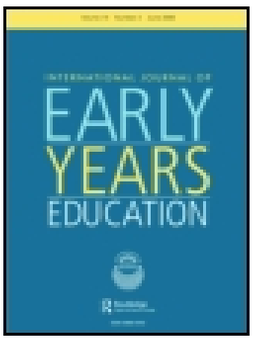

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The use of questions in early years science: a case study in Argentine preschools

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ABSTRACT

The use of effective questions is an essential attribute of successful early years science teaching. In this case study, we analyse the questions and dialogues generated by four preschool teachers from two schools in Buenos Aires, Argentina, of contrasting socioeconomic contexts (one privileged and one underprivileged). We looked at the implementation of two identical enquiry-based science curricular units after a two-month professional development programme. We found that teachers at the more privileged school asked an average of 22% more productive questions, i.e. those aligned with lesson goals (Martens, M. L. 1999. "Productive questions: Tools for supporting constructivist learning." *Science and Children* 36 (8): 24–53. http://search.proquest.com/openview/0fbd77105695538253f998eae1d38ff4/1.pdf?pq-origsite=gscholar&cbl=41736). There were also significant differences between the types of questions asked, with teachers from the lower socioeconomic status school asking more 'attention-focussing' and fewer 'evaluation' questions. Qualitative analysis of the teacher-student dialogues showed that students from the privileged school were exposed to higher-quality learning experiences, despite teachers apparently performing the same activities with the same materials. Our findings highlight the importance of focussing early years science professional development efforts on questioning practices, especially for those teachers working in underprivileged settings, to foster meaningful learning opportunities for all children.

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Science education; early years; enquiry-based teaching; professional development; questioning

Introduction

Although all teachers ask questions as part of their classroom practice, not all questions help student learning to the same extent. Specifically for early years practitioners, being able to ask good questions and establish meaning-making dialogues is a key part of effective teaching, as development of verbal communication is a specific goal (Siraj-Blatchford et al. 2002). Questions are also a key part of student-centred enquiry-based science teaching (Oliveira 2010) as they can provide a starting point for the observation of natural phenomena, contrasting and comparing results, drawing conclusions and

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advancing learning of the concepts and skills of science (Minner, Levy, and Century 2010). In particular, teaching early years science with open-ended, higher-order questions has been found effective in advancing student development, as well as student's own question-asking abilities (Cabell et al. 2013; Jirout and Zimmerman 2015).

However, the use of effective questions and questioning strategies in early years science may present several challenges for teachers (Siraj-Blatchford and Manni 2008). In the first place, research shows that early years teachers do not always ask questions which promote understanding or critical thinking, instead relying often on recall-based, lower-level or closed questions, or simply using questions to monitor and control classroom activities rather than promote deeper learning (Newton 2013; Siraj-Blatchford et al. 2002). Moreover, asking questions in science is especially demanding for early years teachers, as they identify science as a particularly challenging area (Kallery and Psillos 2001) due to several factors such as lack of confidence in knowledge of science content, limited resources and training (Hollingsworth and Vandermaas-Peeler 2017; Kallery 2004).

These factors are worsened in underprivileged contexts in countries where there are great inequalities in the quality of education between schools attending wealthier and underprivileged student populations (Ganimian 2009), such as Argentina, the context of this study. This is partially due to material differences in resources available to schools, but also because wealthier schools are able to recruit more qualified and experienced teachers, as well as provide more frequent opportunities for professional development (Bezem 2012; Luschei and Carnoy 2010).

Encouragingly, providing professional development (PD) for teachers in early years science has been shown to improve teacher practice (Roehrig et al. 2011), as have programmes specifically designed to improve questioning in science (Oliveira 2010). However, a question arises about the ways teachers working at different socioeconomic status (SES) schools take up the lessons from teacher education programmes into their own classrooms.

Thus, in this study we compared how questions were used during the implementation of enquiry-based science lessons in four classrooms of two contrasting SES schools when given the same PD, science materials and lesson plans. For this case study, two contrasting preschools (one privileged and one underprivileged) received an intensive two-month PD session on enquiry-based science for two year children groups (four- and five-year olds), as well as a series of fully-planned science units and materials with which to implement the lessons in their classrooms. As questions are central to effective enquiry-based science practice, we particularly examined how many and which types of questions were used throughout implementation. We also analysed the student-teacher dialogues that arose from teacher questioning in order to understand how these could promote or constrain learning while implementing the same activities and lessons.

We addressed the following research questions:

- What types of questions did teachers from two contrasting SES schools ask their four- and five-year-old students when implementing the same unit following an enquiry-based science PD intervention?
- In what ways did the student-teacher dialogues generated by these questions enable or restrict student learning throughout the teaching unit?

Materials and methods

Research context

Two teachers each from two preschool institutions working with four- and five-year-old children (see Table 1) were selected to voluntarily participate in an enquiry-based science teaching professional development programme. Both schools had previously partnered with the university for various local educational projects, and were selected as they represent both the higher and lower end of the SES spectrum in Province of Buenos Aires, despite being geographically close by.

All four teachers had a degree in preschool teaching and over ten years of experience in their position. However, the on-going professional development opportunities available in both schools were markedly different. School 1 had a tradition of focussing on students' emotional and physical wellbeing and social support, and offered limited in-situ PD courses. School 2, as is often the case in more privileged contexts, had regular in-service training, co-planning sessions and peer observation experiences, and considerably more material resources available.

Professional development programme

Teachers participated in a two-month PD programme aimed at introducing the fundamentals of enquiry-based science through the study of two structured curriculum science units. The units were developed by the researchers, based on effective early years enquiry-based science frameworks and previous work with preschools. This was underpinned by a constructivist approach which places teacher questioning as central to the co-construction of knowledge between teachers and students (Kawalkar and Vijapurkar 2013).

