International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

Factors impacting teachers' argumentation instruction in their science classrooms

Katherine L. McNeill, Rebecca Katsh-Singer, María González-Howard & Suzanna Loper

To cite this article: Katherine L. McNeill, Rebecca Katsh-Singer, María González-Howard & Suzanna Loper (2016): Factors impacting teachers' argumentation instruction in their science classrooms, International Journal of Science Education, DOI: 10.1080/09500693.2016.1221547

To link to this article: http://dx.doi.org/10.1080/09500693.2016.1221547

Published online: 22 Aug 2016.

Submit your article to this journal

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
http://www.tandfonline.com/action/journalInformation?journalCode=tsed20

Download by: [Cornell University Library] **Date:** 23 August 2016, At: 12:26

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
http://dx.doi.org/10.1080/09500693.2016.1221547

Routledge
Taylor & Francis Group

Factors impacting teachers' argumentation instruction in their science classrooms

Katherine L. McNeill[a], Rebecca Katsh-Singer[a], María González-Howard[a] and Suzanna Loper[b]

[a]Lynch School of Education, Boston College, Chestnut Hill, MA, USA; [b]Lawrence Hall of Science, University of California, Berkeley, CA, USA

ABSTRACT
Science education research, reform documents and standards include scientific argumentation as a key learning goal for students. The role of the teacher is essential for implementing argumentation in part because their beliefs about argumentation can impact whether and how this science practice is integrated into their classroom. In this study, we surveyed 42 middle school science teachers and conducted follow-up interviews with 25 to investigate the factors that teachers believe impact their argumentation instruction. Teachers responded that their own learning goals had the greatest impact on their argumentation instruction while influences related to context, policy and assessment had the least impact. The minor influence of policy and assessment was in part because teachers saw a lack of alignment between these areas and the goals of argumentation. In addition, although teachers indicated that argumentation was an important learning goal, regardless of students' backgrounds and abilities, the teachers discussed argumentation in different ways. Consequently, it may be more important to help teachers understand what counts as argumentation, rather than provide a rationale for including argumentation in instruction. Finally, the act of trying out argumentation in their own classrooms, supported through resources such as curriculum, can increase teachers' confidence in teaching argumentation.

ARTICLE HISTORY
Received 27 January 2016
Accepted 3 August 2016

KEYWORDS
Argumentation; teacher beliefs; policy

Recent science education reform documents (National Research Council [NRC], 2012; NGSS Lead States, 2013) and research (Kuhn, 2010) include an increasing focus on students engaging in scientific argumentation. Argumentation is an authentic science practice that enables scientists to develop and debate theories based on evidence (Osborne, 2010). As such, in the classroom, argumentation engages students in opportunities to construct and defend their claims using evidence, as well as critique arguments presented by others. Research has demonstrated significant benefits to students participating in this practice such as improved critical thinking and reasoning skills (Jimenez-Aleixandre & Erduran, 2008) and increased content knowledge (Venville & Dawson, 2010). However, while research has explored teacher and student challenges and benefits of argumentation

CONTACT Katherine L. McNeill kmcneill@bc.edu Lynch School of Education, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA 02467, USA

© 2016 Informa UK Limited, trading as Taylor & Francis Group

instruction (e.g. Berland & Hammer, 2012; Evagorou, Jimenez-Aleixandre, & Osborne, 2012; Jimenez-Aleixandre & Erduran, 2008; McNeill, 2009; Osborne, Erduran, & Simon, 2004; Venville & Dawson, 2010), fewer studies have focused on teachers' understandings of and beliefs about argumentation (Zohar, 2008; Zohar, Degani, & Vaaknin, 2001). The research that does exist indicates that these conceptions can impact the instructional choices teachers make related to argumentation (Sampson & Blanchard, 2012). However, we as a field are lacking a more comprehensive understanding of why teachers enact argumentation in various ways in their classrooms. Although different resources, such as curricula and technology tools, have begun to be developed to support teachers in argumentation (Cavagnetto, 2010), the role of the teacher is important in terms of how these resources are used in classroom settings (McNeill, Pimentel, & Strauss, 2013). Consequently, our research looks to address the following research question: What factors do teachers report as impacting their argumentation instruction in their science classrooms?

Theoretical framework

Importance of scientific argumentation

Traditional science education often emphasises student learning of 'discrete facts' and therefore fails to 'provide students with engaging opportunities to experience how science is actually done' (NRC, 2012, p. ES-1). In contrast, student participation in argumentation encompasses many essential aspects of the scientific enterprise, including making sense of real-world phenomena, articulating understandings of those phenomena and persuading others of ideas (Berland & Reiser, 2009). Argumentation has been included as a key science practice in recent standards in the USA, such as the *Next Generation Science Standards* (NGSS Lead States, 2013), and is explicitly emphasised in the national standards and/or curricula in numerous European countries (Science Teacher Education Advanced Methods [S-TEAM], 2010) in part because it can serve to shift the commonly held belief that science is a set of facts or a single method of inquiry. Instead, students are engaged in complex and cognitively demanding learning experiences that prioritise the social construction of knowledge in ways similar to scientists. Furthermore, engaging students in argumentation can result in numerous benefits such as increasing students' learning of important science content (Venville & Dawson, 2010) and improving students' communication skills and reasoning abilities (Jimenez-Aleixandre & Erduran, 2008).

As the focus on argumentation research has expanded over the last two decades, there has been variation in the definitions and analytic frameworks used in this work (Sampson & Clark, 2008). We define argumentation similar to Jimenez-Aleixandre and Erduran (2008), in that we see the practice as including two related conceptions: (1) incorporation of an epistemic structure in which a claim is supported by evidence and reasoning, and (2) a dialogic process or a social activity in which multiple individuals engage in persuasion and critique. The structural meaning relies on students using claims, evidence and reasoning (McNeill, Lizotte, Krajcik, & Marx, 2006) to construct scientific arguments. Claims are the answers to scientific questions. Evidence consists of measurements and observations that are relevant to a specific claim. Reasoning serves as the link between claims and evidence, often using science ideas to show why evidence supports a claim. These components, however, are simply that – pieces of an argument. For students to engage in argumentation, they must use

these components to accomplish the second meaning, to persuade an audience, debate peers and critique other arguments in ways similar to scientists (Driver, Newton, & Osborne, 2000). Argumentation is a social practice in which students should be both constructing and critiquing claims (Ford, 2008) as they engage with their peers in both the sense-making and persuasive goals of this practice (Berland & Reiser, 2011).

