The Science Classroom as a Site of Epistemic Talk: a Case Study of a Teacher's Attempts to Teach Science Based on Argument

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Abstract
Current science education research and policy highlight the need to conceptualize scientific disciplines not only based on a view of ‘science-as-knowledge’ but also on a perspective of ‘science-as-practice’, placing an emphasis on practices such as explanation, argumentation, modeling and communication. However, classroom discourse is not structured in a way that would normally provide to students the opportunity to engage in such ‘dialogic knowledge-building processes’ (Duschl, 2008a) or epistemic discourse. This study argues that such a change in classroom discourse can be achieved through a focus on argumentation as an instructional approach, which aims to engage students in the epistemic practices of science. This study focuses on a qualitative case study of an experienced teacher’s attempts to use argumentation over a school year as a way to identify elements of epistemic discourse that science teachers could be making part of their everyday science teaching. The analysis of classroom talk focused on a) the teacher’s discursive actions or epistemic operations, and b) the ways in which these discursive actions presented or engaged students in the construction, justification and evaluation of knowledge claims. The analysis revealed that the use of justificatory talk was consistent across the six lessons observed but the same consistency was not identified in attempts to engage students in evaluative practices. This discrepancy would suggest that evaluative practices were not as embedded in the teacher’s classroom talk as the justification or construction of knowledge claims. Implications discussed include the need to reconsider pre-service and in-service teacher training and professional development so that science teachers do not only develop their skills of teaching science based on argument, but also of talking science based on argument.

Keywords: Epistemic practices; argumentation; classroom talk; secondary science; case study

The Science Classroom as a Site of Epistemic Talk: a Case Study of a Teacher's Attempts to Teach Science Based on Argument

Over the past two decades, policy documents in the United States and Europe have argued increasingly for a science education that includes both the epistemic and conceptual aspects of science (AAAS, 1989; EACEA, 2011; NRC, 1996, 2007; 2012; Millar & Osborne, 1998). In fact, there is currently a steady move away from science teaching which frames scientific disciplines based on a view of 'science-as-knowledge' towards a perspective of 'science-as-practice' (Knorr-Cetina, 1999; Pickering, 1992). For instance, *Taking Science to School* (NRC, 2007) and the most recent standards framework produced by the National Research Council (NRC, 2012) both place particular emphasis on scientific practices that cut across scientific disciplines, such as argumentation and modeling. As stated in the new framework, "science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge" (NRC, 2012, p. 26).

Such conceptualizations of science education are congruent with Duschl's (2008a) recommendations for a focus on engaging students in the "dialogic knowledge-building processes that are at the core of science" (p. 269) such as dialogic argumentation. Yet, as research suggests (e.g. Driver, Newton & Osborne, 2000; Jiménez-Aleixandre, Bugallo & Duschl, 2000; Kovalainen & Kumpulainen, 2005; Lemke, 1990; Mortimer & Scott, 2003; Myhill, 2006; Pimentel & McNeill, 2013) classroom discourse is not structured in a way that would normally provide to students the opportunity to engage in dialogic argumentation despite the emphasis placed on the value of dialogic teaching in recent times (Alexander, 2008; Lyle, 2008). Monologic forms of talk initiated by teachers based on the Initiation-Response-Evaluation (IRE) pattern (Cazden, 1988; Sinclair & Coulthard, 1975) are still dominant in science classrooms and frame instruction across a range of age groups.

Bleicher, Tobin and McRobbie (2003) examined a secondary chemistry teacher's classroom talk and found that this was characterized by an emphasis on learning science-related terminology instead of understanding and making links between the concepts discussed; in essence, the way the teacher guided discussion and posed questions constrained students from 'talking science' and thinking scientifically. Kovalainen and Kumpulainen (2005) found that teacher-initiated talk during a science investigation at the primary school level was also characterized mostly by the provision of information or exchanging views amongst teacher and students instead of evidence-based discussion and reasoning. Similar results are reported by Harris, Phillips and Penuel (2012), who found that three teachers' instructional strategies for eliciting students' ideas were consistent and more prevalent in the teachers' discourse, as opposed to strategies for developing students' thinking and reasoning. Pimentel and McNeill (2013) found that whole-class discussions by five secondary science teachers mainly focused on factual information with the teachers taking on the role of the knowledge provider in discussions. This resulted in students' contributions during discussions to be short and with limited instances where students provided reasoning in their responses. Jiménez-Aleixandre et al. (2000) analyzed Grade 9 whole class discussions about a socio-scientific issue in a unit of six lessons. They found that the first four lessons were dominated by the IRE pattern with the teacher controlling classroom talk. In contrast, the two final lessons of the unit required students to share ideas, always state reasons for their views and identify reasons for and against claims. As a result, the nature of classroom talk shifted and students were able to engage in (a) 'true dialogue' during which the teacher posed questions with no definite answers, and (b) 'cross-discussion' (Cazden, 1988; Lemke, 1990), which took place amongst students without direct interference or influence by the teacher. Jimenez-Aleixandre et al. discuss how the traditional patterns of interaction in the first four lessons engaged students in ‘doing the lesson’ following the norms of school science, whereas the emphasis on argument in the final 2 lessons provided a more authentic context for the students and with the opportunity of ‘doing science’.

Sandoval and Morrison (2003) maintain that activities, which require students to construct their own explanations and to provide evidence to support these explanations, but which do not attend explicitly to the discourse that takes place during these activities do not necessarily help students develop an informed understanding of what ‘doing science’ would involve. Sandoval and Morrison (2003) argue that students, in addition to engaging in authentic inquiry activities, need to be provided with opportunities to engage in epistemic discourse. That is, students should engage in discussions and argument about the reasons and criteria they use for choosing one explanation over another, as well as to discuss the role of evidence for their explanations. There is a strong link between epistemic discourse and the practice of argumentation. As an approach to science teaching, argumentation places great emphasis on the use of evidence for supporting or rejecting a theory or idea (Driver et al., 2000; Jiménez-Aleixandre, 2008). The practice of argumentation may promote engagement with the processes of knowledge construction and evaluation (Ford, 2008a; Ford & Wango, 2012), which requires the use of criteria for the selection and evaluation of evidence, the creation of counter-arguments and the provision of justifications. Thus, argument-based learning is considered as potentially promoting and using epistemic discourse in the science classroom and providing students opportunities to view science as an ‘epistemic practice’ (Duschl 2008a, 2008b; Kelly, 2008), that is, a knowledge generative practice and not only as a collection of factual knowledge.

The emphasis placed on dialogic interaction, argumentation and the discourse surrounding epistemic criteria and evidence that is suggested by Duschl (2008a) and Sandoval and Morrison (2003), raises questions about the ways in which classroom talk can be framed to promote epistemic and argumentative discourse, and of the role of the teacher in this process. How can epistemic discourse be identified, promoted and established in the science classroom when teachers use argumentation as an instructional approach? Also, to what extent are science teachers able to promote epistemic discourse during science instruction? This study aims to provide answers to these questions by focusing on the nature of classroom talk used by teachers and analysing this talk through the framework of epistemic practices.

Theoretical Framework

Epistemic Practices and Argumentation

Seeing science as an ensemble of distinct practices is a perspective that has emerged from social studies of science (Knorr-Cetina, 1981; Kelly, McDonald & Wickman, 2012; Lynch, 1993). This ‘social epistemology’ of science (Kelly, 2008; Longino, 2002) views the nature of scientific practices as socially and culturally embedded within a community of scientists that practise science, share results, opinions and communicate collectively, and not only as individuals. These knowledge-generative or epistemic practices concur with the epistemological criteria or ‘regulators of critical discourse’ (Longino 1990; 2002) set by a community of scientists. More specifically, epistemic practices are defined by Kelly (2008) as “the specific ways members of a community propose, justify, evaluate and legitimize knowledge claims within a disciplinary framework” (p. 99).

