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Reanalysing children's responses on shadow formation: a comparative approach to bodily expressions and verbal discourse

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ABSTRACT

The present article contains a reanalysis of data resulting from a research project carried out on a group of five preschool-aged children. The data were collected from a class of 16 children participating in a pre/post research design that focused on the shadow formation phenomenon. The findings of the previous research project, based on a speech plus deictic gesture analysis, indicated that the five children had shown regression or no change in their reasoning. In the light of an embodied perspective into science teaching and learning, the current study examines whether we should use a bodily analysis to reassess the extent of knowledge about shadows among these five students. It demonstrates that most of the children selected improved their reasoning about shadow formation by using iconic gestures. Such conflicting results indicate that bodily expression has its own grammar and, to some extent, communicates a meaning that differs from that of verbal discourse.

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Early years/early childhood; semiotics; cognition; bodily reasoning

Introduction

A number of science education studies have focused on young children's conceptions in order to provide useful knowledge for developing teaching strategies and learning activities (Fleer, 2015; Gustavsson & Pramling, 2013; Impedovo, Delserieys-Pedregosa, Jégou, & Ravanis, 2017). It has been established that preschool-aged children are capable of a deeper understanding of natural phenomena, re-organizing their thoughts in terms of scientific reasoning (Eshach & Fried, 2005; Metz, 1998; Ruffman, Perner, Olson, & Doherty, 1993). For example, specifically designed activities based on the Piagetian framework, as well as on sociocultural theory, can create conditions that facilitate young children's scientific thinking (Fleer, 2009; Fragkiadaki & Ravanis, 2014). The majority of these research papers focus on children's conceptions obtained through oral interviews and classify student reasoning according to its compatibility with scientific standards. This is mainly carried out by analyzing verbal discourse in a framework where the

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student uses material objects or drawings, while the answers are categorised as being more or less correct (Chen, 2009; Fleer, 1996; Kallery, 2011; Kampeza, 2006).

However, a substantial number of researchers consider the generation of meaning to be a multimodal procedure during which factors such as material objects, drawings, gestures, wordings, etc. play an active role (Hostetter & Alibali, 2008; Kontra, Goldin-Meadow, & Beilock, 2012; Tytler, Prain, & Peterson, 2007). Hwang and Roth (2011) regard physics concepts as meaningful constructions based on synergies of heterogeneous semiotic systems activated for their representation. The human body specifically is perceived by researchers as an integral part of the conceptual connection between what is uttered and what is within the physical space (Pozzer-Ardenghi & Roth, 2010; Roth, 2001). This is aligned with the embodied character of cognition, which connects conceptions with the bodily interactions with the material world (Varela, Thompson, & Rosch, 1991; Wilson, 2002). For young children, the human body achieves a greater dynamic since it constitutes a dominant means of expression, more powerful even than speech (Ping & Goldin-Meadow, 2008). However, most research designs based on the traditional view of science education do not perceive the human body as an active element in the conceptualisation of scientific ideas.

Changing this traditional view of the human body's role in science education is the main goal of this study. More specifically, it aims to (a) demonstrate the potential of the human body to generate scientific meanings on its own and (b) emphasise that any analysis of children's discourse based solely on their verbal expression should be considered incomplete. This will be accomplished by investigating how preschool-aged children understand the phenomenon of shadow formation.

Theoretical backround

In the field of the semiotics of science teaching and learning, researchers accept that the way students act corporeally on spatial entities also constitutes a mode of learning (Kontra et al., 2012; Novack & Goldin-Meadow, 2015). Gestures can also generate conditions that facilitate reasoning, thus indicating, according to certain researchers, the possibility of conceptual change (Givry & Roth, 2006). Roth and Lawless (2002), Hostetter and Alibali (2008) and Singer, Radinsky, and Goldman (2008) argue that by interacting through gestures, students use a shared code to communicate, thus gradually contributing to the verbal description of scientific concepts. In other instances, research data illustrate a gesture-speech disparity regarding the information conveyed, resulting in gestures that might communicate antithetical rather than only supplementary meanings (Crowder & Newman, 1993; Goldin-Meadow, 2000; Wagner-Cook & Goldin-Meadow, 2006). Furthermore, as Hadzigeorgiou, Anastasiou, Konsolas, and Prevezanou (2009) argue, not only do bodily modes clarify what is being expressed in verbal discourse, but, on several occasions, can even constitute independent meanings.