Teacher roles in argumentation classrooms

The focus on argumentation requires that teachers take on new roles in the science classroom and develop a distinct classroom culture (Simon, Erduran, & Osborne, 2006). Research indicates, however, that typical science instruction emphasises the transmission of teacher knowledge (Berland & Reiser, 2009; Newton, Driver, & Osborne, 1999), and interactions focus on students talking to teachers instead of to each other (Alozie, Moje, & Krajcik, 2010; Berland & Reiser, 2009). This stands in contrast to the student-to-student dialogical interactions prioritised by argumentation (Driver et al., 2000). For teachers comfortable with this traditional teacher-directed science learning, successfully engaging students in argumentation requires significant changes in their beliefs and instructional techniques (Osborne et al., 2004; Reiser, 2013). Changing teachers' beliefs and instruction has been shown to be a difficult and time-consuming task (Fullan, 2007; Spillane, 2004). Teachers can have very different perspectives, which they use to define their work and frame how they know and recognise problems within their instructional context (Nespor, 1987). In science, teachers' beliefs about themselves and their students often shape their instruction and those beliefs are resistant to change (Bryan, 2012). Because teacher change is situated and personal, teacher enactment and reflection on new reform efforts can be key for teacher change (Clarke & Hollingsworth, 2002).

Many new curricula and technology resources attempt to support classroom instruction that is better aligned with the goals of argumentation (Cavagnetto, 2010). However, teachers' beliefs can significantly impact their use of curriculum and other resources (Bryan, 2012). For example, even when teachers enact a curriculum that includes a focus on argumentation, instruction can vary significantly and still include more traditional and didactic forms of teaching (McNeill et al., 2013). Teachers attempting argumentation instruction may, for example, implement elements of this practice, such as teaching students the structure of an argument, but fail to create a classroom culture necessary for authentic argumentation experiences for students (McNeill, 2009). Teachers may even believe that they are achieving the goals of argumentation when in fact they are teaching in traditional ways (Zohar, 2008), such as relying on an initiate–response–evaluate (IRE) talk structure in the classroom instead of promoting student-to-student debate and critique (Alozie et al., 2010). While there is an increasing amount of research about the enactment of argumentation in the classroom (e.g. Berland & Reiser, 2011; Simon et al., 2006), there still is relatively little work focused specifically on teachers' understandings and beliefs related to argumentation (Zohar, 2008).

Teacher beliefs and classroom instruction

Our study focuses on teachers' beliefs as important for their enactment of argumentation in the classroom. One reason for this is that research indicates that teachers' beliefs may

significantly impact the instructional decisions they make (Pajares, 1992; Richardson, 1996). Pajares (1992) argues that beliefs influence how teachers process new information, and are difficult to revise. Consequently, even when confronted with convincing evidence about new ideas, teachers can maintain earlier perceptions, and can even turn conflicting evidence into support for those earlier beliefs. Specifically for science, Zohar (2008) found that teachers' beliefs about how science knowledge is generated in a classroom can impact the types of learning experiences that are offered to students. Teachers who held 'transmission of knowledge' beliefs prioritised providing information and correct answers to students while teachers with 'knowledge construction' beliefs engaged students in more problem-solving and critical thinking experiences. The first category of teachers believed that it was inappropriate to engage students in critical thinking because it could confuse them, while the second type of teachers saw such opportunities as essential to student learning. While few studies have focused on the specific relationship between teacher beliefs and argumentation (Zohar, 2008), those that do have found similar results – such beliefs can impact argumentation instruction in the classroom (Sampson & Blanchard, 2012).

Teachers' beliefs about their students' capabilities to engage in argumentation may also impact the opportunities students have in the classroom. Research has demonstrated that when teachers hold deficit beliefs of their students they may offer less challenging and cognitively demanding learning experiences to these students (Zohar et al., 2001). Teachers can believe such opportunities are only appropriate for their high-achieving students (Raudenbush, Rowan, & Cheong, 1993; Zohar et al., 2001) or that their students lack specific qualities necessary for success (Prime & Miranda, 2006). However, while research indicates that teachers' beliefs can have an impact on classroom instruction, there is relatively little research focused on these beliefs in relation to argumentation. Consequently, in this study, we investigated what factors teachers identify as impacting argumentation instruction in their science classrooms.

Methods

Curricular context

This research study occurred within the context of the development of a middle school science curriculum, for students typically between 11 and 13 years old. The curriculum was designed using a multimodal approach to learning where students construct an understanding of the key concepts through investigations that focus on four modalities: do-it, talk-it, read-it and write-it (Pearson, Moje, & Greenleaf, 2010). In addition, the curriculum materials were designed to be educative (Davis & Krajcik, 2005), in that they supported teacher as well as student learning about argumentation. One of the key learning goals within the curriculum was for students to be able to successfully construct and critique scientific arguments across reading, writing and talking. As discussed previously, the definition of argumentation in the curriculum focused on two related meanings – a structural aspect and a dialogic process (Jimenez-Aleixandre & Erduran, 2008). For example, the curriculum included a number of explicit goals around argumentation such as, 'knowing that a scientific argument includes a claim, evidence and reasoning', 'examining two competing arguments to determine which is better supported with evidence' and 'building on others' claims by offering additional evidence in discussion'.

Written educative supports for teachers about these two synergistic meanings of argumentation were integrated throughout the curriculum. Specifically, the lessons included textual supports both within the lesson sequence and as text boxes. These educative elements provided teachers with additional support around argumentation, consistent with the criteria of Beyer, Delgado, Davis, and Krajcik (2009) who argue for the importance of including both *rationale* (e.g. logic behind the designers' decisions) and *implementation guidance* (e.g. instructional strategies). For example, in one lesson in which students engaged in a Science Seminar where they debated competing claims using evidence, the lesson plan provided a rationale for teachers for the dialogic focus. The lesson stated, '… scientists can adjust their thinking based on new evidence when it makes sense to do so. Ignoring some evidence and sticking with an idea even if the evidence goes against it is not scientific'. This educative support highlighted the social nature of argumentation and that scientists change their ideas in light of new evidence.

Participants

Sixty-five teachers field tested between one and four six-week Earth and space science curricular units. Teachers were recruited through e-mail list servs in which they were invited to participate in 'classroom field trials of an exciting new middle school science curriculum that combines hands-on inquiry with support for disciplinary literacy (reading, writing and talking about science)'. All participating teachers received a class set of materials, including a digital teacher's guide installed on an iPad, student readings and manipulatives. In addition, teachers who completed the field trial were allowed to keep the iPad for personal use. Teachers began the field trial as early as September, though the start date varied depending on the needs of the teacher and school. All teachers completed the field trial by April.

After completing the field trial, the teachers received a follow-up e-mail in April inviting them to complete an online survey to provide the developers with information on 'how to make the materials more helpful for teaching argumentation'. Upon completion of the survey, teachers received a $40 iTunes gift card. In addition, the last question on the survey invited them to participate in a follow-up phone interview for which they would receive a $60 iTunes gift card.