Research has shown that structured curriculum units can increase science learning in older students (Lynch et al. 2005), as well as emotional well-being amongst pre-schoolers (Baker-Henningham et al. 2009). In this case, the four-year-old group implemented the unit on 'Light and shadows' and the five-year-old group on 'Sound' – both topics which fall within the national curriculum guidelines of 'material explorations' for early years science (Argentine Ministry of Education, Science and Technology 2004). Each

Table 1. Comparison of the two schools involved in the study.

School	School description	Institutional background	Teachers	Age group
School 1	Private parish school with state subsidy involving an underprivileged population. Spanish speaking.	Main focus on student wellbeing and social support. Teachers plan lessons individually. Class size: 25 students approximately.	Sabrina	4-year-olds
			Sonia	5-year-olds
School 2	Private school involving a privileged population. Bilingual school (Spanish and English).	Strong focus on teachers' professional development, particularly promoting metacognition and teacher reflection. Peer observations and co-planning sessions. School-wide science coordinator on campus to help plan and deliver inquiry-based science lessons. Class size: 25 students approximately.	Laura	4-year-olds
			Carla	5-year-olds

unit consisted of four full lesson plans, outlining not only the content and skill objectives for each 30-minute lesson, but also the pedagogical rationale behind each individual activity. They also included explicitly identified key questions that teachers could use to frame activities, as well as starters, experimental activities, opportunities for group work and assessment activities.

However, studies have shown that structured curriculum units are implemented with varying degrees of fidelity (Bismack et al. 2014). Teachers modify them (by design or by accident) to better align with their current teaching practices, sometimes lowering the cognitive load of proposed activities (Marco-Bujosa et al. 2017). For the best student outcomes, teachers must 'bridge the gap' between the materials and the classroom, and understand the aim and nature of each activity before implementation (Arias et al. 2016).

To facilitate this, all teachers also had a one-on-one coach throughout the duration of the programme (Kretlow and Bartholomew 2010), with whom they met on a weekly basis. The coach implemented the same lessons in similar classrooms first, to show the lessons in action, as well as 'proof of possibility' (Cochran-Smith 2004). These coach-modelled lessons were filmed, and then used during subsequent training sessions (Roth et al. 2011), when the coach and teacher would go over the questions used, the answers and dialogues elicited from students and jointly reflect on their effectiveness. The filmed lessons also allowed teachers to revisit and review elements of the model lessons in their own time. In total, the full time of the PD interventions (including observation of model classes, weekly sessions, observation and feedback sessions, and 'homework') came to roughly 30 hours. All materials and resources needed for the implementation of the units were supplied by the researchers.

Data collection

All lessons given by each teacher were filmed. In each case, the second and third lessons of the four-lesson sequence were chosen for analysis (a total of eight lessons across teachers and years groups). These two lessons were chosen in particular as they had a stronger emphasis on science content and enquiry-based science activities than the first lesson (which was more exploratory in nature) and the last lesson (which focussed more on evaluating student learning across the full unit).

Filming allowed us to capture different moments of each lesson (such as small group interactions, one-on-one dialogues and whole group conversations) and understand the context in which each question or conversation was arising. We worked with experienced classroom filmmakers who went in several lessons prior to the official lessons to allow children to become accustomed to the filming process (Stigler et al. 1999).

Teachers were interviewed for about 20 minutes at the end of the process using a semi-structured interview format. Interview questions focussed on understanding teachers' perceptions of the challenges they faced, what they learned and what they enjoyed about working with these structured curriculum units.

Data analysis

To answer our first research question, regarding the types of questions asked by teachers, lessons were transcribed verbatim and analysed. We first counted all questions posed by

the teacher to the students over the course of the full lesson to be able to numerically quantify and compare questioning practices between teachers and schools. As lessons did not all last the same amount of time when implemented (varying from 22 to 68 minutes), we normalised the total to 30 minutes.

We then focussed on the questions asked when teachers worked with all students (i.e. not in small groups or during one-on-one interventions). Here, questions that were specifically related to the lessons' science learning objectives (i.e. excluding those relating to classroom management or behaviour) were counted and categorised as 'productive' (Martens 1999), or 'non-productive' if they did not relate to overall lesson goals or promote student thinking. Statistical differences between both schools based on the proportion of productive/non-productive questions (i.e. grouping both teachers from each school and then comparing against both teachers from the other) were calculated using a Chi^2 test. Proportions of productive/non-productive questions were used rather than absolute values to normalise for differences in the implementation time.

We then categorised each productive question more specifically using an 8-part scale adapted from Martens (1999) (see Table 2). This was done to see which question teachers were asking to elicit different types of thinking in students, such as promoting metacognition, or higher-order learning skills such as reasoning. Again, the overall proportion of each type of productive question was compared between School 1 and School 2 using a Chi^2 test. We also compared between the four-year-old and five-year-old teachers from within each school.

To be able to answer our second research question regarding student-teacher dialogues and their impact on learning, we then undertook a more in-depth, qualitative discourse analysis of the dialogues between teachers and students. As a starting point, we defined effective questioning as clear, related to the lesson objectives, having wait-time, encouraging all students to participate as well as corrects, develops and praises student responses (Wilen and Clegg 1986). We also considered that questions need to form part of a cumulative back-and-forth exchange between students and teachers, where teachers use students' replies to assess and inform the future directions of their teaching (Anijovich and Mora 2010), and arrive at a developmentally appropriate correct answer. In order

Table 2. Categories of productive questions.

