Research in Science & Technological Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/crst20

Teachers' interventions in science education at primary school. The role of semiotic resources during argumentative interactions in classroom

Josephine Convertini, Francesco Arcidiacono & Céline Miserez-Caperos

To cite this article: Josephine Convertini, Francesco Arcidiacono & Céline Miserez-Caperos (2023): Teachers' interventions in science education at primary school. The role of semiotic resources during argumentative interactions in classroom, Research in Science & Technological Education, DOI: 10.1080/02635143.2023.2243835

To link to this article: https://doi.org/10.1080/02635143.2023.2243835

Published online: 11 Aug 2023.

RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION
https://doi.org/10.1080/02635143.2023.2243835

Routledge
Taylor & Francis Group

Teachers' interventions in science education at primary school. The role of semiotic resources during argumentative interactions in classroom

Josephine Convertini[a], Francesco Arcidiacono[b] and Céline Miserez-Caperos[b]

[a]Psychiatric Section of Mental Development, Department of Psychiatry, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; [b]Research Department, University of Teacher Education BEJUNE, Biel/Bienne, Switzerland

ABSTRACT

Background: In the field of science education, adults often set up practical-based activities with the idea of stimulating children's reasoning and approaching science in a playful way. Although the potential role of objects in stimulating social practices has been considered in the literature, how teachers work on semiotic aspects of argumentation is still less explored.

Purpose: In this paper, the purpose is to identify how practice-based experiences settled up by teachers shape children's argumentation in science education.

Sample design and methods: We analyzed argumentation in science tasks involving a total of 39 children (6–7 years old) and their three teachers, coming from two different classrooms of cycle 1 (Harmos, grades 3–4)[1] recruited in the French speaking-part of Switzerland. The tasks were video-recorded and then transcribed. Through the lenses of the pragma-dialectical approach, we selected the argumentative discussions emerging during the experiences and we performed a qualitative analysis of these interactions, by looking at different semiotic resources: speech, gaze direction, deictic gestures, and position of physical objects.

Results: The findings show that teachers play a crucial role in sustaining children's argumentation by the integration of different semiotic resources during the activities.

Conclusion: As argumentation in classroom evolves through the mobilization of various communicative tools, the present study can contribute to strengthen the interplay between different channels of interaction during science education at primary school.

KEYWORDS

Science education; argumentation; teachers' practices; primary school children; semiotic resources

1 Introduction

Research in science education clearly recognizes the role of argumentation as an inquiry-based approach common to various learning experiences for the children's achievement of high-quality results (Erduran and Jiménez-Aleixandre 2008). Current pedagogical paradigms in science education encourage the adoption of a practical approach based on

CONTACT Josephine Convertini josephine.convertini@chuv.ch Psychiatric Section of Mental Development, Department of Psychiatry, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

children's active participation (knowledge construction), rather than the design of activities having children listening to the adult (knowledge transmission) in the classroom (Siry, Ziegler, and Max 2012). Within this active paradigm, pupils can be observed during scientific experimentations and practical activities mediated by technology and different semiotic resources, also requiring the manipulation of objects and the use of different senses, e.g. touch (Ravanis et al. 2013). More particularly, Impedovo et al. (2017) highlighted how both material and social dimensions of learning are necessary, for example to understand shadow formation during an activity involving children's play. This attention to the multiple ways of connecting social and material relationships in the analysis of human interactions is a key aspect of our work: according to previous research (Arcidiacono and Pontecorvo 2019; Peals, Hetherington, and Vandenberghe 2002), we consider that it is relevant to analyze how materiality shapes discursive processes in science education.

As it is recognized that even very young children are able to argue (Pontecorvo and Arcidiacono 2010; Pontecorvo and Sterponi 2006), their engagement in practical activities poses new challenges for teachers interested in promoting explicit and argued science knowledge. In fact, argumentation defined as a verbal activity poorly complies with the science education requirement of favoring children's investigation through experiential activities (often requiring the manipulation of objects and the use of different semiotic resources). When children are faced to practical tasks, their argumentation may be considered as 'incomplete' because is not always supported by verbal statements (Convertini and Arcidiacono 2021).

The present paper focuses on primary teachers' interventions in science education and on the role of different semiotic resources that are mobilized during argumentative interactions with pupils. For these reasons, a collaboration between teachers and researchers has been set up, with the aim of designing a device enabling teachers to work with children so that the latter can learn to think argumentatively during problem-solving situations. To this end, the following questions were addressed by our study: how practice-based science experiences settled up by teachers shape children's argumentation in classroom? How teachers' interventions mobilizing different semiotic resources support argumentation in science? Which are the main features of children's argumentation during these practices in science education?

The paper is organized as follows: firstly, we briefly review the field of argumentation and teaching by advancing the reasons (for teachers) to promote argumentation in classroom. Then, we focus on some semiotic resources in science education that can allow a better understanding of the relevance of argumentation during different experiences at school. In section 3, we introduce our methodological design and the main elements of our study. After the presentation of the results (section 4), a discussion of the findings and a conclusion close the paper.

2 Theoretical framework

2.1 Teaching and argumentation

In field of education, the reasons for teachers to approach pupils' argumentation should be summarized by two main aspects. The first reason is about the connection between

argumentation and knowledge construction. According to Jim and Pérez (2020), 'argumentation is a fundamental discursive activity to the social, linguistic and cognitive development of human beings' (p. 14, our translation). Argumentation appears as a crucial aspect to be investigated in education because of its intrinsic nature as a form of reasoning. Within a dialogical stance, it is possible to define an argumentative event 'as a contextualized form of social practice, in which at least two parties take alternative positions on the same issue' (Zadunaisky Ehrlich 2011, 249). Thus, argumentation is a context-dependent activity (Rigotti and Greco Morasso 2009) that always implies the presentation of alternative argued positions (standpoints) with respect to a problematic question (the issue). Argumentation should not be seen as a conflict in the strict sense: people may agree on the same standpoint, argue and challenging it in a cooperative manner. The moment in which the interlocutors meet the other's position is a situation of transition, of going back to the own reasoning. This dialogical encounter can potentially lead participants to consider aspects of the problem hitherto ignored and can push the interlocutors to adopt a different perspective. For this reason, an invitation to argue is always a request to reason (Greco 2018) and, accordingly, argumentation could be a powerful engine for knowledge building.

A second reason to focus on argumentation is related to the role that it plays in the field of citizen education. In fact, argumentation is relevant for the development of young people and for promoting democratic societies (Schwarz and Baker 2017). Argumentation should be understood in a broad sense, as a mean by which individuals are adapting to the environment and develop the feeling of belonging to a community. According to Migdalek *et al*. (2020), within an argumentative debate, 'resolving a difference of opinion enables children to internalize the values, beliefs and norms of their community' (p. 33, our translation). For this reason, children's participation in argumentative discussions at school is widely encouraged: already from early childhood education, they are invited to take an active role in debates of different nature. For example, the approach named 'Philosophy for Children' (P4C), developed in the 1970s in the United States, is a curriculum that offers children the possibility of expressing an opinion, justifying it, proposing counterarguments and referring to the others' standpoint (Scipione 2020). P4C is not only a matter of reasoning logically: within an argumentative interaction, children can positively gain experience through debating with others (Lipman 1982). As they are invited to listen, to avoid overlapping, and to be familiarized to the art of raising respectful questions, P4C should be an arena in which argumentation is expressed in a constructive way to develop pro-social behaviors and educational values.