Forty-two of the teachers completed the survey and 25 of those teachers then participated in follow-up phone interviews. Of these 42 teachers, the majority taught either 1 unit ($n = 15$) or 2 units ($n = 25$) with only 1 teacher enacting 3 units and 1 teacher enacting 4 units. The participating teachers worked in a range of schools across the USA as well as one teacher in England (see Table 1). The one teacher in England worked at a private American school, which was why the teacher was on the original e-mail list serv. This setting was similar to the other private schools in the study that were interested in new science education reform efforts. Consequently, we included the teacher as part of the sample.

In addition, teachers had a range of teaching experience including teachers with only a couple of years of experience to over 20 years of teaching experience as well as teachers with only bachelor degrees to doctoral degrees (Table 2).

Table 1. School characteristics of participating teachers ($N = 41$)[a].

Geographic region	Northeast, USA	Southeast, USA	Midwest, USA	Southwest, USA	West, USA	England
# of teachers	*7*	*0*	*0*	*15*	*18*	*1*
% Students eligible for free/ reduced lunch	Low <25%	Middle 25–75%	High >75%	Not reported (private schools)		
# of teachers	*4*	*16*	*14*	*7*		
% Students classified as low English proficiency	Low 25%	Middle 25–75%	High >75%	Not reported (private schools)		
# of teachers	*23*	*9*	*2*	*7*		
Type of school	Public, non-charter	Public, charter	Private			
# of teachers	*30*	*4*	*7*			

[a]One teacher wrote an incorrect teacher ID on the survey so we could not link him/her to a school.

Study design

We used a mixed-method approach utilising both quantitative and qualitative data to address the research question (Creswell, 2003). Specifically, we conducted an online survey with close-ended and open-ended items as well as follow-up phone interviews. We used the multiple data sources to triangulate our findings looking for confirming and disconfirming evidence for the emergent patterns (Erickson, 1986).

Data sources

To develop the survey and interview questions, we first reviewed the literature to identify different potential influences that could impact teachers' argumentation instruction. We found twenty influences that fell into six broad categories: typical approaches and practices, teacher beliefs and values, knowledge of argumentation, meeting the needs of all students, environment and supports, and technology. We then presented the 20 influences to our external advisory board. The advisory board provided feedback to narrow the focus of our data collection. This feedback resulted in focusing on seven potential influences related to teachers' beliefs, which were then used to develop survey and interview questions: (1) argumentation as a learning goal in science, (2) argumentation discourse and discussion, (3) teacher self-efficacy, (4) using argumentation to accomplish other educational goals, (5) the role of students' abilities and backgrounds, (6) the human, physical and social context and (7) the role of standards and high-stakes assessments. For the survey, we developed between 8 and 10 close-ended items and 1 open-ended item for

Table 2. Teacher demographic information ($N = 41$)[a].

Type of teaching credentials	Multi-subject (elementary)		Single-subject (secondary)	Other (e.g. SPED)	None
# of teachers[b]	20		21	4	1
Highest level of education	Bachelor's degree (BA, BS)		Master's degree (MA, MS, MEd)	Doctorate (PhD, EdD)	
# of teachers	21		18	2	
Years of teaching experience	1–5	6–10	11–15	16–20	>20
# of teachers	10	9	11	5	6

[a]One teacher's demographic information was unavailable.
[b]Does not add up to 41 because teachers could be placed in more than one category if they possessed more than one type of credential.

each potential influence. The survey items were revised through multiple iterations of feedback from the 10 individuals on the research team considering both alignment with the research literature and accessibility by teachers; however, the items were not piloted with additional teachers prior to this study. The final survey consisted of 60 close-ended items and 7 open-ended items. In addition to Likert-scale close-ended items, we asked the teachers to select the three influences that most impacted their argumentation instruction and the three influences that least impacted their argumentation instruction.

For the phone interview, we designed the protocol to support a conversation with the teacher in which the participant expressed his or her perspective without being biased by the perspective of the interviewer (Marshall & Rossman, 1999). We included one or two open-ended items targeting each of the seven potential influences. The phone interviews were audio recorded and then transcribed for analysis.

Data analyses

For the close-ended items on the survey, we conducted an exploratory factor analysis, because we were interested in exploring potential constructs and did not have predetermined expectations of the number or nature of the factors that would emerge (Henson & Roberts, 2006). To determine whether the data were suitable for factor analysis, we conducted two tests – Bartlett's Test of Sphericity and Kaiser–Meyer–Olin (KMO) measure of sampling adequacy. Bartlett's Test of Sphericity was significant ($p < .001$) suggesting that the variance and distribution of the data were appropriate for factor analysis. However, the KMO measure was low at 0.461 (it should be over 0.5), suggesting that the sample was small for factor analysis (Hogarty, Hines, Kromrey, Ferron, & Mumford, 2005). We decided to continue with the analysis despite the small sample size because of the exploratory nature of the study and because the additional qualitative data could be used to test, question and refine any emerging themes from the quantitative analysis. However, the sample size is a limitation and further research should be conducted with larger sample sizes to determine the generalisability of these patterns beyond this group of participants.

In running the analysis, we used principal component factor analysis using Varimax rotation to combine multiple items into constructs to increase the reliability of our measures and to create more manageable constructs for analysis. We chose to use a Varimax rotation, which is an orthogonal factor solution, because we were interested in identifying distinct constructs (i.e. not correlated) in our items and because of our small sample size. Orthogonal rotations keep the constructs distinct from each other, which can improve the quality of factor solutions for small sample sizes (Hogarty et al., 2005). Another potential limitation of this study is that if we had a larger sample size and used a different rotation, the analysis may have resulted in more significant factors including those that were correlated with each other.

We conducted one-factor analysis including all 60 belief items in the survey. We checked all factors with an eigenvalue greater than 1 for reliability using Cronbach's alpha. All factors with a reliability greater than 0.7 were examined in terms of the potential theoretical construct underlying the items. There were five factors with reliabilities greater than 0.7. The items for four of the factors appeared to represent a theoretical construct from the literature and were included in all subsequent analyses (see Table 3 for sample items).

Table 3. Factors with sample survey items ($N = 42$).