Scientists engage in rational activities, defined by Longino (2002) as those focusing on justification based on evidence and logical reasoning. Scientists also engage in series of decision-making processes and select ways of acting and reasoning, which are social in nature based on a range of forms of social interaction and non-evidential considerations (Dunbar, 1995; Gooding, 1992; Knorr-Cetina, 1981). Hence, scientists' thinking and acting is both based on rational criteria and bounded by social interaction in such a way that "knowledge is produced by an amalgam of heterogeneous acts and not by a particular kind of truth-producing activity guided by logic" (Longino, 2002, p. 7). The selection of one set of data over another to count as evidence for a knowledge claim, the preference to a particular methodological approach and research design, or the ways in which empirical results will be presented to the scientists' disciplinary community to convince them for their significance, are only a few of the choices scientists are required to make during the *construction* of knowledge claims. At each of these steps, scientists need to make evaluative judgments and critique each other's work engaging in the *evaluation* of knowledge claims, and at the same time, use evidential support to *justify* their decisions and *communicate* their views and results in a persuasive manner, regardless of the scientific discipline of which they are part.

The ways in which a knowledge claim is proposed and justified to a particular disciplinary community to convince other scientists of its importance, validity and reliability, is vital for the acceptance of this knowledge claim. Having the appropriate empirical evidence and structured reasoned arguments for a claim, does not necessarily mean it will be immediately and consensually accepted. Latour and Woolgar (1979), based on their ethnographic study of scientific laboratories, provide an account of the transformative phases that an assertion expressed within the boundaries of a laboratory goes through until it becomes a taken-for-granted factual statement (Table 1). A Type 1 statement is of a conjectural nature and is the initial form of what later could be considered factual knowledge. A fact, or a Type 5 statement, is often so obvious to the members of a discipline or a group of scientists that it may not even be stated explicitly. A Type 5 statement needs to be expressed explicitly only when individuals outside the scientists' disciplinary area require further information.

[Table 1]

According to Latour and Woolgar (1979) science textbooks usually include Type 4 and 5 statements, which present the facts of science usually without any consideration of the previous phases. The scientific reasoning and negotiation of knowledge claims that guides the creation of factual statements are thus ignored or omitted from the outcomes and artefacts produced (Suchman, 1990), which results in a partial representation of the practices of science. However, if any individual is to be in a position to participate meaningfully and critically within a particular disciplinary community, they also need to be aware of the existence of Types 1, 2 and 3 statements, which require qualification based on evidence and reasoning. Being aware that knowledge goes through a number of alterations and transformations from the instance that a set of experimental data is created in a scientific laboratory to the moment that it will reach individuals outside the scientific community (Knorr-Cetina, 1981; Giere, 1991; Gooding, 1992), means that individuals have a better understanding of the pathways this knowledge has followed from its generation to the moment it was presented to the public. In this way, individuals are in a better position to engage in the 'critical discourse' (Longino, 1990; 2002) necessary for becoming active citizens of their societies and critical consumers of scientific knowledge (Osborne & Dillon, 2008; NRC, 2012). As Longino (1990, p. 61) states, it is important for citizens to be in a position to ask epistemic questions like "*What is the evidence? Why is this* *data evidence for this hypothesis? Why should I believe this?*" if they are to make sense of, and be in a position to use, scientific knowledge. But, where and how do individuals acquire such awareness and ability to enquire the epistemic status of scientific knowledge statements or claims? We argue that these critical dispositions need to be addressed explicitly in the science classroom.

Ford (2008a, 2008b) argues that science education should offer students the opportunity to develop 'a grasp of practice' of the scientific endeavor, which is characterized by the processes of construction and critique. Ford's argument is based on a commitment to move away from the dominance of declarative knowledge – telling students what to learn or what science is. Instead, he argues that the construction of knowledge should be viewed as a dialectic between construction and critique, where students participate in activities that can help them develop an understanding of how science works and how scientific knowledge is generated through employing reasoning resources similar to those that scientists employ in their practices. This view of science education is consistent with pedagogical perspectives of instruction such as that advocated by Jerome Bruner (1966, p. 72), who argued that educating an individual within a particular discipline:

> is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a process, not a product.

Accordingly, science teaching should introduce and engage students to the knowledge-generating practices of science such as constructing, justifying and evaluating knowledge claims in addition to providing them with the facts of science. Within educational settings, it is the responsibility of science educators to enable their students to participate in the epistemic practices of science and engage in epistemic discourse by modeling these practices with and for them. Yet, the extent to which teachers are able to do so is not clear, if not limited, as studies presented in the previous section (e.g. Bleicher, Tobin & McRobbie, 2003) indicate. What is known about the role of science teachers in modeling epistemic talk in the science classroom?

The Role of the Teacher

The emphasis currently placed on dialogic teaching and on argument-based instruction requires a shift of the role of the teacher in the science classroom. Science teachers need to not only design activities that will ensure the productive participation of students in the learning process but also need to consider how to scaffold their students' learning, and how to model the thinking and reasoning processes they would like their students to use. Thus, the role of the teacher is vital in shaping and framing the purpose of learning activities that students participate in, through the language they use to communicate, share ideas and scaffold students' learning (Berland & Hammer, 2012; Ford & Wango, 2012; Gray & Kang, 2012; Hogan, Nastasi & Pressley, 1999; Lemke, 1990; Pimentel & McNeill, 2013; Polman, 2004; Tabak & Baumgartner, 2004; Webb, Franke, Ing, Chan, De, Freund & Battey, 2008; Windschitl, Thompson, Braaten & Stroupe, 2012). Yet, many studies of argumentation in recent times focus on the quality of students' oral or written argumentation (e.g. Cross, Taasoobshirazi, Hendricks & Hickey, 2008; Evagorou & Osborne, 2013; Katchevich, Hofstein & Mamlok-Naaman, 2013; Lee & Grace, 2012; Osborne, Erduran & Simon, 2004a; Shemwell & Furtack, 2010; Venville & Dawson, 2010; Zohar & Nemet, 2002) and not on examining the nature of the discourse initiated or put forward by the teacher.

The way teachers talk to, and with, their students can influence the dynamics of the teacher-student relationship, which in turn has the potential to create space for the co-construction of knowledge by teacher and students. For instance, Tabak and Baumgartner (2004) argue that students can be enabled to take control of their own learning when the teacher assumes a partner participant structure during student-teacher interactions. The role of the teacher in this case is to participate in student discussion as a peer and to co-construct knowledge with the students. At the same time, the teacher could also model the cultural tools of science, such as language or different forms of reasoning. Berland and Hammer (2012) discuss specifically the role of the teacher in promoting and establishing the use of scientific argumentation by students. Based on the construct of ‘framing’, they have demonstrated how when the teacher in their study assumed a supportive role as a guide of discussion, taking a back seat to classroom interactions, the students were empowered to engage in collaborative discourse and argumentation and created affordances for asking each other questions, requesting for justifications and evidence, and attempting to persuade each other.