Category	Description	Example	
1	Attention – Focussing	Help students fix their attention on significant details	*Can you see the light coming through this material?*
2	Measuring	Help students be more precise about their observations (in the case of preschool, can include observations such as 'more' or 'less')	*How far do you think the sound came from?*
3	Comparison	Help students analyse and classify their observations	*Did it sound the same? How was it different?*
4	Action	Encourage students to explore and make predictions	*What would happen if we covered one of our ears?*
5	Problem-posing	Help students plan and implement solutions	*How can we make that sound louder?*
6	Reasoning	Help students think about experiences and construct new understandings	*Why was it so difficult to see if you had your eyes open?*
7	Meta-cognitive	Help students reflect and organise their learning	*How did we learn about that?*
8	Evaluation	Helps teachers and students evaluate to what extent content has been understood	*Is this material transparent, translucent or opaque?*

Table 3. Average number of questions asked by each teacher (mean number of questions normalised per 30 minutes).

	School 1 (low SES)		School 2 (high SES)	
Teachers	Sabrina	Sonia	Laura	Carla
Average number of questions asked over 30 minute periods	235	160	61	80

to understand the differences in teachers' questioning processes in both contexts, we particularly focussed on comparing the dialogues that emerged as teachers implemented the same activity in each school.

Results

In general, we observed that all teachers asked a large number of questions as part of their lessons, with all four teachers favouring a dialogic exposition strategy (Anijovich and Mora 2010). As our first finding, teachers in School 1 asked considerably more questions on average than did those in School 2 (see Table 3), and also above findings from previous studies (Newton 2013). This would, at first glance, suggest that these lessons were constantly involving students and therefore more dialogic. However, it invites the query as to the content of these questions and how much time was given to student answers.

To then answer our first research question we classified these questions in more detail, as well as analysed the dialogues created by the different types of questions.

Productive or non-productive: that is the question

When differentiating between productive and non-productive questions, we found that the proportion of productive questions formulated by teachers varied significantly amongst schools, with teachers from the higher SES School 2 asking a significantly higher percentage of productive questions than their peers in School 1 ($chi^2 = 32{,}21$, p-value < 0.01) (see Figure 1).

The percentage of productive questions formulated by the teachers from School 2 was considerably higher (75% for Carla and 78% for Laura) than that in School 1 (just above 50% in both cases). In this sense we have one first interesting finding, in that although the absolute number of productive questions was higher in School 1, the proportion of productive questions was higher in School 2. In other words, School 1 used more productive questions, but accompanied by a high number of non-productive questions, which might have 'buried' these productive questions and generated confusion amongst children regarding the purpose of the conversation.

To illustrate the effects of this difference in action, we looked at the specific dialogues that arose as teachers carried out the same learning activities. As both teachers were working with the same structured curriculum unit, this provided us with the opportunity to really 'zoom in' on how different questions and dialogues based around the same activity could lead to differences in learning outcomes. The ensuing findings are therefore in response to the second research question.

Fragment 1 (Quiet or loud?) exemplifies how the same activity (where students were asked to share sounds they had found around their house), was implemented in each

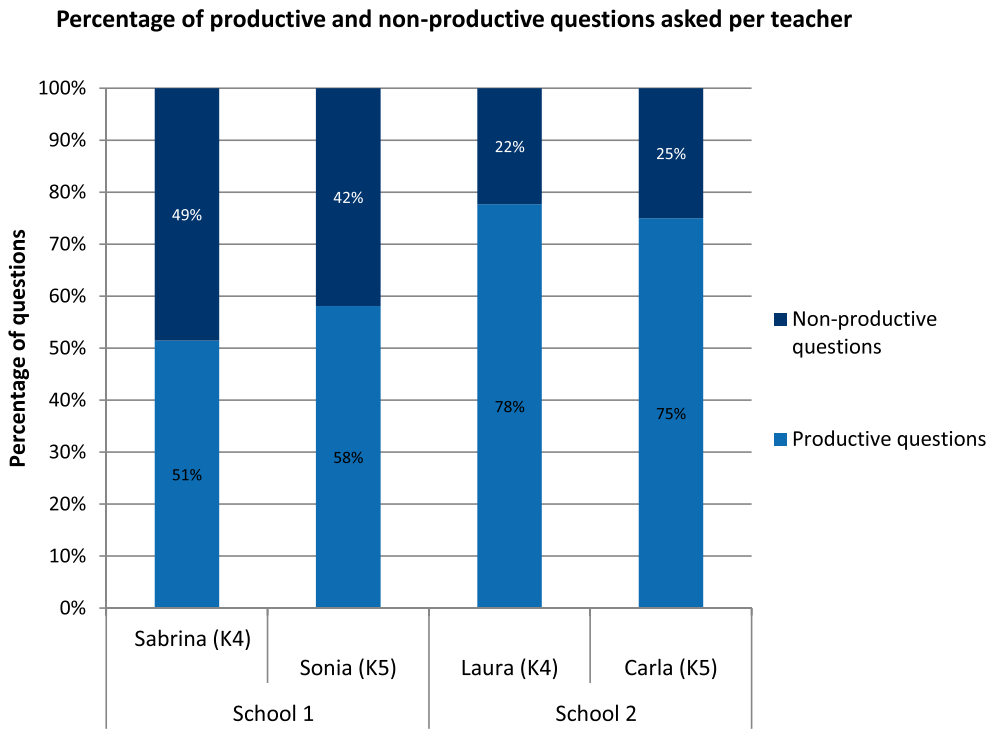

Figure 1. Productive and non-productive questions asked per teacher.

context. In particular, students were asked to distinguish between and compare different types of sound, considering only their intensity or volume, a concept that they had learned in a prior lesson.

Fragment 1: Quiet or Loud? Introduction to Lesson 2 on Sound (Five-year-olds). Students were asked to describe the intensity of sounds they found in their homes.