Factor	Cronbach's alpha	Sample items
Teacher self-efficacy[a] (8 items)	0.902	• I feel confident supporting students in doing argumentation as a means of exploring and understanding science content. • I feel confident facilitating students' construction of an argument in various student settings, such as individually and in small groups. • I feel confident modelling oral argumentation practices for my students.
Context, policy and assessment[a] (7 items)	0.898	• Argumentation is an important part of my state's science standards. • My district, department or schoolwide curriculum goals align with the teaching of scientific argumentation. • Argumentation is tested on my state's science test
Learning goals[a] (7 items)	0.876	• Engaging students in using scientific principles to explain evidence is an important part of science instruction. • It is important for students to talk directly to each other during argumentation discussions. • Engaging students in argumentation is an important part of learning science.
Student background and ability[b] (4 items)	0.787	• Diego's family is new to this country from Mexico and he lives in a local Spanish-speaking neighbourhood. His parents have repeatedly told you that they want him to succeed in school and learn as much as possible. He receives support to learn English during one period of school a day. • Abby has attended multiple schools in the past few years, as her family has had to move into different living situations. Abby says she participated a lot in science classes in her previous schools. She receives free breakfast and lunch at school every day. • Tammy has an IEP for challenges she experiences with reading. Tammy's mother says she likes science and watches TV shows about the environment at home, but is easily frustrated at school.

[a]Teachers' choices: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.
[b]Teachers' choices: 1 = not capable, 2 = somewhat capable, 3 = capable, 4 = very capable.

For the four theoretical factors, we created factors by summing the individual items and dividing by the total number of items for ease of interpretation. Dividing by the total number of items maintained the initial range of choices from 1 = strongly disagree (or not capable) to 4 = strongly agree (or very capable). The fifth factor consisted of eight negative items aligned with a variety of different concepts from the literature (e.g. learning goals, student ability, discussion). Since there was no underlying theoretical concept, rather teachers appeared to respond to them in similar ways because of the negative tone in the items, we did not explore this factor in our qualitative analysis.

We developed coding schemes to analyse both the open-ended items on the survey and the teachers' responses to the interview questions that aligned with these four factors. We developed the coding schemes from both our theoretical framework and an iterative analysis of the data (Miles & Huberman, 1994). For each coding scheme, we included codes that aligned with findings from other argumentation research about teachers' ideas (e.g. focus on fun, hands-on activities from Zembal-Saul, 2009), argumentation literature advocating for particular goals (e.g. importance of critique from Osborne, 2010) and other applicable science education research (e.g. students require special characteristics to achieve in science from Prime & Miranda, 2006). We also developed codes grounded in the teachers' own language from both their written and oral responses (Strauss, 1987).

Two independent raters coded all the open-ended items on the survey and responses from the interview. Inter-rater reliability was calculated by percent agreement. The percent agreement across the open-ended items for the survey was 85% and for the interviews, it was 85%. Disagreements were resolved through discussion by the pair of raters. If the two raters could not reach consensus, the issue was brought to the larger research team for discussion. After coding the open-ended items, we then looked for themes across the data sources by looking for patterns and testing the viability of those themes by examining confirming and disconfirming evidence (Erickson, 1986).

Results

We begin by presenting the results from the close-ended survey items to offer an overview of the different influences teachers indicated were important for their argumentation instruction. First, we present the results from two survey items that asked the teachers to select the three influences that had the most impact on their argumentation instruction and the three influences that had the least impact on their argumentation instruction. On the left-hand side of Figure 1, the two influences that teachers reported having the greatest impact on their argumentation instruction were related to their *learning goals* for their students in terms of both their science learning goals and broader academic goals. On the right-hand side of the graph, the four influences having the least impact were related to *context, policy and assessment* specifically state standards, high-stakes assessments, administrative practices and relationships with other teachers.

Table 4 includes the means and standard deviations for the four theoretical factors and the related theme from the open-ended survey items and interviews. They are ordered based on the means from the factor teachers most agreed with (learning goals) to the factor they least agreed with (school, district and state context) in terms of their impact on instruction. The order of these four factors aligns with the order of the corresponding influences in Figure 1 with items around *learning goals* being the ones they were most

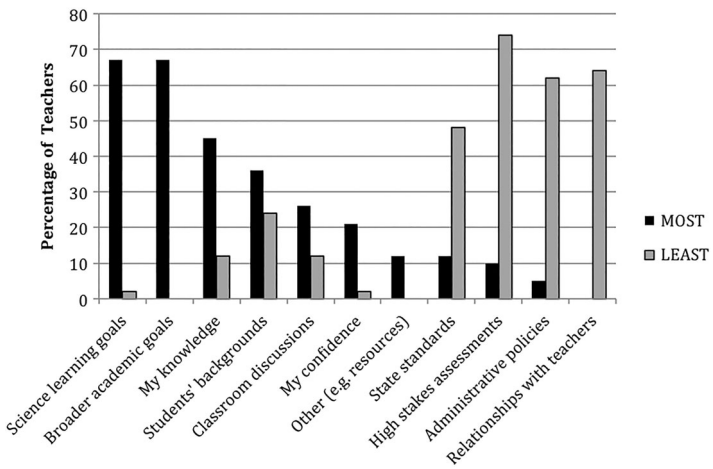

Figure 1. Influences on teachers' argumentation instruction ($N = 42$).

Table 4. Summary of factors influencing argumentation instruction.

Factor	Mean (SD)	Theme from open-ended items and interview
Learning goals[a]	3.64 (0.36)	Theme 1: All teachers indicated that argumentation was an important learning goal for their students; however, they discussed argumentation in different ways.
Student background and ability[b]	3.33 (0.51)	Theme 2: The majority of teachers saw all students as capable of engaging in argumentation, though they also discussed different characteristics of students that impacted their design of instruction.
Teacher self-efficacy[a]	3.20 (0.40)	Theme 3: The majority of teachers had some confidence in teaching argumentation, which was most frequently influenced by either their experience teaching argumentation or their knowledge of their students.
Context, policy and assessment[a]	2.44 (0.66)	Theme 4: The majority of teachers indicated that context, policy and assessment were less important in terms of their argumentation instruction. Some saw a lack of alignment as why it was not as important for their instruction.

[a]Teachers' choices: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.
[b]Teachers' choices: 1 = not capable, 2 = somewhat capable, 3 = capable, 4 = very capable.

likely to agree with while items related to *context*, *policy and assessment* they were least likely to agree with.

We next discuss the four themes that emerged in relation to each theoretical factor providing data from both the survey and interview to illustrate these patterns.

Theme 1: All teachers indicated that argumentation was an important learning goal for their students; however, they discussed argumentation in different ways.

On both the survey and during the interviews, all of the teachers indicated that argumentation was very important in terms of their learning goals for their students; however, the teachers appeared to have different understandings of what counts as argumentation in a science classroom. All 42 teachers on the survey received a score between 3 and 4 for the argumentation learning goals factor with a mean of 3.64. This suggests that, on average, the teachers either selected 'agree' or 'strongly agree' for the seven Likert-scale items describing the importance of argumentation. However, when asked to discuss their learning goals for science in relation to argumentation on both the survey and during the interview, teachers provided a wide range of responses in terms of their descriptions of argumentation (Table 5).