Furthermore, teacher discourse might influence the students’ perceptions of scientific practices and knowledge. Zeidler and Lederman (1989) investigated whether the ways science teachers used language in the classroom affected their students’ ontological understanding of science based on a realist or instrumentalist perspective. Comparison of pre- and post-tests of 18 biology teachers and their students over the period of a semester showed that the students, whose teachers’ discourse had an instrumentalist or realist orientation, demonstrated a change towards the same orientation as their teachers. Moje (1995) reports on a qualitative case study of one secondary school chemistry teacher who was observed teaching for a period of 3 months. Moje (1995) identified three main patterns in the teacher’s classroom talk. These were a) the language of science as a discourse characterized by organization, accuracy and precision; b) the idea that science is a distinct discipline, and so is the language of science; and c) the use of certain linguistic devises such as the personal pronoun ‘we’ to promote a feeling of belonging to a scientific community. Moje (1995) found that these three patterns in the teacher’s classroom discourse influenced the students’ perceptions of science and science learning. Students focused on terminology and procedures to ensure they were precise and accurate in their chemistry lessons. Moreover, they viewed science as distinct from other subjects such as English. For instance, a student compared writing in Chemistry and English and described the former as based on facts and experiments rather than creativity and opinion, which the student thought were elements characteristic of writing in English classes.

Finally, the teacher’s discursive interactions can influence the students’ own way of talking and interacting when learning (Gillies & Khan, 2009; Nussbaum & Edwards, 2011; McNeill & Pimentel, 2010; Ryu & Sandoval, 2012). Gillies and Khan (2009) trained middle school math teachers to pose questions that challenged their students’ thinking and reasoning skills. They then examined the influence of the teachers’ questioning techniques on their students’ ability to collaborate when in groups. They found that the students, whose teachers were trained to pose challenging questions, were better able to pose questions and provide justifications themselves, compared to the students whose teachers were not trained to do so. Ryu and Sandoval (2012) present an elementary teacher’s sustained efforts of prompting her students to provide explicit justifications for their claims throughout a school year. As the year progressed, the students not only used explicit justifications in their discussions but also *requested* justifications from each other and their teacher, engaging in this way in epistemic discourse. Martin and Hand (2009) found that when a teacher started implementing argument-based instruction in her practice consistently and used open-ended questions that prompted students' reasoning, then 'student voice' became more prevalent in her class. As the students' voice in the classroom increased and students were given greater control over their learning, they also started participating in argumentation activities more systematically. Similarly, McNeill and Pimentel (2010) explored and compared the classroom discourse that took place in three different classrooms, where the teachers taught the same lesson on climate change. They found that in the classroom that the teacher asked the most open-ended questions and allowed students to critique or support each other's ideas using evidence and justifications, student talk was both epistemically and dialogically rich. That is, students in this classroom used more evidence and justifications in support of their claims and also engaged in student-student interactions as opposed to the traditional IRE patterns dominant in the other two teachers' classroom talk.

Summary and Research Questions

The conceptualization of science as an epistemic practice has implications for science teaching since science teachers would be required to introduce and engage their students in different discursive and reasoning practices than the ones currently used. The studies presented in the previous sections support the view that the way in which the science teacher uses language to communicate science in the classroom is one of the key features that frame the students' emergent views of science and its practices, and their productive participation in them. The central role of the teacher in modeling classroom talk and framing the interactions that might take place during the learning process would suggest that epistemic discourse needs to be promoted and established by the teachers systematically. Accordingly, research that identifies and explores the epistemic discourse initiated by teachers is needed to determine the ways in which science teachers expose students to the epistemic practices of science. Thus, the purpose of this study was to characterize secondary science teachers' classroom talk as they attempted to use argumentation as a framework for science teaching. The research questions guiding this study were:

- RQ1. What features of epistemic discourse are present in a secondary science teacher's classroom talk during argumentation instruction?
- RQ2. How is this epistemic discourse promoting the epistemic practices of construction, justification and evaluation of knowledge claims in a secondary science classroom?

Exploring how the epistemic practices of science take form through classroom discourse requires a detailed examination of the way in which the scientific practice is presented to the students and of the discursive activities and processes that students are asked to go through to construct their understanding of scientific concepts, phenomena and processes. For that reason, a case study design is adopted in this study, which is further described and justified in the next sections.

Context of the study

This study was conducted as part of a funded two-year Professional Development project (PD hereafter), which aimed to help secondary science teachers and their departments in four schools in a large metropolitan area incorporate argumentation and a more dialogic approach to their everyday practices (Simon, Richardson, Howell-Richardson, Christodoulou & Osborne, 2010; Osborne, Simon, Christodoulou, Howell-Richardson & Richardson, 2013). In this PD program, the model used to introduce and develop argumentation was based on Toulmin's Argument Pattern (Toulmin, 1958), which consists of a claim; warrants or evidence; backings, rebuttals and qualifiers. The approach to continuous professional development adopted was characterized as a 'light touch' approach, since part of the aims of the PD was to investigate the extent to which teachers share experiences within their departments and help each other. Within each of the four schools, two teachers acted as lead teachers for their departments. The lead teachers attended five workshop days over the course of the project, during which they were introduced to the practice of argumentation, helped to develop their knowledge of instructional strategies for implementing argumentation in their science classrooms with different age groups ranging from Year 7 (11-12 years old) to Year 11 (15-16 years old) students, and worked towards a dialogic perspective of science instruction.

Research Design and Methods

Case Study Design and Sample

This study aimed to explore the events and discursive processes taking place within a naturalistic setting of a secondary science classroom where the teacher used argumentation to teach science. An exploratory case study was considered as the most appropriate research design to capture the detailed data required to examine the teacher's discursive interactions. Case studies facilitate the investigation of contemporary events in which the researcher has little control over (Yin, 2009), such as the events taking place in a classroom setting, as well as when the focus of the investigation is the process of learning rather than the outcome. The use of a single case study, does not allow wider generalizations, a limitation of this study that needs to be acknowledged. Yet, the particularization (Stake, 1995) that an exploratory case study design provides is still of value. The exploratory nature of the current case study emphasized the exploration of an event – teaching science based on argumentation – with the intent to create further hypotheses for future investigation (Yin, 2009). That is, conclusions drawn from the case study created could be used to illustrate ways in which specific epistemic features of the teacher's classroom talk could be applied in science teaching to promote the use of epistemic discourse by students.

The participant was identified based on convenience sampling. A teacher from the PD project who was prepared to share more time with the researcher and allow observations for an extensive period of time (one school year) agreed to participate. James (a pseudonym) was one of the senior members of his school's science department. James, a white male in his mid-forties, had 20 years of teaching experience. At the time of recruitment (2009 - '10), James had been working at the same school for ten years and had a leading role within his department being the Head of Biology and providing professional development training to less experienced teachers. In addition, James was teaching general science to Year 8 and Year 9 students (12-14 years old). The school was a mixed-comprehensive secondary school located in a quiet, residential area in the North-West of a large metropolitan area. 11% of students at the school qualified for free school meals and 80% of students came from minority ethnic groups. James' involvement in the PD project begun in the previous school year during which he planned and taught several argumentation lessons. The class observed was a mixed-ability Year 9 (13-14 years old) group of 27 students predominantly of ethnic minority backgrounds, which was representative of the area's population.