Sonia (School 1)	Carla (School 2)
T = Teacher; S = Students; [P] = productive questions; [NP] = non-productive questions	
T: So, did you find any noi … sounds? [P]	T: Well, let's start with … S1. Did you bring a sound? [P]
S1: I did!	S1: My musical box.
T: Let's see, what did you find? [P]	T: We will listen and we are going to try and find out if that sound is loud or soft, let's see. (*S1 makes the sound*). That sound, how do you think it was? [P]
S1: This sound (*makes a noise with his mouth*)	Students: Medium.
T: And what made that sound? [NP]	Students: Soft.
S1: I don't know, but I found it in my house.	Students: Quiet.
T: Where did you find it? [NP]	T: Some people think soft, and others say medium. Does anyone think this sound is loud? [P]
S1: I made it.	Students: No.
T: Ahhh, I see. Did everyone hear him? [NP]	T: Ok, we agree with that, good going. S2, is your sound around here? [NP]
Students: Yes …	S2: I have three.
Students: No..	T: Three sounds? Wow!
T: Want to do that again S1? [NP]	S2: (*claps*) That's from the rain. This is a horse (*makes a sound with her mouth*) and this is a kiss (*air kisses*).
S1: (*makes noise again*)	T: Oh what lovely sounds! Were those sounds quiet or loud or medium or average? [P]
T: Very good. Who else brought a noise? [P]	Students: Medium.
S2: Me (*goes to get backpack*)	
T: Wow! What a mystery. What is she going to bring out? [NP]	
S3: I know, it's a can.	
S4: It's a Disney can!	
S2: (*sits back down again, smiling, and knocks*	

the can with a small stick)
T: Very good! And what are you making the sound with? [NP]
S5: With a can and a thing …
T: It's like a little pencil. Who helped you find that sound? [NP]
S2: My dad.
T: Ok everyone, let's hear who helped her.
Students: Her dad
T: Her dad helped, very good. And who else brought a sound? [P]
S6: I didn't bring one, but I heard one.
T: Ok. Which one? [P]
S6: The sound that a car makes.
T: And what sound do cars make? [NP]
S6: (*makes a car sound*)
T: Very good.
Students: Soft.
T: Medium and soft. For now all the sounds have been medium and soft.
(*Another student stands and searches for his object. Blows a football-shaped trumpet)*
T: I cannot believe it, it's a very loud sound! I didn't know any trumpets with that sound, I've never seen one. What sound is that? [P]
S3: Loud
(*S4 takes out 3 instruments and plays them*)
T: And what are those sounds like? [P]
S4: With these holes (*showing the flute*) you play like that and there are sounds.
T: And is the sound: soft, medium, loud? [P]
Students: Soft.

The fragment shows how Sonia, from School 1, asked questions that pointed to aspects that were not related to the core objective of the activity (for example, she asked where did the sounds come from, who helped students find them, etc.) and she did not inquire about their intensity, the central concept of the lesson. On the other hand, Carla from School 2 continuously asked her students productive questions that were explicitly related to the scientific learning outcomes of identifying and comparing different types of sound in terms of their intensity (such as *'Were those sounds quiet, loud or medium, average?'*).

Similarly, although both teachers praised and valued the students' contributions, only Carla refocused her comments to whether the sound was soft, medium or loud (one of the main objectives of the lesson), and expected 'correct' answers in terms of students actually identifying the noises as loud, medium or soft. For example, this can clearly be seen when she refocused student 4's comment about how the sound is made ('With these holes [showing the flute] you play like that and there are sounds') to identifying the intensity of the sound the instrument makes (soft/loud).

Sonia, on the other hand, focused her questioning mostly on anecdotal aspects. In this sense, we found that some occasions arose which could have been exploited to help students move forward in their understanding of the different types of sound. For example, the fact that many students weren't able to hear the sound S1 made presented an interesting chance for students to perceive the differences between quiet and loud sounds, an opportunity that the teacher did not take advantage of.

These initial results showed that teachers from School 2, even though they asked fewer questions, had a higher proportion of productive questions which provided their students with more opportunities to further their science learning, as the questions they did ask were closely aligned with the specific science learning objectives. Having clear learning goals in mind seems to allow these teachers to adapt their questions according to their students' answers.

Although both teachers from School 1 recognised the importance of questioning as a way of understanding students' prior knowledge and furthering learning, in practice, they were rarely able to use student responses as a bridge between 'where students are' and 'where we want them to be'. In fact, teachers from School 1 were conscious about the difficulties they had regarding asking questions in practice, and identified 'asking good questions' as one of the biggest challenges of working with the unit:

> The thing I'm finding hardest is asking questions. How am I going to ask that question to be able to keep working on the topic, or being scared of asking or how can I set out the activity? (Sonia, School 1)

> I'm struggling a lot to think about which questions I need to ask so that they can learn, to enable them to explore their knowledge and learn (Sabrina, School 1)

On the other hand, School 2 teachers did not identify questions as a difficulty. Instead, what they found most challenging was addressing specific scientific contents, a difficulty that teachers from School 1 also shared. During the teacher training sessions, School 2 teachers seemed more confident in suggesting modifications and adaptations to the unit, including proposing new questions to guide students` thinking processes.

Different questions for different kinds of learning

Within the productive questions, we were also interested in identifying specific types of questions formulated by each teacher, since these types are associated with different learning goals (for instance, promoting metacognition, or higher-order learning skills such as reasoning) (see Figure 2).

The results show that all four teachers asked a variety of productive question types over the course of the analysed lessons. There were, however, significant differences in the relative percentages of different productive question types between School 1 and School 2 ($chi^2 = 31.08$, p-value < 0.01), but not between four-year-old and five-year-old class teachers within each school (School 1: $chi^2 = 9.88$, p-value > 0.1; School 2: $chi^2 = 11.09$, p-value > 0.01). This suggests that it wasn't the specific unit which caused the difference in types of questioning, but rather how that unit was implemented.