For these reasons, the promotion of pupils' active participation in argumentative discussions at school and the development of fruitful exchanges are considered as crucial aspects of education. A constructive dialogue can be achieved through the development of an exploratory talk, in which 'partners engage critically but constructively with each other's ideas. Statements and suggestions are offered for joint consideration. These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered (. . .) in exploratory talk knowledge is made more publicly accountable and reasoning is more visible in the talk' (Mercer 1995, 104). The aim of teachers who are attentive to promote a constructive (argumentative) interaction is to establish the conditions that would lead pupils to make explicit their line of reasoning and to build their knowledge by relying on others' arguments. Alongside these conditions, there are others

related to a diplomatic attitude in a discussion, such as respecting the point of view of others, maintaining an active listening or not preventing others from expressing a point of view. Previous studies have proposed the use of multiple educational devices at school (at different degrees of education, from kindergarten to university) with the aim of exploring and implementing argumentation activities, leading students to develop a reflective discursive thinking (Fortes, Gómez, and Larrain 2020). However, the question of how to design (with teachers) argumentative practices in classroom remains (Miserez-Caperos and Arcidiacono 2021).

Research in the field of education offers a variety of argumentative situations that are proposed to students in many fields, as well as a view of the difficulties they can experience in developing arguments (Buty and Plantin 2008). Although children have a great ability to argue in everyday life (Arcidiacono 2015), the arguments they deploy in classroom often appear disappointing to teachers (Schwarz and Glassner 2003). The situations in which students construct arguments to address the questions asked by their teachers are relatively little documented (Muller Mirza 2015). In contrast to what emerges in spontaneous interactions, argumentation in classroom, and more particularly in scientific settings, rarely emerges spontaneously, although it could be the result of a careful construction (Schwarz and Baker 2017). Thus, it seems that students develop arguments only when teachers are able to set a proper framework and the necessary conditions that push children beyond their current abilities (Convertini 2021b). Under certain conditions, children would thus be able to develop arguments, to justify them, to consider the perspectives of their peers, to present counter-arguments, and so on. For this reason, the need to build with teachers proper designs for argumentative practices is actual.

2.2 Semiotic resources in science education

Early science education is intended to 'develop each child's innate curiosity about the world; to broaden each child's procedural and thinking skills for investigating the world, solving problems, and making decisions; and to increase each child's knowledge of the natural world' (Bredekamp and Rosegrant 1995, 45). Within science education, it is evident that argumentative activities can play an important role for achieving these objectives. Moreover, researchers have clearly recognized the importance of offering children learning experiences founded on practice-based approaches (Siry, Ziegler, and Max 2012). Children are often invited to participate in activities including objects that stimulate different senses, e.g. magnets (Ravanis 1994), flashlights (Impedovo et al. 2017), thermometers (Kampeza et al. 2016), or building blocks (Migdalek, Rosenberg, and Santibáñez Yáñez 2014). Among the many benefits of these activities, scholars highlight the integration of children speaking a different language who can achieve high quality results by approaching science through different channels (Gómez Fernández & Siry, 2018). These elements suggest the necessity to investigate deeply the role of semiotics resources (such as speech, gazes, gestures, actions on objects) in teachers' practices, from the point of view of their impact on children's argumentation. In this sense, we are in line with a recent work made by Tang (2022) who reframes argumentation as a chain of human-material interactions incorporating the role of physical things to construct evidence. As proposed by the author, we recognize the relevance of examining the place of materiality in argumentation also in consideration of the relatively recent attention in science education

(Milne and Scantlebury 2019; Sørensen 2009). More precisely, the question of how materials, in coordination with speech and gestures, work together to create joint meaning in scientific activities at school constitutes a central issue in research on argumentation in science education. Accordingly, in our paper the reference to semiotic resources is considered as the orchestration of material objects, actions and speech to actively create evidence in solving a task, and to better understand how materiality coordinates with speech and actions to shape argumentation.

By referring to speech and gestures as two modes for making meaning within learning situations (Bezemer and Kress 2020), we propose to explore argumentative practices in the context of science education by considering the semiotic resources that contribute to the understanding of pupils' argumentation at school. We also are looking to identify the multimodal resources that make teachers aware of the children's way of combining different skills.

Studies in communication have analyzed the practices of introducing a topic of discussion (González-Martínez and Giglio 2020), the use of pointing gestures in turn-taking (Mondada 2007), the different resources (talking, gazing, manipulation of artefacts) mobilized by children in collaborative problem solving, and when trying to achieve a mutual understanding (Arend and Weis 2016). In addition, other competences (e.g. laughter and smiles) used by students to formulate an opinion on a delicate issue (Petitjean and González-Martínez 2015), the role of pointing gestures in establishing interlocutors' joint attention towards a common object (Mondada 2014) or a situation (Kidwell 2009), the role of gaze direction, deictic gestures, and speech in establishing different positions and reference in argumentative events (Jacquin 2018), the interplay between verbal, gestural, and written semiotic resources in knowledge-construction and mediation (Polo and Colletta 2020), as well as the organization of conversation within an interactional space (González-Martínez et al. 2016) have been indicated as crucial aspects to highlight the richness of semiotic elements of argumentation. In line with these elements, we intend to focus on the importance for teachers of integrating different semiotic resources as means of promoting children's argumentation in classroom. More specifically, we are convinced that science education constitutes a fruitful area to develop designs, co-constructed with teachers, aiming at soliciting their pupils to activate different channels of interaction during practice-based activities in science.

3 Method

3.1 Context and participants

A group of three primary school teachers[2] working in the French-speaking part of Switzerland was involved to investigate how a collaborative design established between researchers and practitioners can enable children to develop both a diplomatic attitude in a discussion and cognitive argumentation, namely argumentation focused on the construction of knowledge. During two school years, we worked together with these teachers and their classroom (HarmoS grades 3–4), involving a total of 39 children (6–7 years old).

The present study is part of an ongoing collaborative research (2020–2023) providing a cycle of repeated interventions (phase 1 and phase 2) with teachers in terms of classroom observations, self-confrontation interviews, co-analyses, and implementation

of new teaching sequences (Arcidiacono and Miserez-Caperos 2022). More specifically, in the phase 1 teachers were requested to choose an activity in which children were invited to enter into an argumentative discussion, while being in line with the objectives of the curriculum (PER[3]). These activities were linked to the MER[4] areas, for example in natural sciences, French or mathematics, and then reworked collaboratively with the researchers, to reflect on the advantages or necessary adaptations. Each activity was thus designed as an *ad hoc* situation, in relation to the pupils' grade. At the end of the first phase, the analyses of classroom argumentative discussions were presented to the teachers by the researchers to conduct a reflexive work on these analyses. Concrete ideas on how to lead children to develop skills in argumentative situations also were shared with teachers. The phase 2 consisted in an iteration of the phase 1. The argumentative situations already developed were adapted, while others were created. In addition, the first concrete ideas shared with the teachers during the phase 1 were completed. At the end of the phase 2, researchers and teachers also continued the reflective work begun in the first phase. An evaluation of the experience also was proposed to the participants.