Data collection

Data collection was based on the observation of argumentation lessons, which were video-recorded. The first author conducted all lesson observations. Participant observation was selected as the best way to interpret the nature of the observations conducted. This way of data collection accounts for the fact that everything observed during the science lessons were documented through the researcher's interpretative framework, knowledge and understanding (Merriam, 1998) although the presence of the researcher was as non-invasive as possible. The researcher did not have any influence on the selection of topic or activities used in the lessons observed. The use of video and audio-recording equipment allowed for the detailed collection of verbal data so as to examine "ways in which knowledge is revealed, shared and embodied" (Heath, Hindmarsh & Luff, 2010, p.8) within the science classroom. The video-recording equipment used focused on the teacher and the discourse initiated by him. The lesson observations took place throughout a school year (October-July) and the frequency depended on the teacher's timetable and availability. The intention was to observe as many lessons as possible throughout the year, both focusing on argumentation and on everyday teaching practices. This paper will focus only on the argumentation lessons taught by James. Six 50-minute argumentation lessons were observed. The lessons observed focused on argumentation in different ways. Two of the lessons (Lesson 1 and Lesson 2) were based on resources from the IDEAS pack (Osborne, Erduran & Simon, 2004b) and the rest were planned by James. Three of the lessons focused on forces and gravity (Lessons 1, 2 and 5) whereas Lessons 3, 4 and 6 focused on photosynthesis, the use of pesticides, and air quality respectively (Table S1 in Supplementary Materials provides further information on each lesson). The argumentation activities employed and the topics investigated depended on the teacher's objectives and planning. For each observation, the teacher was asked to identify why he considered the lesson to be an argumentation lesson. Other supplementary data collected included informal discussions about the lessons, which were recorded in field notes after each observation, samples of students' work and worksheets used.

Data Analysis

The analysis of classroom talk used in this study was based on the notion of epistemic operations (Ohlsson, 1996). Ohlsson (1996) argues that abstract knowledge and understanding can be developed when learners engage in a series of epistemic operations or tasks that have different functions, such as explaining and defining. Examining the learners' epistemic actions through spoken discourse, which is used to "do cognitive work on knowledge or understanding" (Baker, 2002, p. 308), can be an indicator of the extent to which higher-order learning and understanding develops and of the steps that students are asked to go through in order to develop their understanding. In the context of science teaching and learning, identifying the range of discursive actions that students are exposed to, and asked to participate in as they develop their understanding of scientific concepts, can provide an insight of the extent to which teachers provide students the opportunity to go through the transformative phases of scientific knowledge before it is established and accepted within a scientific discipline.

Thus, epistemic operations are defined as discursive actions or talk moves whose function is to promote the creation and development of knowledge and understanding. When individuals perform these epistemic operations they engage in epistemic practices since they contribute towards the generation and establishment of knowledge. 'Practice' is considered as the sum of actions that contribute towards the same objective. For instance, the epistemic practice of evaluation could be put forward through discursive actions such as contrasting differing views and/or making evaluative judgments about a piece of evidence.

[Table 2]

Previous studies have used the construct of 'epistemic operations' in order to organize and characterize student-student talk and examine the ways in which students develop understanding of science concepts through discursive interactions (Jiménez-Aleixandre et al., 2000; Mason, 1996; Pontecorvo & Girardet, 1993). Table 2 provides a synopsis of epistemic operations identified in different studies. Jiménez-Aleixandre, Mortimer, Silva and Diaz (2008) used epistemic operations in an analysis of science teachers' classroom talk. Specifically, they examined how the teachers' use of 'Description', 'Explanation' and 'Generalization' can help students' understanding develop from specific to abstract constructs. Yet, they did not consider the extent to which these three epistemic operations promoted certain epistemic practices.

Thematic analysis (Boyatzis, 1998) and the constant comparative method (Glaser & Strauss, 1967) were employed as techniques for analyzing the textual data. An 'epistemic operation' was coded based on a 'idea unit' (Mason, 1996; Pontecorvo & Girardet, 1993), which represents the smallest unit in which the function of a particular utterance by the teacher could be identified. This 'idea unit' could be a whole sentence, part of the sentence, or of a dialogic nature, including both the teacher and students, in order to capture the context in which the utterance was found. The thematic coding applied to the lesson transcripts of the on-task talk was theory-driven and based on the epistemic operations presented in Table 2. This list was not considered definitive but indicative of the types of talk that could be found in the teacher's discursive interactions, since epistemic operations had not been applied previously to characterize the classroom talk of science teachers in the context of argumentation lessons. The coding process allowed for the identification and creation of new thematic categories, whenever these were thought to be necessary.

The software for qualitative analysis Nvivo was employed for the transcription and coding of the data. First, data were transcribed verbatim by the first author and this process was considered as an initial familiarization with the textual data. The second stage of analysis involved organizing the data based on chronological order from the first to the last observation, and adding any contextual information related, such as lesson plans, observation notes and pictures of the classroom and whiteboards. The enumerative approach to the representation of qualitative data (LeCompte & Preissle, 1993) was applied to quantify the epistemic operations and search for patterns within each lesson and across the 6 lessons. Analysis of the textual data also included exploratory word frequency searches of key terms such as 'evidence', 'why', 'argument' and 'justify'. Double coding was applied when more than one epistemic operation was identified within the same utterance (e.g. an utterance coded as 'Argument' could also include 'Justification' or 'Provides Evidence').

An inter-rater check with an independent researcher was employed to ascertain the degree of reliability of the coding framework. The inter-rater procedure was performed with a larger data set, consisting both of argumentation and non-argumentation lessons taught by James and another teacher. The independent researcher was provided with definitions of each epistemic operation and one lesson transcript to familiarize themselves with the process. Preliminary agreement reached 69%. As a result of the preliminary inter-rater process, definitions were adjusted to reflect the issues discussed with the independent coder and exemplars were added to each definition to enhance clarity of meaning during the coding process (see Table S2 in Supplementary Materials for a full list of definitions and examples of each epistemic operation). Independent coding of further lesson transcripts and extensive extracts from other lessons (to ensure that text both during whole-class and group-work discussions) was then undertaken (4 of

25 lesson transcripts). Final inter-rater agreement reached 94% with differences of opinion discussed and resolved.

Findings

The analysis of the discursive actions of James resulted in the identification of the epistemic operations presented in Table 3. The discursive actions of the teacher were organized into two categories. The first was based on the discursive actions that the teacher *performed* through his talk, e.g. an explanation, definition or description of an event. The second type of epistemic operations identified was those that the teacher used in his attempt to *prompt* or engage students in thinking and/or talking about the concepts taught. For example, if the teacher asked students to provide a definition for a concept then this discursive action would be a 'Prompt for Definition'. Prompts were not always in the form of a question but could take the form of reminders and requests (e.g. 'what I want you to do now is to try and justify your answer' was coded as a 'Prompt for Justification').

[Table 3]

In order to answer RQ2 each of the epistemic operations identified was considered for the extent to which they contributed to the epistemic practices of constructing, justifying or evaluating knowledge claims (Kelly, 2008). Table 4 presents the results of this process. Results are presented based on the sum of instances identified for each epistemic operation in the six lessons, and as a percentage of the total number of epistemic operations (performed and prompted) found. Table 4 also provides information on the organizational format of the classroom for each epistemic operation, with 'whole-class' applied when the teacher was addressing all students and 'group-work' used where the teacher was talking with or to students, as they were engaging in group activities. The sections that follow discuss how different epistemic operations contributed towards presenting and engaging students in the construction, justification and evaluation of knowledge claims, and how these were interlinked in the teacher's discursive interactions with students in order to engage in epistemic discourse.