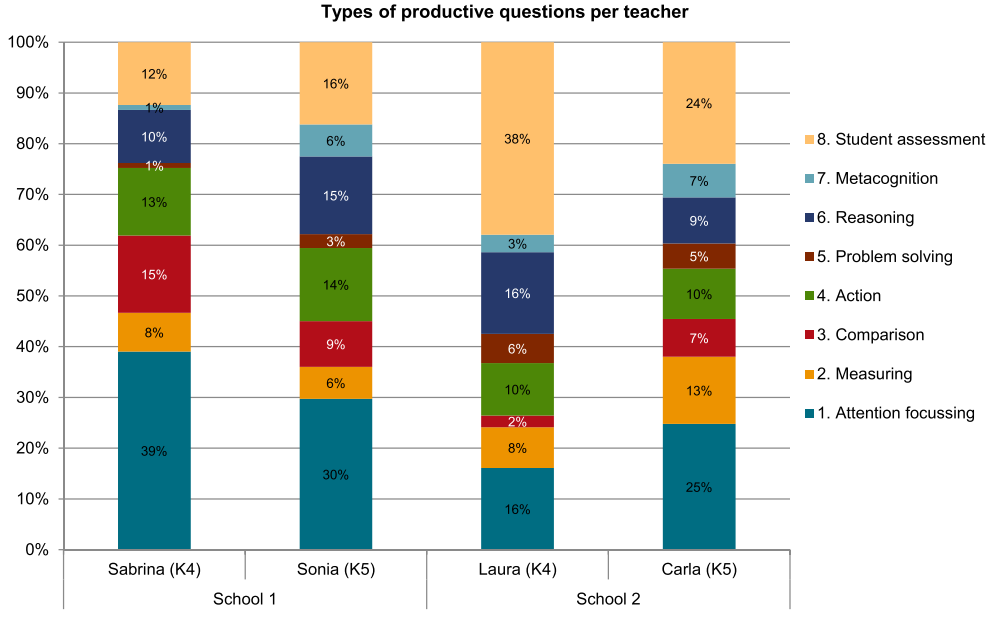

Figure 2. Types of productive questions formulated per teacher.

Lesson transcripts showed that the 'Measuring', 'Comparison', 'Action', 'Problem solving', 'Reasoning' and 'Metacognition' questions were closely associated with the questions proposed within the structured curriculum unit. This suggests that a well-planned unit can provide teachers with a variety of meaningful and productive questions to ask when implementing science activities.

As a result, Laura (four-year-olds, School 2) expressed that the unit provided her with examples of questions and other tools that allowed her to engage students in more in-depth learning than frequently happened prior to implementation:

> The structured curriculum unit fostered students to develop a certain way of thinking. During each lesson, the conversations I was able to sustain about the activities allowed the kids to really develop and deepen their understanding about what they are investigating while playing and having fun.

Our chosen statistical test allowed us to make overall comparisons between the percentages of question types. However, although we cannot make statistical inferences on a category-by-category basis, the types of questions that showed higher differences between schools were the Attention-focussing and Evaluation questions. Our results showed that School 1 teachers asked a higher percentage of Attention-focussing questions (such as 'What did you see?'), compared to School 2, who in turn asked a higher percentage of Evaluation questions compared to their colleagues at School 1 throughout the course of the lesson.

Regarding Attention-focussing questions, both Sabrina and Sonia from School 1 used these types of questions considerably more than any other (39% and 30% respectively). On the other hand, in School 2, Attention-focussing questions made up 16% (Laura) and 25% (Carla). These were the questions that aimed at having students focus on specific details, such as the pitch of the sound they were hearing, or the shape of a shadow. This is an interesting result, as although Attention-focussing questions are important – and it is expected that they should predominate at the preschool level – they are also the type of question with the lowest cognitive load due to being related to direct observations and ideas from prior knowledge.

The other most significant difference between the types of questions asked at each school was in the proportion of Evaluation questions posed by teachers. It can be seen that teachers from School 2 – Carla and to a greater extent Laura – asked a large number of questions aimed at monitoring the students' understanding of scientific contents (24% and 38% respectively). This had consequences on the learning opportunities provided to children, as these questions allowed teachers to collect evidence of their understandings to reorient their teaching strategies. They also helped teachers see whether students had changed their initial ideas about a topic or maintained their misconceptions.

As seen in Fragment 1 (Quiet or Loud?), Carla started the lesson assessing students' understanding of the concept of sound intensity, which was addressed during the previous class. She also used Evaluation questions continuously throughout each lesson activity to guide and monitor the partial conclusions students drew after each experience. For instance, as Fragment 2 (How does sound travel?) shows, after trying if sound could be heard through solid elements such as a table or the wall, how Carla posed a series of questions to check for student understanding.

Fragment 2: How does sound travel? Middle of Lesson 3 on Sound (five-year-olds), School 2
Students are learning that sounds travel through solids, liquids and gasses.

Carla
T = Teacher; S = Students; [P] = productive questions; e = Evaluation questions

T: We did the test. What happened with the table? [P.e]
S1: We heard the sound in the table that was like this [he bangs the door]
T: What conclusion can we draw from this? Can sound travel through the table or not? [P.e]
S2: It can go through the table because it can be heard better when you have the ear on the table.
T: What happened with the wall? S3 you tried it … did sound travel through the wall to your ear? Did it arrive? [P.e]
S3: Yes.
T: It arrived at your ear. This means sound can also travel through the wall. And how about other materials? What about through water? [P]

In this case, Carla was able to check that students had understood that sounds were able to travel through solid materials, and thus asked the follow-up question of whether sound could travel through liquid materials such as water. As the student correctly answered that the sound 'arrived' to their ears, and that it must have travelled through the table to get there, the teacher was able to assess their understanding of the science content. This conversation helped Carla understand where she needed to go next, as well as stimulate productive thinking in her students (Chin 2006).

