how to apply it to my content area [physics]” (P1).

Field-Based Observations

As a part of their classroom-based field experience, students were asked to reflect on the nature of student discourse and argumentation throughout their observations. Three of the 17 study participants chose not to complete this assignment, so the data presented in this section are based on only 14 participants. A majority of individuals (11) reported that student discourse and argumentation were virtually absent from the classrooms they were observing. The following typifies statements made by all of these participants: “There was no discourse in class at all except students ‘illegally’ talking to each other and [the cooperating teacher] telling them to be quiet” (P8). This result is consistent with classroom surveys focused on the characterization of student discourse. These studies suggest that teachers account for the overwhelming majority of classroom talk and that students have few opportunities to engage in argumentation (Driver et al., 2000; Duschl & Osborne, 2002). The 3 participants who did not cite the absence of student discourse provided some specific examples of argumentation in action. The quote below provides one such example:

> *The class sessions dealing with cloning were interwoven with ethical questions. These questions were aimed to address certain aspects of cloning that could be morally/ethically unacceptable. During class, the students were expected to voice their opinions—supported with evidence—about certain concepts of cloning. (P9)*

Despite the fact that most participants did not observe much in the way of student discourse, several (5) discussed opportunities presented in the classrooms that would have been amenable to an argumentation approach. Eight participants, such as the individual quoted below, also discussed their own plans to weave discourse and argumentation into their curriculum.

> *I would like to make discourse an essential part of my instruction and try to work it in at every opportunity. . . . I would teach students about the format of arguments and allow them to evaluate several sources before asking them to take a position. (P10)*

Reflections

The final data source providing insights relative to participant perspectives on argumentation and discourse were self-reflections based on the minilessons that students presented to their classmates. It should be noted that these discourse minilesson presentations were one of four such minilesson and reflection assignments. All of the minilessons were videorecorded, and students were asked to analyze their teaching videos and write a reflection. Most of the participants focused on the practical logistics of their teaching behaviors throughout their reflections. Common topics included the use (or nonuse) of wait time, patterns of nonverbal communication, nervous habits, student interest, and other themes that we might expect preservice teachers to consider as they practice teach. However, in some cases, these reflections provided an opportunity to further understand student perspectives on argumentation. Five of the participants discussed how the experience focused their attention on key elements of classroom discourse. They mentioned such challenges as the importance of thought-provoking questions, how to best moderate student discussions, and grouping strategies. The excerpt below provides an example:

> *This style of teaching [argumentation] is very new and different for me. As I watched the video, I noticed that I seemed to hold back from the conversation and allow the students to do more of the talking. I think this can be a strength and a weakness at the same time. (P11)*

The reflections of four students also demonstrated changes in their perspectives toward argumentation. All four of these instances suggested that actually presenting a discourse minilesson improved the likelihood that these individuals would attempt this approach in the future. For example, P12 offered the following:

> *Before we began this exercise, I was not sure how or if I would ever use discourse and argumentation in my classroom, beyond having students defend their answers. However, I do like this lesson plan and may use it or ones similar to it in my teaching. (P12)*

The participant offering this comment had created a hypothetical scenario related to an environmental problem and challenged her audience to assume the roles of various stakeholders. The audience members were then asked to interpret evidence through the lenses of their roles.

Argumentation Skills

Throughout the course, participants had a number of opportunities to engage in argumentation. Some of these opportunities were captured as data sources to document argumentation skills. At four different times during the semester, participants made written arguments regarding scientific theories, principles, or controversies. Their first arguments were written as a part of the first question set (see Appendix A) administered at the outset of the course. This exercise challenged participants to establish the legitimacy of a commonly accepted scientific theory (i.e., atomic structure, evolution, plate tectonics, and relativity). Once the class had started, but prior to explicit instruction on argumentation, participants were asked to make an argument regarding a scientific issue that is either the frequent cause of misconceptions or is actively contested (see Appendix B). Examples included whether or not solid objects consist mostly of empty space and the effects of anthropogenic carbon dioxide emissions. Following explicit instruction on argumentation, participants wrote a new series of arguments based on the same prompts used prior to instruction. Finally, participants responded to a similar task as a part of the final question set (see Appendix A). Of the 17 participants, 14 completed all four argumentation tasks. These individuals' work was analyzed for argumentation quality over the length of the course.