In the present paper, we focus on the phase 2 and more particularly on practice-based science experiences in which a teacher worked one of the properties of air, namely the fact that air takes up space. Groups of four students take turns leaving their classroom to do a science experiment, which took place in the school corridor. Children were around a table in which the following material was available: a basin full of water, a glass, a paper ball, and a sheet with the task's instructions. Participants were requested to discuss the following issue in order to make hypotheses: if a paper ball is crumpled and placed in the bottom of the glass, does the paper will get wet or dry whether the glass is immersed into the basin full of water? According to the task's instructions, children were requested to support their opinions by arguments. After having expressed their hypotheses, they were free to make the experience (to insert the paper into the glass, and then to reverse the glass by putting it into the basin of water). Afterwards, children were invited to discuss with the teacher and to reflect about the result they observed (namely, the fact that the paper inside the glass remains dry).

As we intended to generate insights on the role of semiotic resources based on the analysis of participants' interactions within a localized case, for the purpose of this study the case has been defined as the series of experiences around the proposed task on air.

3.2 Analytical approach

The interactions involving teachers and children in science education were video-recorded. Two cameras were used to capture the scene from different angles and to ensure a finer-grained analysis of data. All the interactions were transcribed by using the system of transcription elaborated by Jefferson (2004), including not only speech, but also annotations concerning other aspects (such as gaze direction, the position of physical objects and deictic gestures) that could play a role in shaping argumentation.

To analyze the data, we adopted tools from modern and contemporary argumentation theories: the pragma-dialectical approach and a discursive approach have been combined to identify the different components of argumentation that can contribute to shape discussion. The analytical overview from the pragma-dialectical

model of a critical discussion (Eemeren van and Grootendorst 1984, 2004) has been widely applied to analyze argumentative discussions with children. For example, it has proved to be an efficient instrument for disclosing argumentative components in discussions on the resolution of cognitive tasks (Convertini 2021a; Perret-Clermont et al. 2015), in child's argumentation during family mealtime conversations (Arcidiacono, Pontecorvo, and Bova 2022) or while discussing about different topics at school (Greco, Mehmeti, and Perret-Clermont 2017). The analytical overview allows to differentiate between argumentative and non-argumentative components. In addition, it permits to make explicit the standpoint of the argumentation, the arguments and the relation between them (for example, in the event that more than one argument is advanced, it is important to establish how the arguments jointly support the standpoint). The pragma-dialectical approach to argumentation has been used as a normative criterion for segmenting and selecting the sequences for reconstructing the components of an argumentative exchange (standpoints, arguments and types of conclusion).

As the paper focuses on teacher-pupil argumentative discussions in science education, an analysis of how they argue and which semiotic resources are activated during science activities is proposed. As already indicated, the present study adopts an integrated analytical approach, necessary since teacher-pupil argumentative discussions can be better investigated by considering various dimensions of the discourse produced around an activity (specifically: speech, gaze direction, manipulation of artefacts, and deictic gestures) and by treating them in a comprehensive way, namely by looking at how they are interrelated during the interaction (Stivers and Sidnell 2005).

4 Results

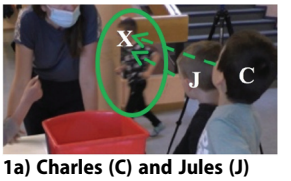
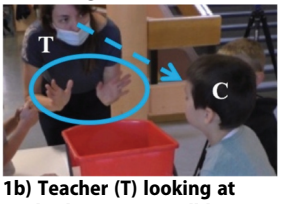
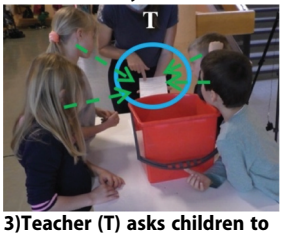
In this section, we present three illustrative examples related to two different groups of children asked to work on the above-mentioned task about one of the properties of air. The excerpts are representative of situations in which different semiotic resources were activated by participants during activities of science education designed to promote argumentation. The examples have been selected on the following ground: the interaction among participants was a fruitful occasion to analyze argumentative discussions about a scientific phenomenon; there was a use of material objects to support children in the scientific experience.

All names in the excerpts are fictitious names. Original French transcription is provided. Pictures of some semiotic resources activated by participants (indicated in *blue* for the teachers, and *green* for the children) are provided in the last column. The sections in bold highlight moments of the interaction that refer to a certain picture (numbered according to the order appearing in the transcription, e.g. 1a, 1b, 2, 3, . . .).

4.1 Excerpt 1

Children are standing around a table on which the material necessary for the task is available. At the beginning of the interaction, the teacher leaves children time to read the sheet and, after a few minutes, she asks what they have understood about what they should do to carry out the experiment. Children answer the question and the teacher grasps the glass to start the experience.

Participants: teacher, Charles, Jules, Lea and Melody.

Turn	Participant	Original French transcription	English translation (verbatim)	
(00:01:16)				
33	Teacher	oui mais maintenant, j'ai juste une question, avant de faire l'expérience, j'aimerais que vous regardiez ailleurs. on va profiter qu'on est ici, on a 10 minutes pour cette expérience, c'est pas beaucoup. d'accord? alors qu'est-ce que je vais dire, oui, je vais faire. *(en reprenant le verre des mains de Melody)* le papier il est mouillé. pourquoi il est mouillé? *(ayant touché le papier)*	yes, but now I have just one question, before doing the experiment, **(1a) I would like you to look elsewhere**. we're going to take advantage of the fact that **(1b) we're here**, we've got 10 minutes for this experiment, it's not a lot of time. okay? so what am I going to say, yes, I'll do it. **(2)** ***(taking the glass from Melody hands)*** the paper is wet. why is it wet? *(having touched the paper)*	 **1a) Charles (C) and Jules (J) look another child (X) crossing the area**
34	Jules	ben, parce qu'elle *(Melody)* l'a mâchouillé comme ça, avec ses mains. *(en désignant Melody et bougeant sa main)*	well, because she *(Melody)* chewed it up like that, with her hands. *(pointing at Melody and moving his hand)*	 **1b) Teacher (T) looking at Charles (C) to recall his attention to the focus (the 'here')**
35	Teacher	ok, je vois que ses mains elles sont mouillées. ok. très bien. on va devoir changer ça *(jeter le papier mouillé et en prendre un qui est sec)*, on va juste se concentrer ici. la question ici du papier, c'est quoi? c'est laquelle? qu'est-ce que? *(en soulignant du doigt le passage sur la fiche)*	okay, I see her hands are wet. okay. all right. we're gonna have to change that *(throw away the wet paper and take one which is dry)*, we'll just focus here. the question here of the paper, what is it? which one is it? what is it? **(3)** ***(underlining the sheet's passage with the finger)***	 **2) Teacher (T) takes the glass from Melody's (M) hand**  **3)Teacher (T) asks children to look at the instructions**
36	Melody	c'est l'air.	it's the air.	
(00:01:53)				