[Table 4]

Constructing knowledge claims

The epistemic practice of constructing knowledge claims within the science classroom was operationalized through attempts by the teacher to provide students with the information necessary for constructing understanding of new concepts. The epistemic operations used to construct scientific knowledge are shown in Table 4. These epistemic operations contributed to sharing information and emphasizing knowledge that students could be using in order to develop understanding and where thus organized under the practice of constructing knowledge claims. These accounted for more than half of the on-task talk generated by James across the six lessons analyzed. The most commonly used epistemic operation was 'Providing Evidence', which is defined as instances where James gave students information or data that they could then use as evidence for constructing their arguments. In addition to making information or evidence available to students James often reflected on the importance of using evidence and discussed the role of evidence for scientific investigations as in the following example:

> to make a judgment about how good or bad the air quality is, you are going to have to use evidence, cause you have to use evidence to make judgments about everything, don't you? (L6)

In this way James modeled epistemic discourse to his students and made the meta-language of science available to them. The meta-language of science refers to specific epistemic constructs such as laws, evidence, explanation, justification etc. (Penney, Norris, Phillips, & Clark, 2003), and is required to make different elements of science visible to the students and introduce them to the language of science (Lemke, 1990).

Supplying students with information was achieved not only through providing direct information, but also through the use of epistemic operations such as 'Description', 'Definition' and 'Generalization'. 'Description' was a common feature in the discursive actions of this teacher (see Table 4), which took place mostly during whole-class interaction and usually served the purpose of providing the context of the lesson or the activity to follow. It is worth noting that although 'Description' was one of the actions that the teacher was often using when talking to the students, it was not a discursive action that he was aiming at engaging students in, as shown from his limited use of 'Prompts for Description'. For the most part, prompting students to provide a description or a definition was used by James as a strategy for eliciting students' ideas (Harris et al., 2012) and as a starting point for the students to initiate discussion about the topic in hand before proceeding to more challenging parts of the activities such as interpreting data or constructing arguments. Thus it could be argued that epistemic operations such as 'Providing Evidence', 'Definition' and 'Description' were setting up the conditions that would then allow students to engage in epistemic discourse through epistemic operations that had a higher epistemic load such as 'Explanation' and 'Argument'.

'Explanation' was considered as every instance where the teacher provided a detailed account of a scientific phenomenon in a way that the causal link between the concepts discussed was made explicit. In the lessons observed 25 instances, in five of the six argumentation lessons, were found where the teacher was providing an explanation of a phenomenon. From those 25 instances, most came during whole-class discussions and in lessons where forces and the relationship between gravity, mass and weight was the topic of discussion.

'Argument' was present only in four of the six lessons (12 instances) with 'Prompts for Argument' being used considerably more (49 instances) and in all lessons observed. The 12 instances of 'Argument' identified in James' classroom talk, modeled argument in two different ways: (a) providing spontaneous arguments (10 instances) and (b) providing exemplar arguments (2 instances). Table 5 provides an excerpt of a spontaneous argument found in Lesson 1, during which students were asked to select from various statements in order to explain what happens to a box as it is let to drop from a height of a thousand meters (Osborne et al., 2004b). In this instance, 'Argument' was provided by James as part of the whole-class discussion that took place at the end of the lesson when students were asked to present their selections.

[Table 5]

James first prompted a group of students to provide an argument in support of the decision to select statement 3B and then presented students with the argument another group discussed with him earlier in the lesson (utterance 351). This alternative perspective presented was consistent with the scientific explanation he was trying to establish during the lesson. In this way, he was using ‘Argument’ in order to promote the scientific explanation associated with the free fall of objects that wanted his students to understand. He then moved on to prompting students for alternative arguments, asking S3 to justify their selection of statement 3A [gravity is roughly the same size throughout the fall]. Finally, he explained why selecting statement 3A was the correct answer and moved on to provide an example (utterance 355).

In the excerpt provided in Table 5, we can see how epistemic operations under construction can be combined with epistemic operations that aim at evaluating knowledge claims in order to promote scientific understanding. James used ‘Argument’ to provide the necessary information for students to construct an understanding of the scientifically accepted explanation of a phenomenon. He did so by contrasting the scientific explanation with other alternative views and allowing students to consider the extent to which the alternatives presented were correct, actively engaging students in the construction and critique of knowledge claims (Ford, 2008a, 2008b) and at the same time, moving away from simple elicitation of ideas towards deepening students’ thinking and reasoning (Harris et al., 2012). However, from the 10 instances that James was found to spontaneously provide an ‘Argument’ this was the only successful attempt to combine these discursive operations, and to model in his classroom talk the epistemic practices of science and how these are interlinked to develop and establish scientific knowledge. In addition, the difference between the instances of ‘Argument’ and ‘Prompts for Argument’ identified in James’ talk would suggest that although he encouraged participation in argument construction, this was not something he was modeling sufficiently to the students through his own discursive actions.

The second way of modeling argument was to provide an ‘exemplar argument’ during which James reflected on the function of each statement in the process of constructing an argument. An example of this process is presented in Table 6, which took place during a whole-class discussion at the start of Lesson 6, using an example from everyday life.

[Table 6]

James included not only the use of evidence in order to provide a justification in support of an opinion but he also provided a description and example of a counter-argument. This explication of argument shows that James at that point was starting to consider other aspects of the process of argumentation with his students, such as counter-argument. This would suggest that his initial representation of argumentation was starting to become more complex and included aspects of argumentation that are more cognitively challenging for the students. However, this exchange took place in the last argumentation lesson taught by James that year which would suggest that students did not have sufficient opportunities to engage with these elements of argumentation whilst learning science previously.

Justifying knowledge claims in James’ classroom talk

Examining James’ justificatory talk separately to his attempts to construct arguments and engage students in decision-making provide an indication of the extent that James was explicating the need to provide reasoning and evidentiary support as part of doing science. James acknowledged the justificatory aspect of scientific practices and used it in both his own discursive actions through the use of ‘Justification’, and as an epistemic action he encouraged his students to develop, through the use of ‘Prompts for Justification’. The role of justification was also pointed out in James’ attempts to define argumentation to the students. Using as a basis the structure of an argument, James modeled argumentation for the students and explicated the components of a good or bad argument (opinion/view, evidence, justification, counter-argument)

as in the excerpt provided in Table 7. In this way, he engaged in epistemic discourse by explicitly discussing the criteria that students should be using when constructing their arguments and when there are evaluating decisions presented to them.
[Table 7]

During this lesson, even though James made explicit one of the main components of argument –the use of data as evidence – and the function of evidence within an argument as to justify a position, he equated argument to justification, constructs of different epistemic function. Justification is only part of the process of argumentation and of its final product – an argument. Even though justification is an integral aspect of the process of argumentation, it is not the only aspect that characterizes argument, but rather, it is the first step in thinking about the strength of any argument. Any argument first needs to advance a claim. Only then is it necessary to provide evidentiary support, and in this way, justify the claim, in order to make it epistemically sound and convincing. James' move to present argument and justification as synonymous at times, could be his way of emphasizing the important part that justification had within the process of arguing. Nonetheless, as evidenced in his descriptions and definitions of argument in Tables 6 and 7, justification prevailed over other facets of argumentation such as evaluation. James recognized the importance of making decisions although he did not interpret that as the need to evaluate a situation but rather, he framed the act of decision-making as one having a viewpoint and using evidence to justify it.

In addition, justificatory talk was equally shared amongst whole-class and group-work discussions, which suggests that justificatory talk was a discursive practice utilized consistently during these lessons. 'Prompts for Justification' were mainly based on asking 'why'. Within his argumentation lessons, there were 60 instances (Figure 1) where James used 'why' as a question or a prompt for students to consider.

[Figure 1]

The use of questions such as 'why' and 'how do you know' is an important element of the practice of argumentation as it strengthens the construction of an argument. In this respect, we would argue that prompting for justification serves a significant function within the science classroom and science teachers should consistently use it as part of their talk moves.