With only two exceptions, all of the participants demonstrated aptitude in the formation of scientific arguments throughout the course, particularly with respect to consistently supporting claims with evidence. The participants, all of whom had studied science extensively and many of whom had worked in science laboratories, seemed to understand the centrality of evidence and effectively used evidence to strengthen their claims. The participants did not reveal tendencies to engage in such fallacious reasoning as making appeals to authority or circular reasoning. Recognizable differences did emerge among three groups of participants in terms of the argumentation patterns displayed at different times of the semester. Individuals representing the largest group showed improvements in their argumentation, another group demonstrated temporary improvements, and the final group showed no changes.

Improved Argument Structure

A majority of the participants (9) demonstrated argumentation proficiency in both argumentation tasks preceding explicit instruction, but revealed more complex arguments in terms of structure in both tasks following explicit instruction. These individuals effectively used evidence to support scientific claims in response to all four argumentation activities, but, for both activities following instruction, added an element of complexity by referring to counterpositions and making plausible rebuttals. Table 2 presents excerpts from the one of the participants (P10) who demonstrated this pattern.

Temporarily Improved Argument Structure

A second group composed of only two participants showed the same pattern as the previous group until the final task (i.e., forming an argument in response to the end-of-semester question set). Like their peers described earlier, they were quite adept at using data to support their claims, and the arguments formed directly after explicit instruction also included counterpositions and rebuttals. However, the final arguments made at the end of the semester had reverted to the level of quality demonstrated prior to instruction. The arguments made appropriate use of evidence, but lacked counterpositions and rebuttals (see Table 2).

No Change in Argument Quality

Three individuals made up the final category. These participants showed no change in argumentation over the course of the semester. At the beginning of this section, I mentioned that, while most participants created fairly high-quality arguments (i.e., claims were consistently substantiated with evidence), two individuals were exceptions and did not demonstrate this basic aptitude. These two participants displayed the same level of relatively low-quality argumentation on all of the four argumentation tasks. One other participant was grouped together with these two because, although she supported claims with evidence prior to explicit instruction, she demonstrated no noticeable change following instruction. Together, these three participants maintained a level of argumentation that seemed completely unaffected by the course activities.

Argument Evaluation

In addition to forming arguments, students in the course were asked to evaluate a pair of arguments related to electric circuits. This task was included in a formal exam toward the end of the course and 2 weeks after the explicit instruction on

Table 2

Argumentation Task Excerpts That Demonstrate the Three Emergent Categories of Argumentation Skills

Preintervention task	Postintervention task	End-of-semester task
Group 1: Improved argument structure Humans and chimpanzees share a common ancestor. . .. How can we apply the concept of evolution to chimps and humans? Phylogenetic relationships can be determined by a variety of methods, including fossil and molecular evidence. Fossil evidence shows chimps and humans share a variety of characteristics. (P10)	Human and chimpanzees share a common ancestor. . .. The fossil records show changes in species diversity over time, which is one of the major components of evolutionary theory. . .. Opponents may claim that the fossil evidence we have is insufficient and because we do not have enough records of intermediate species, we cannot claim that chimps and humans share a common ancestor. I would argue that the fossil evidence is sufficient to support the claim, but there is also molecular evidence that suggests that humans and chimps are so closely related that we must have shared a common ancestor. (P10)	I believe we should not drill in the Alaska National Wildlife Reserve for oil. Drilling would not provide enough oil to risk damaging Alaskan wildlife. . .. The machinery and pollution that comes with drilling for oil would do irreversible damage to the area and a number of endangered species. . .. Those who support drilling in the region state that they would be able to extract the oil by disturbing a very small area. . .. However, the oil reservoirs are likely spread over a very large area and would cause many years of disturbance to reach in the first place. (P10)
Group 2: Temporarily Improved Argument Structure Covalent bonds are stronger than ionic bonds. Consider organic compounds, which consist of mostly covalent bonds and are not very soluble. Ionic compounds, such as NaCl, break apart easily in water and, therefore, do not need as much energy to break apart. . .. Organic compounds, some of which never go into solution with water, have covalent bonds, which are much stronger. (P13)	Covalent bonds are stronger than ionic bonds. Consider organic compounds, which consist of mostly covalent bonds. . .. Thinking along the lines of like dissolves like, one might think that, since water is covalent, organic compounds, which also have covalent bonds, would easily dissolve in water—suggesting that covalent bonds are actually weaker than ionic bonds. However, it takes less energy to break ionic bonds than covalent bonds, so ionic compounds like NaCl will dissolve in water, while many covalent compounds won't. (P13)	We should not drill for oil in the Alaska National Wildlife Reserve because it will hurt the wildlife that is there. Drilling for oil can have drastic ecological consequences which change wildlife habitats in a way that can never be repaired. (P13)