In School 1, however, fewer Evaluation questions were asked (12% in four-year-olds and 16% in five-year-olds). In addition, the bulk of these questions were asked at the end of the lesson, and not throughout each activity as in School 2. This may have negatively impacted student understanding, as teachers became aware of errors and misconceptions only when the lesson was ending. For instance, when comparing the same lesson on 'How does sound travel?' students from School 1 had difficulties establishing through which media sound could travel. Fragment 3 shows how a student responded that sound travelled through the mountains (which she could not have observed during this particular lesson, therefore making this answer 'incorrect' in terms of what the teacher was asking about; a more correct answer would have made reference to the table, water or air examples seen earlier. Also, the teacher could have clarified that the sound didn't come 'from' the air, but rather travelled through the air from the noise's source). In this case the student's responses were not only never picked up and rectified by the teacher, but actually endorsed as correct:

Fragment 3: How does sound travel? End of Lesson 3 on Sound (five-year-olds, School 1)
Students are learning that sounds travel through solids, liquids and gases.

Sonia
T = Teacher; S = Students; [P] = productive questions; e = Evaluation questions
T: Where does the sound come from? [P.e]
S1: From the air.
T: It comes from the air. (*Pointing to the student's drawing*) Are you saying that the girl makes a sound and this is the path sound makes through the air and arrives where? [P.e] (*expecting the answer: ear*)
S2: To the mountain.
T: To the mountain. So, sounds travels through the air and then arrives at your … (*expecting the answer: ear*)
S2: Mountain
T: Very good! Let's give S2 a big applause.

Therefore overall we found that, even when implementing the same unit, there were striking differences in the learning opportunities offered to children, which was in large part due to the nature and quality of the questions asked. Not only were the number and proportion of productive questions different in the two schools, but also the way that teachers used Attention-focussing and Evaluation questions to promote learning were particularly dissimilar, thus implying different opportunities provided to the students of each school.

Discussion

In this paper we aimed to understand how teachers implemented an enquiry-based science unit in two preschools from contrasting socioeconomic contexts following a two-month PD programme focussed on the fundamentals of enquiry-based learning. Given the importance of questioning for effective science teaching across all contexts, we specifically analysed how teachers used questions to foster learning. We looked at the number and types of questions teachers asked, and the impact that these questions had on learning outcomes as identified from student-teacher dialogues.

Overall, we found that all four teachers valued questioning as an important part of teaching, and all asked a large number of questions when working from an enquiry-based science structured curriculum unit. However, we found striking differences between the schools in terms of the types and effectiveness of questions posed by teachers. Firstly, although teachers from School 1 asked more questions overall, the teachers in School 2 asked a considerably higher proportion of productive questions (i.e. those questions which moved children towards specific science learning objectives). Within the productive questions, School 1 teachers asked mostly Attention-focusing questions, which by their nature tend to be of a lower cognitive demand, and School 2 teachers asked considerably more Evaluation questions.

These findings have implications in terms of student science learning and teacher professional development programmes. Regarding student learning, the fact that School 2 teachers aligned their questions with lesson goals, constantly evaluated understanding and, more importantly, truly listened and responded to their children's strengths and misunderstandings, enabled them to generate better opportunities for science learning. By using effective questions and questioning, School 2 teachers fomented meaning-making conversations that accurately ensured that their children were constructing the correct scientific explanations related to the phenomena they were exploring. The students in School 2 were more explicitly guided towards the proposed science learning goals, and teachers used student answers to redirect their questioning towards the construction of new scientific knowledge. In particular, teachers from School 2 were more adept at dealing with student responses, including student mistakes and misconceptions, and utilising these as springboards from which to correct their understanding (Chin 2006).

On the other hand, School 1 teachers did not always effectively respond to their students, leaving incorrect answers frequently unchallenged or disagreements unclarified (such as when half the class shouted 'yes' and the other half 'no', with no agreement). There were also situations when students did not answer exactly what teachers were expecting, leading them to give strong 'hints' (such as 'Light can travel through because the material is traaans … .', when expecting students to say 'transparent'). Due to this,

the students' answers were not as rich, and not as convenient a springboard from which to construct knowledge, as were the responses from students in School 2. The fact that teachers asked so many questions in School 1 (an average of 5–8 questions per minute) also suggests that the driving force of the lessons was teacher talk, rather than true dialogues. School 1 lessons were more teacher-centred, and teachers gave less time for student thinking processes or responses. It also shows that, although useful as a starting point for enquiry-based science practices, providing structured curriculum units with good questions is not enough to fully develop science questioning practices, as these questions need to be part of a wider conversation that foments the construction of knowledge (Aizikovitsh-Udi, Clarke, and Star 2013).

Our results further supports the idea that the number of questions alone is not an indicator of their effectiveness (Cotton 2001), and expands upon this to suggest that the *proportion* of productive questions is important, and we suggest that high numbers of unproductive questions simply 'add noise' and are counterproductive to learning. For more effective teaching to take place, teachers need to have a deep understanding of how to use questions and student answers to build student understanding (Candela 2006). We suggest that future trainings take this into account, highlighting how the same question can enable or restrict a meaning-making dialogue between teacher and student. We suggest that a particular focus needs to be placed on how questions and answers can serve as bridges and springboards from which to redirect teaching towards specific learning goals.

One of the questions that arose for us as a result of these findings was: why were there such marked differences between schools (given that they were carrying out the same lessons following the same, intensive training?). Although it is hard to generalise from only four teachers, one possible explanation might be the level of confidence that teachers had with the science content, as seen by others (Kallery 2004). However, we don't think this was the case in our study, as all four teachers acknowledged their inexperience with the specific light and sound subject matter (which none had studied or taught before).