We broke Table 5 into three sections with the codes in the top section aligning most closely with the structural and dialogical definitions of argumentation in the curriculum (Evidence, Multiple views and Critique), the middle section including important related ideas (Literacy and Citizen) and the bottom three codes representing more general statements or learning goals (Hands on, Critical thinking and Other). Considering that all of the teachers had completed at least one curriculum unit with a focus on argumentation, we were surprised that more teachers' responses did not receive the top three codes in the section Argumentation in Science. As described in the Methods, the curriculum discussed these learning goals related to structural and dialogic argumentation, and included educative supports to help teachers with these elements. From their response to the Likert-scale items on the survey, all teachers viewed argumentation as important; however, only approximately one quarter of the teachers talked about argumentation in terms of the role of evidence, the consideration of multiple claims, or the importance of critiquing

Table 5. Teachers' description of their argumentation goals.

	Code	Description of code	Percentage survey ($N = 42$)	Percentage interview ($N = 25$)
Argumentation in science	Evidence	• Discusses students using or making sense of data or evidence.	12%	36%
	Multiple views	• Describes students considering multiple claims or explanations.	7%	4%
	Critique	• Discusses students critiquing or evaluating claims, evidence or explanations	10%	24%
Broader argumentation goals	Literacy	• Describes student literacy goals, such as reading, writing or talking.	50%	72%
	Citizen	• Discusses how argumentation can help students in their everyday lives to be more informed citizens.	14%	28%
Additional goals	Hands on	• Discusses the importance of 'hands-on science' or 'doing science'.	0%	4%
	Critical thinking	• Describes critical thinking or to engage in higher order thinking.	43%	48%
	Other goals	• Describes another reason or a general/vague response	17%	8%

different perspectives. Two examples illustrate teachers whose argumentation goals aligned with our definitions. For example, we coded Teacher FT39C's survey response as both Citizen and Evidence, because she wrote, 'The goal of all education is to produce effective members of society. The ability to base decisions upon scientific evidence and to evaluate differencing or conflicting evidence is a lifelong skill that benefits all society'. Another teacher's, Teacher FT30A, response during the phone interview was coded as both Critique and Evidence for his discussion of the benefits of argumentation for students during the curriculum including:

> backing up their claims but also in terms of evaluating other people's claims throughout the field trial. But I came up with the evidence and actually looking through the evidence seeing what they agree with what they don't, where it comes from, and actually then forming their own opinion about which claim they believe is valid.

In these two examples, we see the teachers talking about the field trial of the curriculum and discussing the benefits for students in terms of 'evaluating other people's claims' and the consideration of 'evidence'.

In contrast, many teachers focused solely on other broader goals such as connecting to literacy or critical thinking. For example, Teacher FT11A focused on literacy when she wrote,

> Argumentation meets many literacy goals and helps students to learn to use academic language to more formally present their findings. There is of course a great crossover from scientific argumentation to English standards and the skills could be further applied to Social Studies as well.

This interdisciplinary connection is important; however, the response would have been stronger if it also considered characteristics of argumentation in science, such as the use of evidence. Another common goal that teachers expressed in both the survey and the interview was that argumentation was related to critical thinking. It is not that we disagree with this association; however, in many cases, it was unclear what the teacher meant by critical

thinking. For example, Teacher FT25A wrote, 'argumentation crosses all content areas and helps develop critical thinking skills'. During the phone interview, Teacher FT33B provided a similar general discussion about critical thinking:

> The benefit that I believe my students gain participating with this, with this field trial, especially argumentation, was that it gave them an opportunity to critically think and to investigate a little bit more and not just look at things above water.

Consequently, although the field test teachers reported that argumentation was important as a learning goal, their discussion of why argumentation was important raised questions about what the teachers considered to count as argumentation in classroom instruction. We hoped field testing the curriculum would have supported them in developing a richer understanding of scientific argumentation that included the role of evidence, multiple views and critique. As we will discuss in the Discussion, perhaps the design of the educative supports and the limited amount of time were not sufficient to support the majority of teachers in developing this understanding.

Theme 2: The majority of teachers saw all students as capable of engaging in argumentation, though they also discussed different characteristics of students that impacted their design of instruction.

On the survey, the majority of teachers indicated that they saw students with different backgrounds as capable of engaging in argumentation. The mean for this factor on the survey was 3.33, which suggested that on average teachers selected that the students in the four Likert-scale items were either 'Very Capable' or 'Capable' of engaging in argumentation.

For both the survey and interview, we asked the teachers in what ways the students' backgrounds and abilities impacted their argumentation instruction. In discussing their instruction, teachers brought up a wide range of student qualities that impacted the instruction in their classroom (Table 6). On the survey, the most common code was Other/Vague followed by Literacy, while on the interview, the most common code was Literacy followed by None Required, which captured responses that said that all students could engage in argumentation.

For teachers whose responses were coded as Other/Vague, they often either wrote something general like Teacher FT28C who wrote 'social awareness', or instead of focusing on the backgrounds' of students, they focused on the supports students need from their teacher or classroom. For example, Teacher FT33B wrote, 'The knowledge that students need to possess to be successful in doing science argumentation is having teacher support, being free to express his or her ideas without being criticised, and opportunity to research and investigate the concept being taught'. This second quote is similar to teachers' responses coded as None Required. For example, Teacher FT41A wrote,

> I don't think students need to possess particular abilities. I do feel like this is a skill that needs to be appropriately scaffolded in order for students to be successful. I have seen students in 2nd grade effectively engage in argumentation as it was well scaffolded.

This suggests that the teachers saw the role of the teacher or curriculum as being more important than students' backgrounds or abilities.

Table 6. Teachers' description of the importance of student background and ability.

Code	Description	Percentage survey ($N = 42$)	Percentage interview ($N = 25$)
None Required	Describes that students do not need particular background experiences or abilities	7%	44%
Literacy	Describes literacy, such as students' abilities with reading, writing or communication skills	31%	56%
Critical Thinking	Describes critical thinking or higher order thinking skills	17%	16%
Science Content	Describes science content knowledge, subject matter knowledge or facts	14%	32%
Interest	Discusses student interest, engagement or motivation	12%	40%
Home Experience	Discusses home or parental support	0%	28%
ELL	Talks about ELLs or English as a second language	0%	24%
Special Needs	Talks about students having special needs, learning disabilities or students with IEPs	0%	16%
Other/Vague	Describes another reason or a general/vague response	52%	4%

In terms of literacy, teachers described proficiency in skills such as reading, writing and talking as important for students' successful engagement in argumentation. For example, on the survey Teacher FT12A wrote, 'Being able to write a paragraph and use logic to construct it appropriately with an intro a body to support and a transition to the next paragraph'. And Teacher FT22A wrote, 'They also need to learn expression so they can communicate with peers and adults'. During the interview, teachers who talked about the importance of literacy were also more likely to elaborate on how they took this into consideration in their enactment of argumentation lessons. For example, Teacher FT06A explained, 'I know that some can't write at the level they're expected, so I know that basically that I'm going to have to make changes according to their abilities'. Overall, the majority of teachers felt that all students were capable of engaging in argumentation; however, teachers reported that the students' abilities did impact their classroom instruction in terms of the supports they provided their learners.