In the first excerpt, some children are looking around (1a) and the teacher reminds them that they have little time to do the activity, and therefore it is necessary to focus on the task (1b 'we're here': she recalls the attention of Charles by moving her hands towards the table and depicting the basin full of water). In this way, she is trying to ensure the possibility of having everybody focused on the task and ready to start in due time. Then, the teacher takes the glass that Melody was holding (2), as children are requested to explain why the paper is wet. In fact, inside the glass there is a paper and the teacher, while touching it, notices that it is wet. As this piece of paper should not be wet, she asks children 'why is it wet?' (turn 33). Jules responds to the teacher (turn 34) by saying 'because she chewed it up like that, with her hands' and pointing at Melody while moving his hand. In doing so, Jules indicates the classmate as responsible for the fact that the paper is wet. In addition, he tries to imitate a gesture (by inserting the hands in the basin) that Melody made before that the teacher reached the table. In fact, the hands of Melody are wet because she inserted into the basin full of water and then she took a piece of paper and put it into the glass. As the teacher had not witnessed the incident, Jules informs her by telling it and partially reconstructing the scene through gestures. Afterwards, the teacher come back to the task and asks children to read again the instructions' sheet (3).

The argumentative episode concerning the first Melody's attempt of putting the paper into the glass is reconstructed as follows:

Issue: Is the paper wet?

Standpoint 1 (Jules): Yes

Argument 1 (Jules): Because Melody chewed it by hands

According to the pragma-dialectical approach, it is possible to reconstruct the inferential process of Jules' argument, namely: 'If it is true that Melody's hands are wet and if it is true that she touched the piece of paper, then the piece of paper also will be wet'. If we compare Jules' speech with the inferential reconstruction of his reasoning, we can observe that his intervention lacks a premise: 'Melody's hands are wet'. However, although Jules does not make this premise explicit, he does point to her hands. In turn 35, the teacher intervenes by saying 'okay, I see her hands are wet': through this intervention, she completes Jules' inferential reasoning by making explicit one of the implicit premises. Specifically, when Jules points to Melody, the teacher follows Jules' focus and looks too at Melody's hands.

Since children were asked to perform a task (and not just to express an opinion about something), it is expected that their arguments will be only partially made explicit through the verbal channel, and will be accompanied by gestures. What the teacher could do is to turn these gestures into words (for instance, by paraphrasing the gestures, verbally). This can allow children to establish a common ground for an argumentative discussion (as there might be children who do not observe the gesture, or do not understand its meaning, or maybe some of them prefer a verbal channel). In addition, it can allow the teacher to check if she has understood the meaning of the gesture and if children are discussing the same issue (e.g. the teacher can check if the children are not aware of the gesture).

4.2 Excerpt 2

At the beginning of the activity with another group of participants, the teacher verifies that children have understood what the activity consists of. Thus, she inserts a piece of paper at the bottom of the glass and asks children to make a prediction about what will happen once the glass is inserted (vertically and upside down) into the basin full of water. The teacher collects children's predictions about the experiment and assigns turns of talk. Children indicate their hypotheses: Emma reports that the piece of paper will get wet; Naomi thinks that the paper will fall from the glass and be wet; Erine thinks that the piece of paper will be wet and fall off the glass because of its weight; Thibaud indicates that the piece of paper will be wet. After gathering everyone's opinion, the teacher repeatedly reminds pupils to play the experiment. One at a time, children begin to dip the glass into the basin of water.

Participants: teacher, Emma, Erine, Naomi and Thibaud.

Turn	Participant	Original French transcription	English translation (verbatim)	
(00:04:50)				
137	Teacher	il faut pas oublier ce qu'on avait pensé en premier, parce que c'est pas, c'est pas grave si c'est pas vraiment ce qu'il s'est passé.	**(4) we must not forget** what we had thought at first, because it is not, it does not matter if it is not really what happened.	 **4) Teacher (T) invites Naomi (N) to remember the initial hypothesis**
138	Thibaud	*(Erine insère le verre dans le récipient d'eau)* vas-y, relève. il est pas mouillé, elle rentre dedans mais le papier (. . .)	*(Erine inserts the glass into the basin of water)* **(5) go, take it up**. it's not wet, it fits in it but the paper (. . .)	 **5) Thibaud (Th) takes the glass from basin**
139	Erine	il est pas mouillé. *(en giclant ses camarades avec l'eau sur ses mains)*	it's not wet. *(squirting classmates with water on her hands)*	 **6) Teacher (T) looks at Erine (E) to recall her attention (instead of squirting the classmates)**
140	Teacher	donc il est pas mouillé. Erine! *((en la regardant))*	so it's not wet. Erine! **(6)** ***((looking at her))***	
141	Erine	Thibaud il m'a fait la même chose.	Thibaud he did the same thing to me.	
142	Thibaud	elle rentre pas, l'eau, elle rentre pas.	it does not fit, the water, it does not fit.	
(00:05:15)				

The excerpt starts when the teacher (turn 137) reminds Naomi to what it has been already thought (4). Then, Erine inserts the glass into the basin of water, but Thibaud (5) takes the glass and says 'go, take it up. it is not wet, it fits in it but the paper (. . .)' (turn 138). Erine completes the sentence by saying 'It's not wet' (turn 139) and then squirts the classmates with the water. The teacher recalls Erine (turn 140) and directs the gaze towards her (6) in order to recall the child's

attention to the scientific activity at stake. To defend herself, Erine answers: 'Thibaud did the same thing to me' (turn 141).

The argumentative structure of the last pupils' argumentation is summarized as follows:

Issue: Can I squirt my classmates with water?

Standpoint 1 (Erine): Yes *Standpoint 2* (Teacher): Non

Argument 1 (Erine): Because Thibaud did the same thing to me

According to the analytic overview, the issue of discussion ('Can I squirt my classmates with water?') is implicit in the excerpt. Erine's standpoint ('yes') is implicit and it is somehow presented through her action (squirting classmates with the water). When the teacher says 'Erine' by looking at her, the child interprets the adult's gaze as a standpoint: 'You can't throw the water towards classmates'. In this case, the teacher's use of gaze direction is effective, as the child understand the message and focuses her attention on the ongoing task.

If we look at the construction of the argumentative discourse concerning the problem of the experiment (does the paper will get wet or dry whether the glass is immersed into the basin full of water?), we can consider the role of the teacher as relevant. In the excerpt, she leads children to develop their argumentative thinking; indeed, by repeating Erine's words ('so it's not wet', turn 140), she gives children the time to think and to propose other arguments. This way of proceeding leads Thibaud (turn 142) to continue with the construction of his argumentative discourse 'it does not fit, the water, it does not fit'. By saying this, he mentions that if the paper is not wet it is because the water 'does not fit' in the glass. This argumentative reflection is interesting, because the child mentions that the water 'fits in' (turn 138); thanks to Erine's observation 'it's not wet' (turn 139), and the repetition of Erine's argument by the teacher 'it's not wet' (turn 140), Thibaud changes his mind and proposes a counter-argument ('the water does not fit in the glass', turn 142) indicating that he managed to change his understanding of the problem.