Evaluating knowledge claims in James' classroom talk

Evaluative practices were identified in James' classroom talk in two ways. First, through evaluation as a discursive action and second, through the process of counter-argument. 'Evaluation' was identified in 34 instances throughout the 6 lessons observed and was found to take place when James' followed-up a student response by (a) further questioning during which the teacher was providing different viewpoints or prompting students to consider other views and (b) providing further explanatory comments or making generalizations in whole class. In this way, James challenged students' perceptions and prompted them to evaluate and reconsider their responses based on the evidence available.

During questioning sequences it seemed that even though James was guiding students towards the correct answer or explanation for the topic of discussion, he nevertheless seemed to avoid stating directly the right answer to the students and instead he was responsive to their ideas (Maskiewicz & Winters, 2012), attempting to elicit the replies he wished through further questioning and by prompting students to consider alternative evidence and to justify their viewpoints. An example of this approach was presented previously in Table 5, where James was able to successfully combine the epistemic practices of construction and evaluation through providing students with different perspectives, and then evaluating students' arguments during a whole class discussion. A successful attempt to combine justificatory and evaluative talk is given in Table 8, this time during group work discussion, during which James was helping a pair of students develop their argument in deciding whether a given statement was true or false (L2).

[Table 8]

James initially prompted Student 1's reasoning in utterance 279 and then questioned the student's response. When he established that there was disagreement within the pair, he prompted them again to provide justifications (utterance 284), which acted as a scaffold for students to start evaluating the statement based on their own understanding of forces. Hogan et al. (1999) have found that teachers can act as catalysts in group discussions by prompting students to re-consider their thinking and clarify their ideas. This was done by James implicitly in utterance 281 where he questioned the student's response, in a way that encouraged them to reconsider their answers and engage in epistemic discourse by providing reasons in support of their viewpoints.

As in the case of 'Prompts for Argument', the epistemic operation of 'Prompts for Evaluation' was a more explicit attempt on the part of the teacher to engage his students in epistemic discourse. For instance, during Lesson 2, James asked students to carefully listen to each other's views since as he pointed out to them, 'you may be asked what you think about it; you may be asked to evaluate it; if you agree or not' (L2). Yet, the use of 'Prompts for Evaluation' varied considerably, with most prompts found in Lesson 3 (22 instances) and Lesson 2 (10 instances) but only one instance found in Lesson 4.

Another aspect of the evaluative processes that took place in the lessons observed was the use of 'Counter-Argument' as an evaluative mechanism. Teacher and students need to be able to evaluate a position before they can offer a counter-position and/or counter-evidence. In the argumentation lessons taught by James, 'Counter-Argument' seemed to be one of the discursive actions that he engaged in, especially in combination with evaluative comments, as discussed above. Yet, he did not make any explicit and consistent efforts to prompt students to construct counter-arguments themselves. Specifically, 'Prompts for Counter-Argument' was present in four of the six argumentation lessons observed. However, the vast majority of instances (26/31) were found in Lesson 4, which specifically focused on identifying counter-evidence and constructing counter-arguments. This was the first time that James provided an exemplar counter-argument for the students and discussed with them how to structure counter-arguments, although later on in that lesson James did not make any further attempts to model counter-argument for the students. The only other time that modeling of counter-argument was found was as part of the exemplar argument during the last argumentation lesson he taught at the end of the school year (Table 6).

Finally, James did not use 'Counter-Argument' as part of his talk to the same extent he prompted his students to use it. However, students need to be provided consistently with examples of how to construct counter-arguments in order to improve their ability to counter-argue (Glassner & Schwarz, 2005). The inconsistent and context-dependent manner in which James used 'Prompts for Counter-Argument' supports the interpretation that providing alternative viewpoints and counter-evidence was not one of the aspects of argumentation that he aimed to address through his lessons, with the exception of Lesson 4.

Discussion

The analysis of the teacher's classroom talk presented in this study aimed at identifying features of epistemic talk in a science classroom during argument instruction (RQ1) and the ways in which specific features of the teacher's talk promoted the epistemic practices of constructing, justifying and evaluating knowledge claims (RQ2). Examining the teacher's talk in this way, can be useful in providing an insight to the ways that the nature of classroom discourse can be transformed through the use of specific epistemic operations, or combinations of them, in order to address the various epistemic practices of science and not focus solely on the acquisition of factual information (Ford, 2008a). The findings of this study include the organization of the teacher's epistemic talk on first, the epistemic operations he performed and second, that he prompted his students to engage in, which can demonstrate the extent to which this teacher modeled specific types of talking to the students (e.g. 'Argument') and the extent to which he encouraged his students to engage in this talk (e.g. 'Prompts for Argument'). The analysis revealed James' use of justificatory talk was consistent across the six lessons observed but the same consistency was not identified in his attempts to engage students in evaluative talk through 'Prompts for Evaluation' and 'Prompts for Counter-Argument'. This discrepancy would suggest that evaluative practices were not as embedded in James' classroom talk as the justification or construction of knowledge claims.

The science classroom as a site of epistemic talk

Based on the epistemic operations identified in this teacher's classroom talk and their function in presenting and engaging students in epistemic practices, it has been shown that the teacher in this study was able to take the role of the 'constructor' (Ford 2008a, 2008b). Attempts that aimed to construct knowledge claims focused on epistemic operations, whose function was to provide students with the information and content they could use as evidence to construct and support their arguments and counter-arguments. The information provided through epistemic operations such as 'Definition', 'Description' and 'Generalization' was of a Type 4 and Type 5 statements based on Latour and Woolgar's (1986) categorization (Table 1), presented as unequivocal factual statements that did not require any further support. Gray and Kang (2012), who studied experienced teachers' discursive interactions during laboratory-based activities report similar findings, with the teachers in their study found to be supporting only half of the claims they were putting forward. Thus, epistemic operations such as 'Description' and 'Definition' were discursive actions of a lower epistemic load or 'epistemic forcefulness' (Siegel, 1995), compared to other epistemic operations that also contributed to the construction of knowledge claims, such as 'Argument' and Explanation'. Epistemic load could be defined as the degree to which classroom discourse represents and mirrors epistemic practices of science and the processes that scientists go through to produce scientific knowledge. Consequently, it could be argued that epistemic discourse during the construction of knowledge claims was modeled and promoted to a greater extent when discursive actions such as 'Argument' and 'Explanation' were used. Yet, as discussed in the Findings section, epistemic operations such as 'Argument' were not consistently used by James across the argumentation lessons he taught.

'Argument' was defined as any attempt by the teacher to put forward a viewpoint, which is supported by evidence. In this sense, the discursive action of 'Argument' is different from the product of argument based on Toulmin's (1958) argument structure. Elements such as backings and rebuttals, which would require engagement in evaluation as well as construction of knowledge claims, would not be part of an 'Argument' at the first instance, during dialogic interactions with students, although qualification of statements could be provided by James as a discussion developed with students. For instance, in the excerpt provided in Table 5, 'Argument' was part of the construction of knowledge claims as its function within James' talk was to present students in whole-class with a viewpoint put forward by one of the student groups during groupwork. James took the role of the constructor of knowledge (Ford, 2008a) and negotiated with students the correct scientific meaning of ideas whilst at the same time he evaluated the students' arguments and provided them with alternative ones as to establish the validity of the accepted scientific explanation amongst the students.