Group 3: No Change in Argument Quality		
Humans and chimps share a common ancestor. They share ∼98% of their DNA. They both have opposable thumbs and various other characteristics, which indicate that they are both derived from a common ancestor. (P14)	Anthropogenic CO2 emissions have affected global climate. Prior to the industrial revolution, the temperature of the earth remained relatively constant; but, in the last 100 years, the average temperature has risen by a full degree . . . (P14)	We should drill for oil in the Alaskan Reserve. Gas prices are way too high. We should not have to depend on overseas countries for oil if we can get it cheaper by drilling here in the U.S. It would greatly benefit our economy. (P14)

argumentation. The students were asked to analyze and evaluate the following two arguments:

A. Parallel circuits (with multiple electric devices) consume more energy than series circuits (with multiple electric devices). Mr. Wizard clearly showed this phenomenon, and you would be crazy not to accept it.
B. Parallel circuits (with multiple electric devices) consume more energy than series circuits (with multiple electric devices). Two bulbs in a parallel circuit will burn equally bright because each bulb is provided with an independent source of electron flow; whereas, the same bulbs will be dimmer in a series circuit. Some people might think that parallel and series circuits with the same electric devices attached would consume the same amount of energy, but because parallel circuits provide multiple paths for electric flow, they consume more energy than series circuits, which provide a single pathway for electric flow.

All of the 17 participants provided an evaluation of the arguments and most made reasonable assertions regarding their quality. In response to Item A, 9 participants correctly cited the lack of data. Eight participants identified the appeal to authority as evidence of fallacious reasoning, and 3 others cited an ad hominem attack. Six participants analyzed the argument by applying Toulmin's Argument Pattern (1958), but half of these individuals drew inappropriate conclusions. The 3 who erroneously applied TAP struggled with classifying data and warrants. Argument A did not actually include data and warrants, but these 3 participants identified statements as evidence to "fit" the argument to Toulmin's general structure.

In response to Item B, 11 participants cited the evidence used in support of the claim. Three individuals recognized and commented on the inclusion of a counterposition and a rebuttal. Ten participants applied TAP for analyzing the argument; however, 1 individual did so incorrectly. He mislabeled the warrant. Table 3 displays participant evaluations representative of the trends just discussed.

Discussion

This study describes the inclusion of argumentation in a secondary science methods course. It was not the case that argumentation became the exclusive focus of instruction in the course: Argumentation was one of several themes stressed as fundamental issues relevant to high-quality science education. The study also documents student perspectives on argumentation and discourse, as well as how student argumentation skills are manifested as they experience the course.