4.3 Excerpt 3

This is the continuation of the same video considered for the excerpt 2. Children plunged the glass into the basin of water one at a time. Each of them made the experiment. Then, Naomi suggests to the teacher to put more paper into the glass, to see if in this case the result would be different (namely, if the piece of paper will remain dry). Children insert more paper into the glass and try again, by putting it vertically into the basin of water. The piece of paper remains still dry. Naomi proposes to put less paper, to see if the result changes. She inserts the glass into the basin but, instead of doing it vertically, she tilts it slightly: the water begins to enter into the glass and the paper gets wet.

Participants: teacher, Emma, Erine, Naomi and Thibaud.

The teacher reminds Naomi to the initial action (7) and suggests to repeat slowly the same action, to closely observe what happens once the glass is tilted (turn 188). The child tilts the glass and the water starts to enter. Then, the adult asks what is the difference between the present situation and the previous one (turn 192), by showing a gesture (pointing) to indicate that the glass is floating (8). Thibaud argues that when the glass is placed upright, the water does not enter (turn 195). While children rush to pick up the wet paper at the bottom of the

glass (9), the teacher asks again why there is no water into the glass and what would be the role of air (turn 200). Thibaud inserts his hand into the glass to 'test' the absence of air (10). The teacher reminds children that at the beginning of the experiment they said that the glass is empty and contains no air. Erine takes the floor to intervene: while putting her hand into the glass (11) to show the 'presence' of air, she argues that the air prevents the water from entering (T. 201). This is accompanied by the movement of plunging the glass in the water (12a) and bringing it up right (12b).

The argumentative episode can be reconstructed as follows:

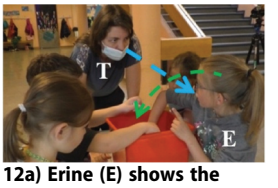
Issue: Will the paper be wet?

Standpoint (Children): No (implicit)

Turn	Participant	Original French transcription	English translation (verbatim)	
(00:07:25)				
188	Teacher	Naomi qu'est-ce que tu as fait pour mouiller le papier? réfléchis sur ce qu'on a fait.	Naomi what did you do to get the paper wet? **(7) think about what we did.**	 **7) Teacher (T) reminds Naomi (N) to the initial action**
189	Naomi	ben, je l'ai tourné sans faire exprès	well, I turned it without doing it on purpose	
190	Teacher	donc tu l'as tourné. alors fait doucement, refais la même chose que tu as fait avant, mais doucement pour qu'on voit ce qu'il se passe. c'est pas la même chose que tu as fait. refais ce que tu avais fait.	so you turned it. so do it slowly, do the same thing you did before, but slowly so we can see what's going on. it's not the same thing you did. do the same thing you did before.	
191	Naomi	ce que j'ai fait?	what I did?	
192	Teacher	oui, tu l'as fait tourner et puis du coup, c'est comme ça, c'est quoi la différence au final?	yes, you turned it around and then, that's how, what's the difference in the end?	 **8) Teacher (T) is pointing to show that the glass is floating**
193	Naomi	c'est que le verre, il flotte.	it is that the glass, it floats.	
194	Teacher	le gobelet, oui. du moment où il flotte, alors on va regarder, observez tous? Thibaud	the glass, yes. **(8) as long as it floats**, so let's have a look, everyone is looking? Thibaud	
195	Thibaud	il y a pas d'eau là. il y a pas d'eau qui rentre.	there's no water there. there's no water coming in.	
196	Teacher	ahaha, Thibaud il a vu du coup, il arrive à voir que dans le verre, il y a pas d'eau qui rentre. mais si le verre il flotte, qu'est-ce qu'il se passe? on va voir, on va enlever	ahaha, Thibaud has seen, he sees that in the glass, there is no water coming in. but if the glass floats, what happens? we will see, we will remove	

(*Continued*)

(Continued).

Turn	Participant	Original French transcription	English translation (verbatim)	
197	Naomi	*(en lâchant le verre)* il se retourne. *(le verre se retourne dans le baquet, l'eau le remplit, l'enseignante le remonte remplit d'eau)*	*(dropping the glass)* it turns over. *(the glass turns over in the basin, water fills it, the teacher brings it back up with water)*	 **9) Children act simultaneously to take out the wet paper**
198	Teacher	et pourquoi il y a de l'eau ici?	and why is there water here?	
199	Naomi	et bien parce que là, il s'est retourné, il est dans l'eau.	well, because now it's turned around, it's in the water.	
200	Teacher	*(les enfants se précipitent pour prendre le papier mouillé au fond du verre)* mais qu'est-ce qui change en fait, dès le moment qu'il est retourné dans l'eau? on va juste réfléchir encore une fois sur ce qui s'est passé. vous avez dit qu'il y a pas d'air en fait. vous avez dit qu'il y avait pas d'air ici mais comment ça se fait que le papier il est pas mouillé. si on pense à l'air ou à l'eau?	**(9)** ***(children rush to pick up the wet paper at the bottom of the glass)*** but what actually changes, once it's back in the water? we'll just think again about what happened. you said **(10) there's no air actually**. you said there was no air here but how come the paper isn't wet. if we think of air or water?	 **10) Thibaud (Th) inserts his hand into the glass to 'test'**
				 **11) Erine (E) puts her hand into the glass to show the 'presence' of air**
201	Erine	le verre ici il a du papier et quand on fait comme ça *(en tournant le verre à la verticale)*, directement mais il y a quand même un peu d'air, mais ici *(en mettant sa main dedans le verre)*, l'air, elle empêche que enfin c'est l'air tu vois là si je fais ça, *(en bougeant à plusieurs reprise sa main dans le verre)* sans papier et comme ça *(en plongeant le verre droit dans l'eau et le remontant droit)*	the glass here has paper and when we do like that *(turning the glass vertically)*, directly but there is a little air, but here **(11)** ***(putting her hand into the glass)***, the air, it prevents that, well it is the air you see there **if I do that, (12a)** ***(moving her hand into the glass)*** without paper and like that *(plunging the glass right in the water* **(12b)** ***and bringing it up right***)	 **12a) Erine (E) shows the movement to the teacher (T)**
				 **12b) Erine shows the result to the teacher (T)**
202	Thibaud	c'est mouillé *(en touchant le verre)*	it's wet **(13)** ***(touching the glass)***	
203	Teacher	Mais il était déjà mouillé avant	But it was already wet before	 **13) Thibaud inserts his hand into the glass to verify the result**

(00:09:12)

Argument 1 (Thibaud): There is no water coming in

Argument 1.1 (Erine) Because there is a bit of air that prevents (the water from entering the glass)