However, the combination of 'Argument' and 'Explanation', and the move from construction to evaluation, as previously presented in Table 5, was an exception and not the norm in James' classroom talk. This aspect of constructing knowledge claims was rare since James did not usually use 'Argument' in combination with alternative perspectives discussed by groups of students. Ford and Wango (2012) argue that if individuals are to be said to understand a concept, they need to be able to explain that concept, to demonstrate an awareness of the fact that this explanation prevails amongst alternatives and finally, that the extent to which this prevailing takes place is because the scientific ideas have been subjected to an evaluative process, which using evidence demonstrates its superiority amongst alternatives. The findings of this study would suggest that James, through his talk provided affordances for his students to develop their understanding of science concepts through focusing on the use of evidence (mainly) and on explanations but not through engaging students *systematically* in the processes of revising and evaluating ideas in order to demonstrate why the scientific explanation was better than others. As a result, students were less consistently exposed to epistemic discourse that focused on evaluative processes. When James did move from construction to evaluation, justificatory talk seemed to act as a catalyst in increasing the epistemic load of classroom talk.

The role of justification within construction and critique

The role of justification and justificatory talk was central to promoting epistemic discourse and making James' classroom talk more epistemic, as it actively and explicitly engaged both the teacher and the students in providing support for their ideas. Consistently prompting students to engage in justificatory talk and modeling this way of talking for the students is vital if students are to make it part of their own discursive actions (Ryu & Sandoval, 2012; Siegel, 2008). James presented justification as an essential element of his talk during the six argumentation lessons. The consistency with which he used 'Justification' and 'Prompts for Justification' across his argumentation lessons was not characteristic of other epistemic operations he used such as 'Argument', 'Prompts for Evaluation' and 'Counter-Argument'. Following-up evaluative comments with 'Prompts for Justification' encouraged students to provide further reasoning in response to the initial question posed, a finding consistent with Pimentel and McNeill's (2013) analysis of teachers' classroom talk.

Making the role of justification explicit in classroom talk through epistemic operations such as 'Justification' and 'Prompts for Justification' can facilitate the move from the constructive to the evaluative processes and can provide further opportunities for engaging in critique and evaluation. In constructing an argument, the proponent of the argument needs not only to use data to support their claim but also to demonstrate explicitly how that data warrant support to the claim put forward. In this way, justificatory reasoning is demonstrated and the 'epistemic forcefulness' (Siegel, 1995, p.162) of the claim can be established. Evaluation is the epistemic practice of considering a claim in comparison to other views or opinions and in light of contradicting or confirming evidence. Such evidence might add to the validity of the claim or undermine it to the degree that needs to be re-structured, qualified or abandoned altogether. In this process of evaluation, justificatory reasoning is employed to demonstrate why one claim is better than another so as to strengthen the judgment made and establish the better argument. For instance, being able to state whether a claim put forward is valid or not, needs an awareness that personal belief through the agreement or disagreement with the statement proposed is not sufficient to convince others of the judgment made. Rather, a justification, which explicitly provides the reasons for or against the statement, is required. Consequently, individuals need to be able, and know how to provide justifications for their beliefs, and this ability should be demonstrated not only in presenting a viewpoint, that is, in constructing a claim, but also when being critical about one's own or other individuals' claims and arguments, that is, in evaluating knowledge claims.

Conclusions and Implications

McNeill and Pimentel (2010) argue that a shift in the nature of classroom discourse requires an examination of both the role of the teacher and students during these discourse processes. This study has analyzed teacher-initiated discourse in argumentation-based instruction in a systematic way by categorizing the epistemic function of teacher talk, an area of research that is underdeveloped. Harris et al. (2012) outline the need for more specific discourse moves to be identified, in order to help students develop their understanding of scientific concepts. This study has provided a set of prompts that can generate and promote epistemic discourse by students such as prompting for evaluation, comparisons and justifications. Such are the practices that science educators would wish their students to be able to undertake in order to develop their understanding of science as an epistemic practice, and actively engage in the practices and discourse of science (NRC, 2007). Students will only begin to understand the significance of these scientific practices if teachers use the full range of discourse acts which support such practices. However, as the analysis focused only on the function of the teacher's talk, claims of the extent to which students actually took on certain ways of talking cannot be made. Further, although the findings of this study are confined by the limitations of a single case study design, the analysis provides an illustration of how the nature of classroom discourse can be transformed by focusing on particular epistemic operations that can promote the use of epistemic discourse. The use of discursive actions by the teacher in the science classroom, such as those that encouraged students to provide justifications and evaluations, facilitated a move away from attention usually given to declarative knowledge through actions such as 'Description' and 'Definition'. Instead, classroom discourse was framed in a way that allowed the enculturation of students into the epistemic practices of science.

The teacher prompts identified in this study, can be seen as a form of scaffolding that allows students to access ways of thinking scientifically (Ford & Wango, 2012) and can encourage students to use them until these are internalized (Tabak & Baumgartner, 2004) becoming part of the students' discourse. As Ford and Wango (2012) demonstrate in their analysis of student-teacher discourse, when teachers prompt their students to justify and evaluate their answers, they frame the role of the students as not only the providers of claims but also the providers of appropriate reasons to back up those claims and to provide alternatives. The inconsistent manner with which different prompts were used by the teacher in this case study, would suggest that science teacher educators need to identify ways in which future science teachers can be helped to develop their discursive repertoires to ensure that they are presenting the full range of epistemic practices to students in a systematic and consistent manner. We assert that evaluation as an epistemic practice needs to be given special consideration within teacher education by helping science teachers understand its role in creating and establishing scientific knowledge, and by providing opportunities to embed evaluative practices into their teaching practices. This will allow teachers to provide a balanced range of activities between authoritative and dialogic teaching (Mortimer & Scott, 2003; Scott, 1998; Tabak & Baumgartner, 2004) and will help them promote not only the construction and justification of knowledge claims through epistemic discourse but also the evaluation of knowledge claims.

Finally, the teachers' ability to scaffold argument-based discussions successfully needs to be addressed further in science education research. PD programs should provide opportunities for the teachers to develop their own argument-based discursive actions, through proving feedback on the teachers' attempts to teach argumentation lessons, the types of prompts and questions they use during their lessons, and organizing workshops where the teachers are themselves participating in argument and counter-argument construction. That is, science teachers need to be introduced and trained not only into *teaching* science based on argument, but also *talking* science based on argument. In this way, elements of argument-based instruction would be easier to be transferred and made part of everyday science teaching that develops an understanding of the epistemic practices of science. Even though some efforts in this direction have taken place recently (e.g. Windschitl, Thomson & Braaten, 2008; Windschitl et al., 2012) in facilitating the development of discourse tools for beginning teachers in model-based inquiry teaching, this is limited. Thus, it is suggested that science education researchers now need to focus on ways that in-service, and pre-service, teacher training can facilitate the development of teacher talk in ways that will reflect more clearly and explicitly the epistemic practices of science.