Pozzer-Ardenghi and Roth (2005) studied the function of photographs in the teaching of science, while Arzarello, Paola, Robutti, and Sabena (2009) focused on how diagrams work in the teaching of mathematics. Both these groups of researchers established that to construct meanings, teachers and students apply deictic as well as iconic gestures as interpretative filters over inscriptions. In general, gestures, changes in body posture, movement within space, and actions on material objects constitute conceptual links between what is uttered and the spatial arrangements of a learning environment (Abrahamson, 2009; Hwang & Roth, 2011; Vosniadou, Skopeliti, & Ikospentaki, 2005). Specifically, deictic and ergotic gestures conceptually interconnect speech and material objects. By pointing, deictic gestures underscore visible properties of physical space, while ergotic gestures reveal the concealed characteristics of material objects. For example, by manipulating a globe, children can reveal the Earth's self-rotation (Vosniadou et al., 2005). Roth (2001) argues that the teaching framework's morphology (i.e. material objects, layout of experiments) influences the forms of the iconic gestures students use; consequently, these forms create a conceptualisation framework, especially when students construct interpretative patterns for a natural phenomenon. According to the same researcher, this can lead more rapidly to cognitive achievements than frameworks that do not promote the use of gestures. It is also maintained that corporeal actions nourish the students' imagination, enabling them to visualise entities that are non-visible entities (i.e. the movement of electrons) or even entities that cannot yet be schematised through verbal discourse (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001; Roth, 2001; Singer et al., 2008). During teaching, the absence of gestures on the part of the teacher blocks the interaction between speech and material objects, thus rendering the objects inactive factors in the meaning making process. Additionally, when material objects are absent, the students' bodies become factors of representation as the iconic gestures cooperate with the mental images of the objects (Ping & Goldin-Meadow, 2008).

From an embodied cognition perspective, concepts or ideas cannot be constructed without the bodily experiences of sensing and acting on the environment (Clark, 2001; Wilson, 2002). Bodily interactions in the material world are what distributes cognition across humans and the natural and social environment, allowing them to extend their thinking (Hutchins, 1995; Suchman, 1987). The idea of embodied cognition does not refer to the human body as a one-way mediator applying what conceptions the mind has already arrived at. On the contrary, the human body is an external thinking tool that plays both a causal and a physically constitutive role in cognitive processing (Shapiro, 2011).

To study preschool-aged children's reasoning on the phenomenon of shadow formation, some researchers analyze verbal discourse along with the deictic gestures that indicate the point where the shadow is formed; in other cases, how the students manipulate objects to create the shadow are also recorded (Delserieys, Jégou, & Givry, 2014; Gallegos-Cazares, Flores-Camacho, & Calderon-Canales, 2009; Ravanis, 1996). In other researches, where the students select images or draw, the bodily analysis is limited to the children's deictic gestures (Chen, 2009; Delserieys-Pedregosa, Impedovo, Fragkiadaki, & Kampeza, 2017; Knight, 2008). We might say that the above-mentioned researches do not contain an in-depth analysis of the role the children's bodies play as a 'grammatical mode' in their reasoning. The exception might be the work of Impedovo et al. (2017), who try to describe how the body and verbal discourse mutually influence each other. Their analysis, however, studies a group of children rather than separate individuals; therefore, it is not possible to follow the progress of the verbal discourse-gestures relationship for each child separately. Additionally, the analysis neither shows nor records the children's iconic gestures, i.e. those gestures that represent something and possess in and of themselves a separate semantic content, sometimes functioning as verbal discourse (Roth, 2002). In certain cases, iconic gestures, due to their greater similarity to what they are expressing, are better than verbal discourse at depicting the contents of a conception (Roth, 2001).

The current research explores whether the human body assumes a special role in the making of meaning through a comparison of two data analysis methods: speech- and body-based analysis. The research question is whether the outcomes concerning children's reasoning about shadow formation depend on the context of analysis. We hypothesise that a study of bodily expressions will reveal elements in the children's thinking and conceptualizations, which they were unable to express through verbal discourse.

Methodology

Research design

To test our hypothesis, we applied the method of *reanalysis*. Namely, a second analysis of qualitative data, which were initially collected and analyzed within the framework of another research project with a different purpose than the current study. In the previous study, the data analysis was speech based, while in the current study the same data were analyzed in a body-based context.

Previous study

The data pertained to the shadow formation phenomenon and were collected from a kindergarten class of 16 children within the typical pretest – teaching intervention – posttest framework (Herakleioti & Pantidos, 2016). The objective of previous research was to explore the learning impact on kindergarten children (4–5.5 years old), who had never been taught the concepts of shadow and light. More specifically, the children were asked, through individual and semi-structured interviews, to provide predictions and explanations regarding the mechanism of shadow formation, both before and after a properly designed teaching intervention. All three phases of the process were video recorded. In the teaching intervention, the children's body often acted as an obstacle while the shadow was formed on a screen attached to the wall (see Figure 1).

Furthermore, the children formulated hypotheses with the flashlight turned off, and tested them by turning it on. They could experience their body as an obstacle, explore the 'journey' of the light by moving in the space, but also test whether the areas in front of and behind the obstacle were illuminated or not. Taking an active part in the phenomenon provided them with the experience of shadow formation.