According to the analytic overview, the issue of discussion ('Will the paper be wet?') is implicit in the excerpt. Children's standpoint ('no') is implicit too and can be reconstructed starting from their arguments. Thibaud (turn 195) says that 'there's no water coming in' and Erine (turn 201) adds 'because there is a bit of air that prevents (the water from entering the glass)'. Children's argumentation is subordinative, as Erine's argument supports and strengthens Thibaud's argument. In a way, Thibaud's argument is valid because is in turn supported by another argument. Moreover, Erine's argument can only be understood if we look at the different elements of her intervention. In this case, the glass is no longer just an object part of the setting of the teacher activity. Erine uses the glass to show her point: it becomes a prosthetic instrument of reasoning. The child also uses the hand in an instrumental and unconventional way, to 'represent' air (when she closes her hand and puts it into the glass). In the following part of the same activity, the teacher asks children to do 'something'. By consequence, it is expected that children's answers also will be expressed by manipulating the objects. In fact, one of the reasons why children may not participate in an argumentative discussion is that they have no standpoint on the topic under discussion. The recorded experience about the effect of putting a glass with a paper into a basin of water makes possible to get out of this eventual *impasse*, by allowing children to develop hypotheses and find their place in the discussion. Children can propose standpoints and arguments: since they are talking about air, they need to build a standpoint based on the experimentation they made. Through the experience, children can understand that the paper will remain dry if they would put the glass vertically into the basin of water. They can experience it directly, by touching the paper. After having figured out that the paper remains dry, they can start making assumptions about this result: is it because of the amount of paper or perhaps it is related to the position of the glass? Children's attempts can play as counter-arguments in trying to discover the answer, by excluding some alternative arguments. Children can inductively try to find the solution and, by manipulating the objects, they can benefit from the teacher's interventions that lead them to develop their reasoning based on the direct experience they can made.

Table 1. Summary of the observed semiotic elements and their use.

Semiotic resource	Use and examples in the observed activities
Speech	To regulate the activity (okay? Well, we'll just focus here), to instruct participants (yes), to argue and counter-argue (I see, because)
Gaze direction	To redirect attention and focus (teacher), to check the other's activity, to look for evidence (child)
Position of physical objects	Material objects available to everybody (basin), to one or more participants without an established designation (the glass, the paper), to a specific person (instructions' sheet – firstly available to children, then only to the teacher)
Deictic gestures	Touching a specific object (taking the glass to do the experiment; manipulating the objects to verify, to show; attributing the glass to involve somebody; using more papers to intervene in the activity)

This excerpt also highlights the potential contribute of the adult in the development of children's argumentative discourse and understanding the problem at stake. Through her suggestions ('do the same thing you did before', turn 190) and questions ('what's the difference in the end?', turn 192; 'so let's go and have a look, everyone is looking?', turn 194; 'what happens?', turn 196; 'and why is there water here?', turn 198), the teacher leads children to reflect, to develop arguments and to reach an understanding of the problem.

5 Conclusion

Our study aimed at investigating how practice-based science experiences settled up by teachers shape children's argumentation, how teachers' interventions support argumentation and which are the main features of children's argumentation during science education practices. We have adopted an integrated approach, combining tools from modern and contemporary argumentation theories (the analytical overview, according to the principles of the pragma-dialectic model of a critical discussion) and multimodal instruments of analysis. This combination seems necessary since children can develop specific ways of arguing, according to their own 'culture' in discussing and performing social activities (Keel 2014), that are not the merely imitation of the adults' world. Besides, it is well known that children's argumentation has its own peculiarity and the comparison to the adults' argumentation is not recommended. Indeed, such a comparison can only lead to a deficit view of children without helping us to understand their ways of arguing in different situations. This empirical approach avoids preconceived assumptions about how children think and interact, while favoring the observation of the interaction *in situ* (Bateman and Church 2017).

The results of our study show that children's argumentation can be better investigated by considering various resources (such as speech, gaze direction, position of objects, and deictic gestures) activated during an activity, and by looking at how these are interrelated during the interaction. Through this perspective, we offered a view of the child as a highly competent actor (Keel 2016). For this reason, the adoption of the above-mentioned analytical approaches allowed a privileged access to the observation of how different semiotic resources shape argumentative activities in science education.

Besides the role of the teacher's guidance, our findings also reveal the relevance of the configuration of objects, the participants' gestures and their gaze's direction, without which that would be no argumentation. The activation of these semiotic components (see Table 1) seems central to strengthen the children's participation in cognitive argumentative practices.

The findings of our study show how the use of participants' speech is effective in combination with different other resources such as gazes, deictic gestures, and position of physical objects. This suggests a variety of possible ways to sustain different forms of reasoning in science education at primary school also considering the material configuration of the activity. At the same time, the proposed design seems adequate to accompany teachers in building fruitful argumentative settings within classroom. The implications related to the relevance of proposing various learning experiences to children – also based on experimentation and manipulation of objects – reinforce previous works (Convertini, Arcidiacono and Miserez-Caperos 2022; Miserez-Caperos 2017) that have

shown how several dimensions of the discourse produced around an activity contribute to support cognitive argumentation at school. In fact, teacher's interventions can have a relevant effect in promoting or not argumentation, as adults do not only converse with children, but contribute to establish the setting of the interaction by their intentions and capacities to manage a discussion (e.g. assigning or not the turn of talk, promoting or not every point of view, making available the objects, directing the gaze, using deictic gestures). The role of teachers is then crucial to create the proper conditions to invite children to develop opinions and standpoints, for example by making countersuggestions, by encouraging their expression, by allowing time for reflection, by repeating what they say, by asking only one question at a time, by requiring clarifications and explanations.

This reinforces the need of mobilizing different semiotic resources to elicit argumentation: these elements are important and should be considered when an adult is trying to lead children to develop an argumentative discourse around a scientific task. While engaged in science education practices, children are often invited to take part in a complex system of activities: as multimodal analyses comprise different semiotic modes that have gained more currency in science education (Tang, Tan, and Mortimer 2021), further research should be encouraged to connect materiality to argumentation. In fact, as highlighted by Tang (2022), 'we need to forge a stronger theoretical and pedagogical connection between our interactions with the material world and the process of argumentation' (p. 1004). Within the school context, the verbal channel in argumentative interactions may not be the most privileged one. As we are convinced that the approaches and methods adopted to study children's argumentation in science curriculum should fit with the children's participation (and not vice versa), we intend to promote a more teachers' awareness of the role of different semiotic resources that contribute to shape reasoning in science education.

Notes

1. Compulsory schooling consists of eleven years, between the ages of 4–5 and 14–15, divided into three cycles: cycle 1 HarmoS grades 1–4; cycle 2 HarmoS grades 5–8; and cycle 3 HarmoS grades 9–11.
2. Two teachers were working part-time in the same class, which is why the population of this research includes three teachers working in two classrooms.
3. The PER («Plan d'études romand», in French) determines a global project for the pupils' education. It describes what pupils should learn during their compulsory education and the levels to be reached at the end of each cycle.
4. The MER («Moyens d'enseignement romands», in French) refers to the different printed textbooks used at school by teachers and students.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The APC was funded by the University of Lausanne.

ORCID

Josephine Convertini http://orcid.org/0000-0002-5357-2665
Francesco Arcidiacono http://orcid.org/0000-0001-7535-9630

Data availability statement

Data supporting the reported results are stored on a password-protected institutional server.

References

Arcidiacono, F. 2015. "Argumentation and Reflexivity." In *Reflexivity and Psychology*, edited by G. Marsico, R. Andrisano-Ruggieri, and S. Salvatore, 169–193. Charlotte: Information Age Publishing.