A second hypothesis that might explain the observed differences between schools is teachers' implicit views of the relationship between language and learning, which became evident in the dialogues they were able to generate and how they used student answers to guide them towards knowledge building. As we observed, even when giving teachers the same training, materials and lessons plans, the difference in the quality of learning opportunities seemed to arise from the specific questioning and dialogues generated spontaneously when implementing the same lessons. In School 1, teachers wanted students 'to say what I wanted' (Sabrina) or 'say the right answer' (Sonia), showing their own conception of learning as more encyclopaedic and teacher-centred, where the teacher imparts knowledge and questions only as a way of checking students' progress, rather than as a tool to construct new understanding. On the contrary, teachers at School 2 showed, in their dialogues with children, how students' ideas were important tools for the collective construction of meaning.

This may have been influenced by the prior opportunities for PD available at their respective schools. Unlike their colleagues at School 1, teachers at School 2 had received frequent on-going professional development (although not focussed on science) and were continuously asked to reflect with their peers upon their practice and on the process of student learning. Although this study only examined two institutions, the results suggest that

understanding these differences in contexts may be fundamental to be able to respond appropriately when designing new professional development programmes.

Along the same line, the cultures of each of the institutions were very different in regards to what was expected from children. In School 2, there is a clear focus on student learning and academic development, but less so in School 1, which acts as more of a community support centre. As such, the children in School 2 were noticeably more 'primary school ready', and more accustomed to lesson routines such as taking turns, reflecting and sharing their thinking, often giving long verbal answers. This was not the case in School 1, where at times the children visibly struggled with the longer periods of concentration demanded by the proposed science lessons. In this sense, teachers from School 1 had the extra challenge of introducing new classroom routines when implementing the unit.

Despite it being difficult to generalise from only two schools, in terms of the implications for PD efforts for schools of different SES contexts our findings suggest that teachers from the lower SES school would have perhaps needed further support with a more specific focus on the role of dialogue in constructivist learning as part of the PD programme. In particular, the analysis of videos showing their own in-classroom questions and dialogues from which to reflect upon their own practice might have supported them better in providing stronger learning opportunities for their students.

Developing effective teaching practices across all SES contexts is particularly important as high-quality early years education can promote student success many years later in both science education (Saçkes et al. 2011), and counteract disadvantages associated with coming from an underprivileged background (Schweinhart and Weikart 1997). However, this case study suggests that the context that is most in need of these meaningful dialogues shows a dearth of them. Given the striking differences we have shown in the kinds of learning opportunities children receive by age four and five, we end with a reminder of the urgency of this task.

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References

Aizikovitsh-Udi, A., D. Clarke, and J. Star. 2013. "Good Questions or Good Questioning: An Essential Issue for Effective Teaching." In *CERME8: 8th Congress of the European Society for*

Research in Mathematics Education. Antalya, Turkey. http://cerme8.metu.edu.tr/wgpapers/WG17/WG17_Aizikovitsh_Udi.pdf

Anijovich, R., and S. Mora. 2010. *Estrategias de enseñanza: otra mirada al quehacer en el aula* [Teaching Strategies: Another Look at What to do in the Classroom]. Buenos Aires: Aique.

Argentine Ministry of Education, Science and Technology. 2004. *Núcleos de aprendizaje prioritarios* [National Curriculum Guidelines]. Buenos Aires: National Ministry of Education. http://www.me.gov.ar/curriform/nap.html

Arias, A. M., E. A. Davis, J-C. Marino, S. M. Kademian, and A. S. Palincsar. 2016. "Teachers' Use of Educative Curriculum Materials to Engage Students in Science Practices." *International Journal of Science Education* 38 (9): 1504–1526. doi:10.1080/09500693.2016.1198059.

Baker-Henningham, H., S. Walker, C. Powell, and J. Meeks Gardner. 2009. "A Pilot Study of the Incredible Years Teacher Training Programme and a Curriculum Unit on Social and Emotional Skills in Community Preschools in Jamaica." *Child: Care, Health and Development* 35 (5): 624–631. doi:10.1111/j.1365-2214.2009.00964.x.

Bezem, P. 2012. *Equidad en la distribución de la oferta de educación pública en Argentina* [Equity in the Distribution of Public Education in Argentina]. Washington, DC: Inter-American Development Bank.

Bismack, A. S., A. M. Arias, E.A. Davis, and A. S. Palincsar. 2014. "Connecting Curriculum Materials and Teachers: Elementary Science Teachers' Enactment of a Reform-Based Curricular Unit." *Journal of Science Teacher Education* 25, no. 4: 489–512. doi:10.1007/s10972-013-9372-x.

Cabell, S. Q., DeCoster, J., LoCasale-Crouch, J., Hamre, B. K., & Pianta, R. C. 2013. "Variation in the Effectiveness of Instructional Interactions Across Preschool Classroom Settings and Learning Activities." *Early Childhood Research Quarterly* 28 (4): 820–830. doi:10.1016/j.ecresq.2013.07.007.

Candela, A. (2006). "Del Conocimiento Extraescolar al Conocimiento Científico Escolar [From Extracurricular Knowledge to School Science Knowledge]." *Investigación* 11 (30): 797–820. http://www.comie.org.mx/documentos/rmie/v11/n030/pdf/rmiev11n30scB02n02es.pdf.

Chin, C. 2006. "Classroom Interaction in Science: Teacher Questioning and Feedback to Students' Responses." *International Journal of Science Education* 28 (11): 1315–1346. doi:10.1080/09500690600621100.

Cochran-Smith, M. 2004. *Walking the Road: Race, Diversity and Social Justice in Teacher Education*. New York: Teachers College Press.

Cotton, K. 2001. "Classroom Questioning." *School Improvement Research Series* 3. http://www.learner.org/workshops/socialstudies/pdf/session6/6.ClassroomQuestioning.pdf.

Ganimian, A. 2009. *How Much Are Latin American Children Learning? Highlights From the Second Regional Student Achievement Test (SERCE)*. Harvard University OpenScholar. http://econpapers.repec.org/paper/qshwpaper/38411.htm.