Theme 3: The majority of teachers had some confidence in teaching argumentation, which was most frequently influenced by either their experience teaching argumentation or their knowledge of their students.

For the Likert-scale survey items, on average, teachers received a score of 3.2 for self-efficacy, suggesting that they were closer to agree (3.0) than strongly agree (4.0) in terms of their confidence in teaching argumentation. Overall, teachers responded lower to these items compared to the Likert items about student learning goals or students' capabilities, but were still fairly positive.

The open-ended items on the survey and in the interview focused on what influenced their confidence. The teachers discussed a variety of different factors that impacted their confidence (Table 7). The two factors most frequently discussed were their prior experiences teaching argumentation and their knowledge of their students, both of which explicitly connect to their personal classroom experiences.

For example, in terms of teaching experience, Teacher FT30A talked about how his 'teaching experience has given me the confidence to teach argumentation because I

Table 7. Teachers' description of their self-efficacy for argumentation.

Code	Description	Percentage survey ($N = 42$)	Percentage interview ($N = 25$)
Teaching Experience	Discusses teaching argumentation	26%	52%
Knowledge of Students	Describes knowledge of students in terms of engagement or abilities	24%	40%
Physical Resources	Describes using a curriculum, the field test of the curriculum, or other resources	12%	24%
Knowledge of Argument	Describes their knowledge of argumentation or talks about knowing strategies to support students	10%	20%
Learning Experience	Describes experiences in professional development, college/university experiences, or experiences at a conference	14%	12%
Knowledge of Content	Describes their knowledge of the science content or subject matter knowledge	12%	0%
Human Resources	Discusses other people (e.g. fellow teacher)	2%	0%
Other/Vague	Describes another reason or a general/vague response	26%	12%

recognise its importance'. Similarly, during the interview, Teacher FT38B talked about teaching argumentation making her more confident because:

> I think with anything, the more you do it the more confident you become. So yes, I'd done it in certain areas of the Earth science curriculum but to be honest I had never done it in the rocks and minerals unit. So that was a new approach and I did like it.

In discussing teaching argumentation, she also explicitly linked that teaching to the field test curriculum in her classroom. For knowledge of students, teachers also linked their confidence to their classroom experience. Specifically, a number of teachers talked about how aspects of argumentation that were either successful or difficult for their students increased their confidence. For example, teacher FT28A on the survey wrote, 'When my students are actually engaged and participate in the debates, my confidence goes up because they are able to show me that they are learning'. Although this teacher focused on a strength, other teachers focused on student challenges. For example, in her interview, Teacher FT10A explained:

> trick is to get them [the students] to explain why that evidence supports their data or their claim. And that is the big leap … That is the tricky part. And that is where I think I've learned a lot on how to do that. Even from the first unit, I did the Rocks in the Fall and then I did Currents in the Spring

In this example, the teacher explains how learning about her students' challenges, specifically in the context of enacting the curriculum, increased her confidence. This suggests the importance of having teachers try argumentation out in their classroom instruction, as these experiences can improve their self-perceptions of being capable of integrating and supporting this practice in their instruction.

Theme 4: The majority of teachers indicated that context, policy and assessment were less important in terms of their argumentation instruction. Some saw a lack of alignment as why it was not as important for their instruction.

In contrast to learning goals, teachers reported that context, policy and assessments had the least impact on their argumentation instruction (see Figure 1). For the policy and

assessment factor on the survey, teachers' scores ranged between one and four with an overall mean of 2.44, which means that, on average, teachers were between 'disagree' and 'agree' for the seven Likert-scale items in terms of their impact on their argumentation instruction. The seven items targeted a variety of ideas in this area of context and policy, such as school and district administration, state standards, state science tests and support from other teachers.

On both the survey and interview, there were open-ended items that asked teachers about the relationship of argumentation to state standards and assessments. In contrast to their responses to the close-ended items, when specifically asked about the importance of assessments and standards in an open-ended format, the majority of teachers did discuss a relationship with their argumentation instruction (Table 8). Consequently, the teachers appeared to believe that this factor played a role; however, it just did not have as large of an impact on their argumentation instruction as other factors, such as their learning goals.

For the teachers who discussed that assessments or standards did not impact their instruction, the majority explained that argumentation was not a focus for their state. For example, on their surveys, Teacher FT25A wrote, 'no … i feel the state test is to[o] fact driven' and Teacher FT11A explained, 'The test is not set up for critical thinking, but rather for concept/fact based understanding. Therefore, understanding claim/convincing evidence/reasoning will not help a student answer a question about commonalities among the noble gases'. Teacher FT13A offered a similar explanation in her interview stating that:

> So, the state standards don't really, you know, impact my teaching as much as what I know to be true about you know, being a scientist, and working with my inquiry team and my science staff about the process of science.

This suggests that these teachers saw the standards and tests as focused on the memorisation of facts, which they saw as different from the goals of argumentation. Despite these differences, the teachers still viewed argumentation as important for their classroom instruction.

In contrast, the teachers who did see a relationship were more likely to talk about alignment or that the standards/assessments were moving towards greater alignment. At the time of this study in the USA, a number of states had adopted or were in the process of adopting new standards for English-Language Arts (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010) and for science (NGSS Lead States, 2013), which included a greater focus on argumentation. This transition moment may have impacted the way the teachers responded to these

Table 8. Teachers' description of the importance of assessments and standards.

Code	Description	Percentage survey ($N = 42$)	Percentage interview ($n = 25$)[a]
Yes Impact	States that assessments or standards do impact their argumentation instruction	69%	68%
No Impact	Says that assessments or standards have little or no impact on their argumentation instruction	26%	32%
Vague	Provides a vague response or does not answer the question	5%	12%

[a]The interview does not add up to 100%, because three teachers contradicted themselves saying both yes and no.

questions. The English standards, the Common Core, were adopted first and a number of teachers discussed this alignment. For example, Teacher FT06A wrote on her survey, 'these skills are highly tested in 6th grade English-Language Arts' and Teacher FT02A discussed in her interview ' … looking at the English writing skills in sixth grade, I did look at that, and I kind of follow that but argumentation really helped with addressing some of those things'. Other teachers focused on science. For example, FT38B discussed that her state, 'requires three written questions that ask students to give and support evidence for their claim'. Similarly, Teacher FT36A explained in his interview that his state, ' … is heading towards higher level thinking questions … and I think argumentation helps them start thinking that way'. Consequently, the question remains whether teachers viewed context, policy and assessment as having a smaller impact on their argumentation instruction because of this particular transitory moment in the US education system or if these factors never have as great an impact on their instruction as other factors, such as their learning goals for students.