Arcidiacono, F., and C. Miserez-Caperos. 2022. "Développer l'argumentation à visée cognitive en classe: un dispositif collaboratif entre chercheur·e·s et enseignant·e·s." *Enjeux pédagogiques* 39:28–29.

Arcidiacono, F., and C. Pontecorvo. 2019. "On Materiality: Home Spaces and Objects as Expanding Elements of Everyday Experiences." *Forum: Qualitative Social Research* 20 (3): art. 5.

Arcidiacono, F., C. Pontecorvo, and A. Bova. 2022. ""But the Vanilla is healthy!" Children's Expression of Arguments to Justify Their Non-Compliances in Family Conversation." *Learning, Culture & Social Interaction* 34:art. 100630. https://doi.org/10.1016/j.lcsi.2022.100630.

Arend, B., and C. Weis 2016. A Multimodal Conversation Analytic Approach to Investigate a Joint Problem Solving Task Accomplished by Children in a Mathematics Classroom. In *Proceedings of ICERI2016 Conference*, Seville (pp. 3707–3713). IATED.

Bateman, A., and A. Church. 2017. "Children's Use of Objects in an Early Years Playground." *European Early Childhood Education Research Journal* 25 (1): 55–71. https://doi.org/10.1080/1350293X.2016.1266221.

Bezemer, J., and G. Kress. 2020. "Semiotic Work in the Science Classroom." *Cultural Studies of Science Education* 15 (1): 71–74. https://doi.org/10.1007/s11422-019-09957-4.

Bredekamp, S., and T. Rosegrant. 1995. *Reaching Potentials: Transforming Early Childhood Curriculum and Assessment*. Vol 2. Washington, DC: NAYEC.

Buty, C., and C. Plantin. 2008. *Argumenter en classe de sciences: du débat à l'apprentissage*. Paris: INRP.

Convertini, J. 2021a. "An Interdisciplinary Approach to Investigate Preschool Children's Implicit Inferential Reasoning in Scientific Activities." *Research in Science Education* 51 (1): 171–186. https://doi.org/10.1007/s11165-020-09957-3.

Convertini, J. 2021b. "Psychosocial Obstacles in Young Children Argumentative Interactions." *Education Sciences* 11 (5): 224. https://doi.org/10.3390/educsci11050224.

Convertini, J., and F. Arcidiacono. 2021. "Embodied Argumentation in Young Children in Kindergarten." *Education Sciences* 11 (9): 514. https://doi.org/10.3390/educsci11090514.

Convertini, J., F. Arcidiacono, and C. Miserez-Caperos 2022. Developing Young Children's Cognitive Argumentation in Collaboration with Teachers: The Role of Verbal and Non-Verbal Argumentative Components in Classroom Activities. In L. Gómez Chova, A. López Martínez & J. Lees edited by, *EDULEARN22 Proceedings*, Palma, Mallorca (pp. 3283–3288). IATED Academy.

Eemeren van, F. H., and R. Grootendorst. 1984. *Speech Acts in Argumentative Discussions*. Foris. https://doi.org/10.1515/9783110846089.

Eemeren van, F. H., and R. Grootendorst. 2004. *A Systematic Theory of Argumentation: The Pragma-Dialectical Approach*. Cambridge University Press. https://doi.org/10.1017/CBO9780511616389.

Erduran, S., and M. P. Jiménez-Aleixandre. 2008. Argumentation in Science Education. Perspectives from Classroom-Based Research. New York: Springer.

Fortes, G., M. Gómez, and A. Larrain. 2020. "Diseño de un programa de formación docente para el desarrollo de conocimiento pedagógico de contenido de la argumentación." *Cogency, Journal of Reasoning and Argumentation* 12 (2): 169–205.

Gómez Fernández, R., and C. Siry. 2018. "Opening Up'a Science Task: An Exploration of Shifting Embodied Participation of a Multilingual Primary Student." *International Journal of Science Education* 40 (7): 771–795.

González-Martínez, E., A. Bangerter, K. Lê Van, and C. Navarro. 2016. "Hospital Staff Corridor Conversations: Work in Passing." *Journal of Advanced Nursing* 72 (3): 521–532. https://doi.org/10.1111/jan.12842 .

González-Martínez, E., and M. Giglio. 2020. "Introduire les points soumis à discussion lors d'une réunion: une analyse conversationnelle longitudinale." *Travaux neuchâtelois De Linguistique* 72 (72): 31–71. https://doi.org/10.26034/tranel.2020.2898.

Greco, S. 2018. "Designing Dialogue: Argumentation as Conflict Management in Social Interaction." *Travaux neuchâtelois De Linguistique* 68 (68): 7–15. https://doi.org/10.26034/tranel.2018.2842.

Greco, S., T. Mehmeti, and A. N. Perret-Clermont. 2017. "Do Adult-Children Dialogical Interactions Leave Space for a Full Development of Argumentation? A Case Study." *Journal of Argumentation in Context* 6 (2): 193–219. https://doi.org/10.1075/jaic.6.2.04gre.

Impedovo, M. A., A. Delserieys-Pedregosa, C. Jégou, and K. Ravanis. 2017. "Shadow Formation at Preschool from a Socio-Materiality Perspective." *Research in Science Education* 47 (3): 579–601. https://doi.org/10.1007/s11165-016-9518-x.

Jacquin, J. 2018. "Multimodal Positioning and Reference in Argumentative Talk-In-Interaction: Balancing Context-Dependency and Context-Independency." *International Review of Pragmatics* 10 (2): 198–218. https://doi.org/10.1163/18773109-01002004.

Jefferson, G. 2004. "Glossary of Transcript Symbols with an Introduction." In *Conversation Analysis: Studies from the First Generation*, edited by G. H. Lerner, 13–31. Amsterdam: Benjamins.

Jim, G., and L. V. Pérez. 2020. "Concordancia entre observadores de las estrategias argumentativas empleadas por niños preescolares." *Traslaciones Revista latinoamericana de Lectura y Escritura* 8 (14): 12–30. https://doi.org/10.48162/rev.5.008.

Kampeza, M., A. Vellopoulou, G. Fragkiadaki, and K. Ravanis. 2016. "The Expansion Thermometer in preschoolers' Thinking." *Journal of Baltic Science Education* 15 (2): 185. https://doi.org/10.33225/jbse/16.15.185.

Keel, S. 2014. "L'organisation préférentielle des accords dans le quotidien familial: le cas des accords parentaux suite à un tour évaluatif de l'enfant." In *Corps en interaction: participation, spatialité, mobilité*, edited by L. Mondada, 145–191. ENS. https://doi.org/10.4000/books.enseditions.32675.

Keel, S. 2016. *Socialization: Parent-Child Interaction in Everyday Life*. Routledge.

Kidwell, M. 2009. "Gaze Shift as an Interactional Resource for Very Young Children." *Discourse Processes* 46 (2–3): 145–160. https://doi.org/10.1080/01638530902728926.

Lipman, M. 1982. "Philosophy for Children." *The Journal of Philosophy for Children* 2 (3–4): 35–44. https://doi.org/10.5840/thinking1982339.