Hollingsworth, H. L., and M. Vandermaas-Peeler. 2017. "'Almost Everything we do Includes Inquiry': Fostering Inquiry-Based Teaching and Learning with Preschool Teachers." *Early Child Development and Care* 187 (1): 152–167. doi:10.1080/03004430.2016.1154049.

Jirout, J., and C. Zimmerman. 2015. "Development of Science Process Skills in the Early Childhood Years." In *Research in Early Childhood Science Education* (pp. 143–165). Dordrecht: Springer. doi:10.1007/978-94-017-9505-0_7.

Kallery, M. 2004. "'Early Years Teachers' Late Concerns and Perceived Needs in Science: An Exploratory Study." *European Journal of Teacher Education* 27 (2): 147–165. doi:10.1080/026197604200023024.

Kallery, M., and D. Psillos. 2001. "Pre-school Teachers' Content Knowledge in Science: Their Understanding of Elementary Science Concepts and of Issues Raised by Children's Questions." *International Journal of Early Years Education* 9 (3): 165–179. doi:10.1080/09669760120086929.

Kawalkar, A., and J. Vijapurkar. 2013. "Scaffolding Science Talk: The Role of Teachers' Questions in the Inquiry Classroom." *International Journal of Science Education* 35 (12): 2004–2027. doi:10.1080/09500693.2011.604684.

Kretlow, A. G., and C. C. Bartholomew. 2010. "Using Coaching to Improve the Fidelity of Evidence-Based Practices: A Review of Studies." *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children* 33 (4): 279–299. doi:10.1177/0888406410371643.

Luschei, T. F., and M. Carnoy. 2010. "Educational Production and the Distribution of Teachers in Uruguay." *International Journal of Educational Development* 30 (2): 169–181. doi:10.1016/j.ijedudev.2009.08.004.

Lynch, S., J. Kuipers, C. Pyke, and M. Szesze. 2005. "Examining the Effects of a Highly Rated Science Curriculum Unit on Diverse Students: Results From a Planning Grant." *Journal of Research in Science Teaching* 42 (8): 912–946. doi:10.1002/tea.20080.

Marco-Bujosa, L. M., K L. McNeill, M. González-Howard, and S. Loper. 2017. "An Exploration of Teacher Learning From an Educative Reform-Oriented Science Curriculum: Case Studies of Teacher Curriculum Use." *Journal of Research in Science Teaching* 54 (2): 141–168. doi:10.1002/tea.21340.

Martens, M. L. 1999. "Productive Questions: Tools for Supporting Constructivist Learning." *Science and Children* 36 (8): 24–53. http://search.proquest.com/openview/0fbd771056955382 53f998eae1d38ff4/1.pdf?pq-origsite=gscholar&cbl=41736.

Minner, D. D., A. J. Levy, and J. Century. 2010. "Inquiry-based Science Instruction-What is it and Does it Matter? Results from a Research Synthesis Years 1984 to 2002." *Journal of Research in Science Teaching* 47 (4): 474–496. doi:10.1002/tea.20347.

Newton, L. D. 2013. "'Teachers' Questions: Can They Support Understanding and Higher-Level Thinking?" *Journal de Recherches* 1: 6–17. http://dro.dur.ac.uk/14996/1/14996.pdf.

Oliveira, A. W. 2010. "Improving Teacher Questioning in Science Inquiry Discussions through Professional Development." *Journal of Research in Science Teaching* 47 (4): 422–453. doi:10.1002/tea.20345.

Roehrig, G. H., M. Dubosarsky, A. M. Mason, S. Carlson, and B. Murphy. 2011. "We Look More, Listen More, Notice More: Impact of Sustained Professional Development on Head Start Teachers' Inquiry-Based and Culturally-Relevant Science Teaching Practices." *Journal of Science Education and Technology* 20 (5): 566–578. doi:10.1007/s10956-011-9295-2.

Roth, K. J., H. E. Garnier, C. Chen, M. Lemmens, K. Schwille, and N. Wickler. 2011. "Videobased Lesson Analysis: Effective Science PD for Teacher and Student Learning." *Journal of Research in Science Teaching* 48: 117–148. doi:10.1002/tea.20408.

Saçkes, M., K. C. Trundle, R. L. Bell, and A. A. O'Connell. 2011. "The Influence of Early Science Experience in Kindergarten on Children's Immediate and Later Science Achievement: Evidence From the Early Childhood Longitudinal Study." *Journal of Research in Science Teaching* 48 (2): 217–235. doi:10.1002/tea.20395.

Schweinhart, L. J., and D. P. Weikart. 1997. "The High/Scope Preschool Curriculum Comparison Study Through Age 23." *Early Childhood Research Quarterly* 12 (2): 117–143. doi:10.1016/S0885-2006(97)90009-0.

Siraj-Blatchford, I., and L. Manni. 2008. "'Would You Like to Tidy Up Now?' An Analysis of Adult Questioning in the English Foundation Stage." *Early Years: An International Research Journal* 28 (1): 5–22. doi:10.1080/09575140701842213.

Siraj-Blatchford, I., S. Muttock, K. Sylva, R. Gilden, and D. Bell. 2002. *Researching Effective Pedagogy in the Early Years*. Oxford: University of Oxford. http://dera.ioe.ac.uk/4650/1/RR356.pdf.

Stigler, J. W., P. Gonzales, T. Kawanaka, S. Knoll, and A. Serrano. 1999. *The TIMSS Videotape Classroom Study: Methods and Findings From an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States*. U.S. Department of Education National Center for Educational Statistics: NCES 99-074. Washington, DC: Government Printing Office.

Wilen, W., and A. Clegg. 1986. "Effective Questions and Questioning: A Research Review." *Theory and Research in Social Education* 14 (2): 153–161. doi:10.1080/00933104.1986.10505518.