Most participants agreed with a premise central to the planning of this investigation: Argumentation plays a fundamental role in the practice of science. However, tension emerged between the prevailing notions of the students and me, as the instructor, concerning the role of argumentation in science classrooms. I conceptualized argumentation as an important aim of science education, whereas most participants perceived argumentation as a pedagogical strategy for achieving such goals as improved acquisition of content knowledge. This trend was directly evident

Table 3
Participant Trends in Argumentation Evaluation

Evaluative focus	Example
Significance of evidence	This argument [A] states a claim, "Parlel circuits consume more energy than series circuits," but has no data to support the claim. The claim may be true, but without evidence to support it, the argument lacks validity. Without data, a claim is not convincing. (P16)
Identifies fallacious reasoning	This argument also uses an appeal to authority (i.e., Mr. Wizard) to justify the argument. This tactic is a common mistake in poor argumentation. (P17)
Recognized counter positions and rebuttals	The argument is well constructed and even contains a potential rebuttal to a likely counterargument ("some people might think that . . . provide a single pathway for electric flow"). (P15)
Application of Toulmin's Argument Pattern (TAP)	Data: Two bulbs in parallel circuit will burn equally bright, whereas two bulbs in a series circuit will be dimmer Warrant: Because parallel circuits provide multiple paths for electric flow, they consume more energy than the single pathway of series circuits Claim: Parallel circuits consume more energy than series circuits. (P6)
Misapplication of TAP	Data: Parallel circuits consume more energy than series circuits Claim: You are crazy not to accept this Warrant: Mr. Wizard clearly shows this phenomenon. (P12)

in comments participants offered as a part of the question sets and more indirectly in the reported patterns of incorporating argumentation in instruction. Most participants reported using argumentation strategies during their student-teaching experiences, but the vast majority of these individuals reported using these techniques in only one or two isolated instances. Two individuals indicated more systematic approaches to incorporating argumentation, which may support the view of argumentation as an educational goal in its own right as opposed to a means to another educational end. These two participants were exceptions more closely aligned with my own normative expectations than the majority of their peers; but at least a few individuals represented exceptions of the opposite extreme. Four participants did not try incorporating argumentation in their teaching practices at all, and at least one of these individuals felt unprepared, even if she had wanted to do so. The fact that these four students did not incorporate argumentation did not necessarily indicate a divergence in thought relative to the role of this construct, compared to their peers who tried using argumentation strategies. In fact, one participant indicated a desire to promote classroom discourse, but opted not to do so, given the practical limitations of a restricted student-teaching schedule. However, two students discussed not seeing a place for argumentation in their specific disciplinary foci. While most participants embraced the notion of using argumentation at least as a pedagogical tool, a small number of students adopted more polarized perspectives: A few participants embraced argumentation as a central focus of science education; whereas, a couple did not seem to find the construct useful, even in a limited sense.

In terms of evaluating the effectiveness of the course as a means of promoting argumentation, the evidence suggested mixed results. Very few students adopted perspectives positing argumentation as a goal central to science education, but most did assume (or at least maintained) a positive stance toward using argumentation strategies. The data suggested that students found some of the exercises and materials presented as a part of the course useful. Students reported using specific strategies, such as argument dissection, as well as activities seen in class, presented by both their peers and me. Positive results from the course also emerged from data collected as a part of participant field experiences. Participants experienced dissonance among the perspectives they saw manifested in their field experiences and those presented as a part of the methods course. The overwhelming majority reported that their observations of science classrooms were devoid of organized opportunities for student discourse. This is not a surprising result (see Duschl & Osborne, 2002); however, it was encouraging to see that the participants cited many opportunities to use argumentation strategies, and most reported a willingness to attempt structuring experiences designed to promote student discourse and argumentation.

A factor that likely contributed to the relative success of the course was the level of student preparedness. Fifteen of the 17 participants demonstrated proficiency in the formation of scientific arguments from the outset of the course. My job as the instructor was simplified by the fact that I did not have to devote a great deal of instructional time and effort to understanding the bases of scientific argumentation. Rather, I was able to focus on how argumentation and discourse could be incorporated in science classrooms. By specifically highlighting strategies for enhancing the complexity of an argument (viz., incorporating counterpositions and rebuttals) and standards for evaluating arguments, the course activities seemed to positively affect student argument formation and evaluation. A likely explanation is that the course experiences raised awareness of some specific argument features. Most participants showed improved argument complexity following explicit instruction. However, assessments of argumentation farther removed from the support and expectations of the course would be interesting, especially considering the fact that the initial gains displayed by two participants were no longer evident by the end of the semester.