Mercer, N. 1995. *The Guided Construction of Knowledge: Talk Amongst Teachers and Learners*. Multilingual Matters.

Migdalek, M. J., N. S. Peralta, M. L. Ramírez, and M. I. Ibañez. 2020. "Argumentar en el jardín de infantes: Análisis exploratorio según la actividad y la función pragmática." *Traslaciones Revista latinoamericana de Lectura y Escritura* 8 (14): 29–51. https://doi.org/10.48162/rev.5.009.

Migdalek, M. J., C. R. Rosenberg, and C. Santibáñez Yáñez. 2014. "Estrategias argumentativas en niños pequeños: un estudio a partir de las disputas durante el juego en contextos escolares." *Revista Signos* 47 (86): 435–462. https://doi.org/10.4067/S0718-09342014000300005.

Milne, C., and K. Scantlebury, Eds. 2019. *Material Practice and Materiality: Too Long Ignored in Science Education*. Springer International Publishing. https://doi.org/10.1007/978-3-030-01974-7.

Miserez-Caperos, C. 2017. *Étude de l'argumentation à visée cognitive dans des interactions entre adulte et enfants: un regard psychosocial sur le modèle pragma-dialectique*. PhD thesis, University of Neuchâtel.

Miserez-Caperos, C., and F. Arcidiacono. 2021. "Developing Cognitive and Knowledge-Oriented Argumentation in Classroom: Perspectives." In *Education in Europe: Perspectives, Opportunities and Challenges*, edited by A. Kokkinou, 109–149. New York: Nova Science.

Mondada, L. 2007. "Multimodal Resources for Turn-Taking: Pointing and the Emergence of Possible Next Speakers." *Discourse Studies* 9 (2): 194–225. https://doi.org/10.1177/1461445607075346.

Mondada, L. 2014. "Pointing, Talk, and the Bodies: Reference and Joint Attention as Embodied Interactional Achievements." In *From Gesture in Conversation to Visible Action as Utterance: Essays in Honor of Adam Kendon*, edited by M. Seyfeddinipur and M. Gullberg, 95–124. Amsterdam: Benjamins.

Muller Mirza, N. 2015. "Les paradoxes de l'argumentation en contexte d'éducation." In *L'argumentation dans les contextes de l'éducation*, edited by N. Muller Mirza and C. Buty, 167–195. Bern: Lang.

Peals, D., K. Hetherington, and F. Vandenberghe. 2002. "The Status of the Object. Performances, Mediations, and Techniques." *Theory, Culture and Society* 19 (5–6): 1–21. https://doi.org/10.1177/026327602761899110.

Perret-Clermont, A.-N., F. Arcidiacono, S. Breux, S. Greco, and C. Miserez-Caperos. 2015. "Knowledge-Oriented Argumentation in Children". In *Scrutinizing Argumentation in Practice*, In edited by F. H. van Eemeren and B. Garssen, 135–149. Amsterdam: Benjamins. https://doi.org/10.1075/aic.9.08per.

Petitjean, C., and E. González-Martínez. 2015. "Laughing and Smiling to Manage Trouble in French-Language Classroom Interaction." *Classroom Discourse* 6 (2): 89–106. https://doi.org/10.1080/19463014.2015.1010556.

Polo, C., and J. M. Colletta. 2020. "The Multimodal Mediation of Knowledge. Lessons Learned from Examining Explanatory Practices Used During a Café Scientifique." *Education Didactique* 14 (1): 9–29. https://doi.org/10.4000/educationdidactique.5292.

Pontecorvo, C., and F. Arcidiacono. 2010. "Development of Reasoning Through Arguing in Young Children." *Культурно-историческая психология/Cultural-Historical Psychology* 4:19–29.

Pontecorvo, C., and L. Sterponi. 2006. "Learning to Argue and Reason Through Discourse in Educational Settings." In Learning for Life in the 21st Century, edited by G. Wells and G. Claxton, 127–140. Hoboken, New Jersey: Blackwell.

Ravanis, K. 1994. "The Discovery of Elementary Magnetic Properties in Preschool Age: Qualitative and Quantitative Research within a Piagetian Framework." *European Early Childhood Education Research Journal* 2 (2): 79–91. https://doi.org/10.1080/13502939485207621.

Ravanis, K., M. Papandreou, M. Kampeza, and A. Vellopoulou. 2013. "Teaching Activities for the Construction of a Precursor Model in 5-To 6-Year-Old Children's Thinking: The Case of Thermal Expansion and Contraction of Metals." *European Early Childhood Education Research Journal* 21 (4): 514–526. https://doi.org/10.1080/1350293X.2013.845440.

Rigotti, E., and S. Greco Morasso. 2009. "Argumentation as an Object of Interest and as a Social and Cultural Resource." In *Argumentation and Education. Theoretical Foundations and Practices*, edited by N. Muller Mirza and A.-N. Perret-Clermont, 9–66. Springer US. https://doi.org/10.1007/978-0-387-98125-3_2.

Schwarz, B. B., and M. J. Baker. 2017. *Dialogue, Argumentation and Education. History, Theory and Practice*. Cambridge University Press. https://doi.org/10.1017/9781316493960.

Schwarz, B. B., and A. Glassner. 2003. "The Blind and the Paralytic: Supporting Argumentation in Everyday and Scientific Issues." In *Arguing to Learn: Confronting Cognitions in Computer-Supported Collaborative Learning Environments*, edited by J. Andriessen, M. Baker, and S. Suthers, 227–260. Kluwer. https://doi.org/10.1007/978-94-017-0781-7_9.

Scipione, L. 2020. "Philosophy (And Argumentation) for Children: Some Reflection for Primary School." *Childhood & Philosophy* 16:1–25.

Siry, C., G. Ziegler, and C. Max. 2012. ""Doing science" Through Discourse-In-Interaction: Young Children's Science Investigations at the Early Childhood Level." *Science Education* 96 (2): 311–326. https://doi.org/10.1002/sce.20481.

Sørensen, E. 2009. *The Materiality of Learning: Technology and Knowledge in Educational Practice*. New York: Cambridge University Press.

Stivers, T., and J. Sidnell. 2005. "Introduction: Multimodal Interaction." *Semiotica* 156 (1–4): 1–20. https://doi.org/10.1515/semi.2005.2005.156.1.

Tang, K.-S. 2022. "Material Inquiry and Transformation as Prerequisite Processes of Scientific Argumentation: Toward a Social-Material Theory of Argumentation." *Journal of Research in Science Teaching* 59 (6): 969–1009. https://doi.org/10.1002/tea.21749.

Tang, K. S., A.-L. Tan, and E. F. Mortimer. 2021. "The Multi-Timescale, Multi-Modal and Multi-Perspectival Aspects of Classroom Discourse Analysis in Science Education." *Research in Science Education* 51 (1): 1–11. https://doi.org/10.1007/s11165-020-09983-1.

Zadunaisky Ehrlich, S. 2011. "Argumentation Discourse of Kindergarten Children: Features of Peer Talk and Children-Teacher Talk." *Journal of Research in Childhood Education* 25 (3): 248–267. https://doi.org/10.1080/02568543.2011.580040.