Discussion

The role of context, policy and assessment

Overall, teachers viewed their learning goals as having important impacts on their integration of argumentation instruction into their classrooms while context and policy issues had limited effects. This is in contrast to previous research that suggests that teachers may choose to not integrate reforms into their classroom instruction when they believe that they do not prepare students for assessments (Li, Klahr, & Siler, 2006). Teachers can feel that dialogic argumentation discussions are too time consuming and they need to cover content more quickly to prepare for standards and high-stakes testing (Alozie et al., 2010; Sampson & Blanchard, 2012). Furthermore, recent federal and state policies in the USA have resulted in many schools focusing on language arts and mathematics with limited time for science (Marx & Harris, 2006). We had anticipated that teachers would discuss assessments or policy issues as important for their argumentation instruction. As we will discuss under Limitations, this sample of teachers may have different views from other teachers, because of their interest in enacting this reform-oriented curriculum. However, this lack of impact may also be because teachers perceived a misalignment between argumentation and current science education policy. A number of teachers discussed a lack of focus on argumentation in assessments or by their administration, yet they perceived argumentation as an important learning goal for their classroom instruction.

As standards and reform efforts roll out in the USA and in other countries with a focus on argumentation, this issue of alignment remains an important question. A lack of coherence in the education system around new reform efforts can undermine substantial instructional change (Allen & Penuel, 2015). It is possible that an increased focus of standards, assessments and policies on argumentation could result in a greater integration of argumentation in classroom instruction. Yet, the challenge remains that current standardised assessments often do not align with the ambitious teaching goals advocated in recent reform efforts such as the increasing focus on science practices (Pellegrino, Wilson, Koenig, & Beatty, 2014). Furthermore, teachers' beliefs about alignment of standards

and assessments can differ greatly from policy-makers, curriculum developers and professional developers (Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2009). Consequently, this suggests that teachers may need a variety of supports and resources to help them understand the alignment of argumentation with current policies, standards and assessments. Furthermore, it is important for there to be coherence across the different educational stakeholders in terms of this key science practice.

Importance of classroom experience in promoting self-efficacy

In terms of confidence, the teachers had some confidence in teaching argumentation. In this study, the two elements that were reported as most impacting teachers' confidence were their prior teaching experience and their knowledge of their students, both of which link to their classroom experience. In addition, some teachers explicitly discussed these experiences in relation to physical resources, such as the field test curriculum. This suggests the importance of different resources, such as curricular and technology tools (Cavagnetto, 2010), for supporting the integration of argumentation in the classroom. The use of these types of tools could encourage teachers to try out argumentation in their classroom which they may not feel comfortable with on their own. These resources could also show teachers various approaches for integrating argumentation into instruction, which ideally would support teachers in developing rich understandings of both the structural and dialogic elements of this practice. These results align with other work that suggests that opportunities to enact new curriculum, activities or tools with students are important for supporting teacher learning (Kazemi & Hubbard, 2008). The act of experimenting with new reforms in their classrooms, particularly when teachers are engaged in critical reflection on their instructional practice, can support teacher learning of new reforms like argumentation (Knight-Bardsley & McNeill, 2016). Specifically, in our study, we found that teachers reported these types of classroom experiences influenced their own confidence for teaching argumentation.

Supporting all students in argumentation

Even with teachers viewing argumentation as important and increasing their self-confidence, there are still challenges around the successful integration of argumentation into classroom instruction. Although the teachers in this study viewed argumentation as important for all students, there was substantial variation in how teachers discussed their argumentation learning goals. The majority of teachers did not focus on the characteristics of evidence, multiple views and critique, which were important elements of the structural and dialogic definitions of the science practice within the enacted curriculum. Supporting teachers in argumentation can take considerable time, potentially longer than one year, and require teacher reflection and reframing of their current instruction (Simon et al., 2006). Consequently, the type and length of support in the curriculum materials may not have been sufficient to support teachers in developing a deep understanding of argumentation.

Furthermore, these discrepancies raise concerns about how argumentation is and will be integrated into classroom instruction. The *Framework for k-12 science education* (NRC, 2012) includes a rationale for why the authors do not use the term inquiry '… because the

term "inquiry", extensively referred to in previous standard documents, has been interpreted over time in many different ways throughout the science education community' (p. 30). The results from this study offer the same caution around science practices, such as argumentation. Berland and Hammer (2012) raise similar concerns in their discussion of 'pseudoargumentation' in which students pay more attention to following directions and satisfying the teacher than developing social and epistemological understandings of scientific argumentation. We argue that avoidance of 'pseudoargumentation' may also be an important consideration for teachers (McNeill, González-Howard, Katsh-Singer, & Loper, 2016) as they try to integrate these new reform efforts into their existing classroom instruction.

Limitations and future work

From their self-report in the survey and interview, we cannot determine the quality of the teachers' argumentation instruction. Future research comparing teachers' beliefs to their classroom instruction could provide greater insight into some of these findings. For example, the teachers discussed all students as being capable of argumentation; however, some teachers described needing to provide different scaffolds or supports depending on students' backgrounds and abilities. Other research suggests that teachers can see student abilities as barriers for argumentation instruction (Sampson & Blanchard, 2012; Zohar et al., 2001) and that teachers can oversimplify this complex task resulting in decreased opportunities and learning gains for students (McNeill, 2009). Consequently, this raises the question of whether the different scaffolds mentioned by teachers still provided all students with opportunities to engage in rich learning experiences, or if the opportunities were different for students labelled as low-achievers. Furthermore, our sample size is small for factor analysis and the participants included voluntary teachers interested in enacting reform-oriented curriculum. A larger and more representative sample may result in different themes. For example, a more general sample of teachers may not value argumentation as an important learning goal or may report that context, policy and assessment have a larger impact on their instruction compared to these volunteer teachers. Consequently, further research should be conducted to determine whether or not these patterns are consistent beyond this group of participants.