In evaluating arguments, participants generally performed well. However, one trend did emerge with possible implications for argumentation instruction. In evaluating two arguments, individuals applied Toulmin's Argument Pattern 16 times. Twenty-five percent of these TAP applications were incorrect. This relatively high rate of error suggests the need to revisit the instructional focus on TAP. A reasonable conclusion is that the learning experience relative to TAP was not as effective as it should have been. While I do not question the legitimacy of this conclusion, the inclusion of TAP in argumentation instruction in the context of science teacher education should also be reconsidered. The individuals who misapplied TAP consistently struggled with identifying warrants. Distinguishing among data and warrants may be important for discourse analysis or other lines of research, but the task may present unnecessary complexity for science teachers and students. I am not suggesting that science teachers and students could not fully apply TAP, given appropriate support; I am questioning its utility. In reflecting on my own teaching practice and learner needs, I will modify my future instruction to stress connections between claims and data, both of which are integral components to TAP, but will not require students to distinguish between data and warrants.

Although argumentation is central to science, it is frequently absent from typical science classrooms. Methods courses for preservice teachers represent one possible vehicle for promoting argumentation in science education. The course described in this paper served as a means of raising awareness of the place of argumentation in science and classrooms and promoting argumentation skills. Most of the participants did not adopt the sociocultural perspective on argumentation that served as a basis for the course, but they generally embraced the idea of using argumentation and discourse as useful classroom strategies. Given the challenges of being a new teacher (Adams & Krockover, 1997; Luft & Patterson, 2002), it might be unrealistic to expect preservice teachers to adopt this transformative view of argumentation and science education. Therefore, efforts to promote argumentation as an instructional focus should also be initiated and continued with practicing teachers, and these efforts should continue to be researched.

Appendix A

Question Sets

Beginning-of-semester question set

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion or philosophy)?
2. Why is science teaching important? What do you want your students to "take away" from their learning experiences with you?
3. What role should discourse (conversation or argumentation) play in science? What role should discourse (conversation or argument) play in middle and secondary school science classrooms?
4. In a best case scenario, what should science teaching "look like?" What should be the roles of students and teachers in the science classroom?

5. Select one of the scientific theories below; briefly describe the theory and justify its acceptance. Answer this question as if you were trying to establish the legitimacy of the theory to someone who was unfamiliar with the theory.

    a. Atomic structure
    b. Evolution
    c. Plate tectonics
    d. Relativity

End-of-semester questions

1. How have your ideas about science teaching changed throughout your experiences this semester?
2. How did you use (or not use) inquiry in your student teaching classroom(s)? If you incorporated inquiry, describe how you did this (providing specific examples of what you did) and discuss how well it worked or didn't work. If you didn't incorporate inquiry, discuss why you opted not to use inquiry.
3. How did you use (or not use) discourse/argumentation in your student teaching classroom(s)? If you incorporated discourse/argumentation, describe how you did this (providing specific examples of what you did) and discuss how well it worked or didn't work. If you didn't incorporate discourse/argumentation, discuss why you opted not to use discourse/argumentation.
4. Make an argument for one of the positions below. (Select one side of the argument to defend).

    a. Nuclear power should/should not be used for the generation of municipal electricity.
    b. New lines of embryonic stem cells should/should not be harvested for medical research.
    c. We should/should not drill in the Alaska National Wildlife Reserve for oil.
    d. The United States *should/should not* attempt to send astronauts to Mars.

Appendix B

In-Class Argument Prompts

Instructions: Select and defend one of the following claims:

– Covalent bonds are/are not stronger than ionic bonds.
– Humans and chimpanzees share/do not share a common ancestor.
– Anthropogenic CO_2 emissions have/have not affected global climate.
– The table upon which you are working is/is not mostly empty space.
– A 3 kg mass dropped from 500 m will/will not strike the earth with greater momentum than a 3 kg mass dropped from 200 m.

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