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- Table S1
- Table S2

Table 1
Types of knowledge claims as discussed by Latour and Woolgar (1979)

Type	Nature of statement	Example	Usually appear in…
Type 1	conjecture or speculation	It may be that A…	End of papers or private conversations among scientists of a group
Type 2	claim or tentative suggestion	There is evidence to suggest that A…	Papers and drafts circulated within a group of scientists
Type 3	referring to other statements	It has been reported by Smith (2012) that A relates to B	Review and published papers usually including a reference
Type 4	without any qualifying modalities	'A relates to B'	Textbooks and teaching materials
Type 5	taken-for-granted statement	–	Conversations and/or papers addressed to members of the community
		'A'	Conversations with individuals outside the scientists' discipline

Table 2
Synopsis of epistemic operations identified in the literature

Pontecorvo & Girardet (1993)	Ohlsson (1996)	Mason (1996)	Jiménez-Aleixandre et al. (2008)	Jiménez-Aleixandre et al. (2000)
	Describing		Describing	
Defining	Defining	Defining	Defining	Defining
	Exemplifying			
Predicting	Predicting			Causality (Relation of cause–effect, looking for mechanisms)
	Explaining		Explaining	
Evaluation	Critiquing (Evaluating)			
	Arguing	Arguing (claim; justification; concession; opposition; counter-opposition)	Constructing arguments	
Categorising			Classifying	Classifying
		Generalising	Generalising	
Appealing to analogies, conditions, consequences, implications, authority etc.		Appealing to evidence, experience, data, analogies etc.	Appealing to analogies and metaphors	Appealing to analogies, instances or attributes as a means of explanation
			Calculating	
				Consistency with other knowledge, experience, commitment to consistency
			Constructing narrative	
				Plausibility

Table 3
The epistemic operations identified in the teacher's talk

	Type of epistemic operations	
	Teacher-performed	Teacher-Prompted
Epistemic operations	Analogies & Metaphors	
	Argument	Prompts for Argument
		Prompts for Classification
	Compare and Contrast	Prompts for Comparison
	Counter-Argument	Prompts for Counter-Argument
	Definition	Prompts for Definition
	Description	Prompts for Description
	Evaluation	Prompts for Evaluation
	Exemplification	
	Explanation	
	Generalisation	
	Justification	Prompts for Justification
	Modeling	Prompts for Modeling
	Prediction	Prompts for Prediction
	Provides Evidence	Prompts for Evidence

Table 4
Epistemic operations found in James' classroom talk

	Instances (%)	Group-work	Whole class
Construction (61%)			
Provides Evidence	74 (9)	38	36
Prompts for Evidence	83 (10)	55	28
Description	49 (6)	14	35
Prompts for Description	25 (3)	15	10
Generalisation	38 (5)	15	23
Definition	37 (5)	15	22
Prompts for Definition	2 (0.2)	2	0
Exemplification	37(5)	13	24
Modeling	27 (3)	4	23
Explanation	25 (3)	9	16
Argument	12 (1)	5	7
Prompts for Argument	49 (6)	29	20
Analogies & Metaphors	10 (1)	2	8
Prediction	1 (0.1)	1	0
Prompts for Prediction	28 (4)	16	12
Justification (15%)			
Justification	58 (7)	26	32
Prompts for Justification	64 (8)	33	31
Evaluation (24%)			
Evaluation	34 (4)	16	18
Prompts for Evaluation	52 (6)	31	21
Compare & Contrast	37 (5)	24	13
Prompts for Comparison	11 (1)	8	3
Counter-argument	32 (4)	18	14
Prompts for Counter-Argument	31 (4)	18	13

Table 5
Example of teacher attempting to engage students in argument and counter-argument

		Classroom Transcript	Epistemic Operation
349	James:	Tell why you choose 3B, why do you think that gravity gets a lot bigger as the box gets closer to the earth.	Prompt for Argument
350	Students 1, 2:	Because we did the [experiment with the] pencil.	
351	James:	I overheard somebody else telling me about space and about the fact that if you go into space you have no, there is no gravity so the idea that maybe the further away from the earth you get the less gravity there is in which case that person felt that 3B was the right answer for that reason.	Argument
		Did anyone pick 3A [gravity is roughly the same size throughout the fall]? OK. [Student 3], why did you pick 3A?	Prompts for Counter-Argument
352	Student 3:	Because a thousand meters is not high up…	
353	James:	So are you happy with the idea that gravity changes as you move away from the earth, like these guys thought,	
		but you don't think a thousand meters is very far away from the earth so you don't think it's going to change very much. So you've gone for [statement] 3A.	Counter-Argument
		OK, and where you the same?	Prompts for Evaluation
354	Student 3:	Yes.	
355	James:	OK. I'd go with them [Students 3 and 4]. So you are all right but they are more right than you are. It changes but it doesn't change very much over a thousand meters.	Evaluation

Table 6

James' attempt to provide an exemplar argument in Lesson 6

		Classroom Transcript	Epistemic operations
11	James:	Someone might say to you that England are a rubbish football team. […] But, but unless they offer you some justification that is not an argument […] If I was to say to you that England are a rubbish football team because	Argument
		Germany beat them 4-1 and should've beaten them 9-1, […] and every time the Germans came at the English great holes appeared in the English defense through which the Germans were able to run and score, then, I've presented you with an argument because I've given you	Justification
		some justification for suggesting that England are a rubbish football team. If I just said to you England are a rubbish football team that is not an argument. It's just a statement. But if I back it up with some evidence... [for	Justification
		example], [name] scored a goal, the goal was disallowed by the referee; there's now a discussion going on about whether we should have goal-line technology.	Provides Evidence
14	Student:	Yes.	
15	James:	You can argue for or against goal-line technology. People who argue for goal-line technology say that it's important	Argument
		that the right decision is made because these decisions are really important […] Goal-line technology would	Justification
		eliminate mistakes like the ones we saw in the Germany game. However, people would argue that goal-line	Counter-Argument
		technology slows the game down. That you lose the flow	Counter-Argument
		that makes football so entertaining. Somebody else might argue that that's not the case because if you had a fourth official who was watching everything on video playback, they're connected to the referee by a wireless microphone and in seconds they could inform the referee of a problem and the problem could be resolved.	Justification
		What I have just done is I just presented you with an	
		argument. I've got a position-should we have goal-line technology, shouldn't have got goal-line technology- and I justified my position. OK? And in fact, we offered a counter-argument as well, didn't we, to the goal-line technology? It stops the flow; actually it doesn't	Description
		because… […] When you make judgments about things	Exemplification
		scientifically you've got to use evidence to justify your argument.	Prompts for Justification

Table 7
James' attempts to define the practice of argumentation in Lesson 1

		Classroom Transcript	Epistemic operations
27	James:	This lesson is about argument, OK? "Yes, it is/No it isn't; yes, it is/No it isn't". That's not argument. OK?	Exemplification
		When we talk about argument, what we mean…	Definition
28	Student:	Explanation.	
29	James:	Yeah. Justifying your thinking, essentially that's what argument is. Justifying your position. OK? We're going to look at some data. It relates to photosynthesis, which is why you started off thinking about those four statements […].	Justification
		You are going to have to make some decisions but you're going to have to justify those decisions. That's what argument is. OK? So you are going to be describing things, explaining them and justifying them; in other words you are going to be arguing ['Describe, Explain, Justify, Argue' are written on the board throughout the lesson]	Prompts for Justification

Table 8
Example of James' attempt to engage in epistemic talk based on evaluative practices

		Classroom Transcript	Epistemic Operation
278	Student 1:	Yeah, will that be true [the net force is always in the same direction as the ball is moving]?	
279	James:	Why do you think that's true?	Prompts for Justification
280	Student 1:	Cause the net force is in the same direction as the ball [inaudible]	
281	James:	Is it?	Evaluation
282	Student 1:	I don't know.	
283	Student 2:	I said false.	
284	James:	So you don't agree. Why do you think it's not true?	Prompts for Justification
285	Student 2:	Because the overall force, and that includes air resistance and all that, so when it's in the air, there is air resistance and air resistance isn't going to the way that the ball is moving.	
286	James:	Which way is air resistance going?	Prompts for Evidence
287	Student 2:	The opposite direction.	
288	James:	OK. So what's the overall force on the ball? So the ball is going to go like this, yeah? The question is: is the overall force on the ball always in that direction? Always that way or not?	Prompt for Argument