Nevertheless, the findings suggest that future educative curriculum and teacher education experiences may need to focus less on convincing teachers that argumentation is important and more on supporting teachers in developing a stronger understanding of what counts as argumentation. Teachers believed that argumentation was important and this was the main factor that impacted the integration of argumentation into their instruction. However, teachers may need to develop a stronger understanding that students' successful engagement in argumentation is different from general critical thinking or hands-on science, but includes specific epistemic commitments in terms of how claims are constructed, debated and critiqued in science. There is a danger that teachers will relabel their existing instruction using terms from new reform efforts (Cohen, 1990), such as argumentation, rather than change their instruction to develop a classroom culture that prioritises argumentation in which students collaboratively construct and critique claims about the natural world.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Science Foundation under the *Constructing and Critiquing Arguments in Middle School Science Classrooms: Supporting Teachers with Multimedia Educative Curriculum Materials* grant [DRL-1119584].

References

Allen, C. D., & Penuel, W. R. (2015). Studying teachers' sensemaking to investigate teachers' responses to professional development focused on new standards. *Journal of Teacher Education*, *66*(2), 136–149.

Alozie, N. M., Moje, E. B., & Krajcik, J. S. (2010). An analysis of the supports and constraints for scientific discussion in high school project-based science. *Science Education*, *94*(3), 395–427.

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching*, *49*, 68–94.

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education*, *93*, 26–55.

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education*, *95*, 191–216.

Beyer, C., Delgado, C., Davis, E., & Krajcik, J. (2009). Investigating teacher learning supports in high school biology curricular programs to inform the design of educative curriculum materials. *Journal of Research in Science Teaching*, *46*(9), 977–998.

Bryan, L. A. (2012). Research on science teacher beliefs. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. 1, pp. 477–495). Dordrecht: Springer.

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in k-12 science contexts. *Review of Educational Research*, *80*, 336–371.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18*, 947–967.

Cohen, D. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis*, *12*(3), 311–329.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches*. Thousand Oaks, CA: Sage.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, *34*(3), 3–14.

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

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (pp. 119–161). New York: Macmillan.

Evagorou, M., Jimenez-Aleixandre, M. P., & Osborne, J. (2012). 'Should we kill the grey squirrels?' A study exploring students' justifications and decision-making. *International Journal of Science Education*, *34*(3), 401–428.

Ford, M. J. (2008). Disciplinary authority and accountability in scientific practice and learning. *Science Education*, *92*, 404–423.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). New York: Teachers College Press.

Henson, R. K., & Roberts, J. K. (2006). Use of exploratory factor analysis in published research: Common errors and some comment on improved practice. *Educational and Psychological Measurement*, *66*(3), 393–416.

Hogarty, K. Y., Hines, C. V., Kromrey, J. D., Ferron, J. M., & Mumford, K. R. (2005). The quality of factor solutions in exploratory factor analysis: The influence of sample size, communality and overdetermination. *Educational and Psychological Measurement*, *65*(2), 202–226.

Jimenez-Aleixandre, M. P., & Erduran, S. (2008). Argumentation in science education: An overview. In S. Erduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 3–28). Dordrecht: Springer.

Kazemi, E., & Hubbard, A. (2008). New directions for the design and study of professional development: Attending to the coevolution of teachers' participation across contexts. *Journal of Teacher Education*, *59*(5), 428–441.

Knight-Bardsley, A. M., & McNeill, K. L. (2016). Teachers' pedagogical design capacity for scientific argumentation. *Science Education*, *100*, 645–672.

Kuhn, D. (2010). Teaching and learning science as argument. *Science Education*, *94*(5), 810–824.

Li, J., Klahr, D., & Siler, S. (2006). What lies beneath the science achievement gap: The challenges aligning science instruction with standards and tests. *Science Educator*, *15*(1), 1–12.

Marshall, C., & Rossman, G. B. (1999). *Designing qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.

Marx, R. W., & Harris, C. J. (2006). No child left behind and science education: Opportunities, challenges and risks. *The Elementary School Journal*, *106*(5), 467–478.

McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education*, *93*(2), 233–268.

McNeill, K. L., González-Howard, M., Katsh-Singer, R., & Loper, S. (2016). Pedagogical content knowledge of argumentation: Using classroom contexts to assess high-quality PCK rather than pseudoargumentation. *Journal of Research in Science Teaching*, *53*(2), 261–290.

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

McNeill, K. L., Pimentel, D. S., & Strauss, E. G. (2013). The impact of high school science teachers' beliefs, curricular enactments, and experience on student learning during an inquiry-based urban ecology curriculum. *International Journal of Science Education*, *35*(15), 2608–2644.

Miles, M., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

National Governors Association Center for Best Practices and Council of Chief State School Officers. (2010). *Common core state standards for English language arts and literacy in history/social studies, science, and technical subjects*. Washington, DC: Author.

National Research Council (NRC). (2012). *A framework for k-12 science education: Practices, cross-cutting concepts and core ideas*. Washington, DC: National Academies Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, *19* (4), 317–328.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, *21*(5), 553–576.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states* (appendix F). Washington, DC: National Academies Press.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science*, *328*, 463–466.

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.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307–332.

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science*, *328*, 459–463.

Pellegrino, J. W., Wilson, M., Koenig, J. A., & Beatty, A. S. (2014). *Developing assessments for the Next Generation Science Standards*. Washington, DC: National Academies Press.

Penuel, W., Fishman, B. J., Gallagher, L. P., Korbak, C., & Lopez-Prado, B. (2009). Is alignment enough? Investigating the effects of state policies and professional development on science curriculum implementation. *Science Education*, *93*(4), 656–677.

Prime, G. M., & Miranda, R. J. (2006). Urban public high school teachers' beliefs about science learner characteristics. *Urban Education*, *41*, 506–532.

Raudenbush, S. W., Rowan, B., & Cheong, Y. F. (1993). Higher order instructional goals in secondary schools: Class, teacher, and school influences. *American Educational Research Journal*, *30*(3), 523–553.

Reiser, B. J. (2013, September). *What professional development strategies are needed for successful implementation of the Next Generation Science Standards?* Paper presented at the Invitational Research Symposium on Science Assessment, Washington, DC.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. *Handbook of Research on Teacher Education*, *2*, 102–119.

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.

Sampson, V., & Clark, D. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education*, *92*, 447–472.

Science Teacher Education Advanced Methods (S-TEAM). (2010). *Report on argumentation and teacher education in Europe*. Trondheim: S-TEAM/NTNU.

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.

Spillane, J. P. (2004). *Standards deviation: How local schools misunderstand policy*. Cambridge, MA: Harvard University Press.

Strauss, A. L. (1987). *Qualitative analysis for social scientists*. Cambridge: Cambridge University Press.

Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching*, *47*(8), 952–977.

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

Zohar, A. (2008). Science teacher education and professional development in argumentation. In S. Erduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 245–268), Dordrecht: Springer.

Zohar, A., Degani, A., & Vaaknin, E. (2001). Teachers' beliefs about low-achieving students and higher order thinking. *Teaching and Teacher Education*, *17*, 469–485.