The analysis of the data from the initial study examined the verbal discourse of the children and the occasional deictic gestures made by the pointer finger towards the area of shadow formation. Contrary to the teaching intervention, the pre/posttest did not seek to activate the children's body. It was a standard framework, which detected the children's conceptions on the shadow formation phenomenon (see Figure 2).

In the first analysis and regarding the scientific model, the students' answers were classified as adequate, fair, and inadequate according to the criteria in Table 1. It is worth mentioning that Table 1 contains the criteria used to classify the children's answers as regards to the mechanism of the shadow formation phenomenon only. Namely: (a) shadow formation area, (b) rectilinear propagation of light, and (c) obstruction of light.

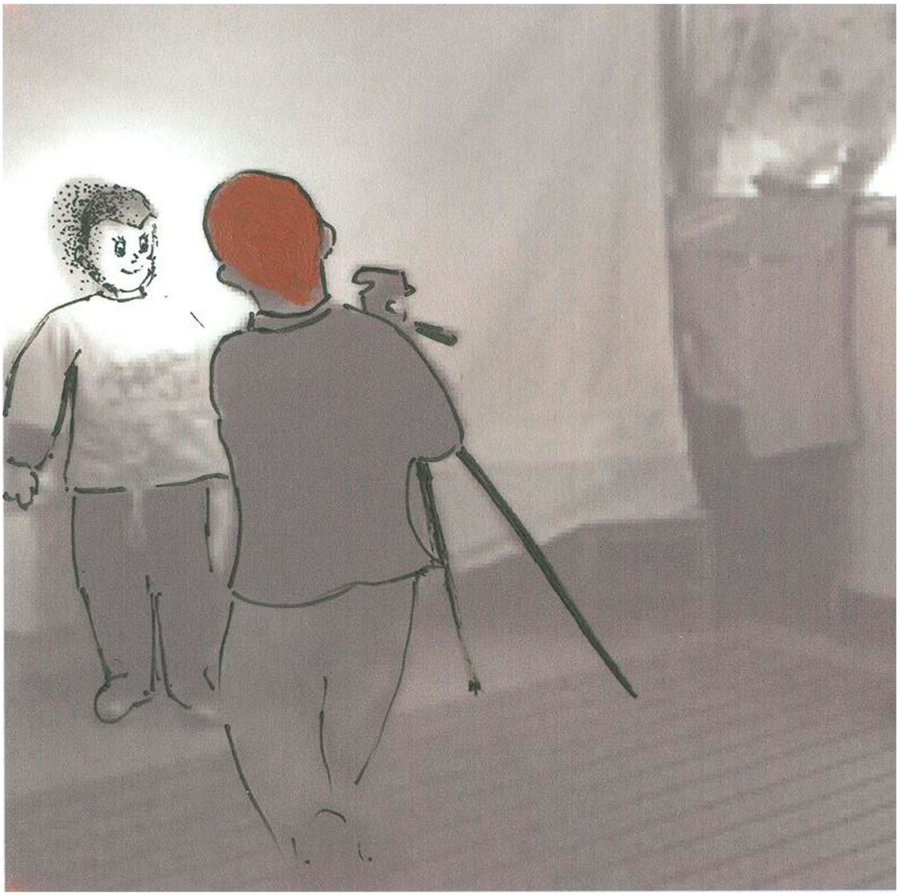

Figure 1. In the teaching intervention the children's bodies were crucially activated.

The findings showed that a total of 11 children moved to fuller answers compared to their pretest answers, while the remaining five children demonstrated no progress. Actually, three of these five children demonstrated no change and two demonstrated regression in their reasoning. Table 2 presents the performance of the children in the pre- and posttest for each dimension of the phenomenon. The performance evaluation was based on the children's utterances and on the deictic gesture they used in each case.

There was no change in the reasoning of children S2 and S8. They formulated fair responses both in the pre- and posttest since they only identified the shadow formation area through the word 'here' plus the deictic gesture of the pointer finger.

Child S16 also evinced no change, providing adequate answers in both the pre- and posttest, using the word 'here' + [pointing behind the brick] and the phrases 'the light goes forward' and 'the brick obstructs'.

Child S6 displayed regression, moving from a fair to an inadequate response. In the pretest, it uttered the adverb 'here' + [pointing behind the brick] and the phrase 'it obstructs' + [pointing to the brick], identifying the shadow formation area and obstruction respectively. On the contrary, in the posttest, the child gave wrong answers.

Figure 2. The interview framework in pre/post tests.

Table 1. Framework of speech plus deictic gesture analysis applied on children's responses.

Types of children's responses		
Adequate	Fair	Inadequate
Identifies, with help or alone, the area where the shadow will be formed and explains in terms of rectilinear propagation and obstruction of light	Identifies, with help or alone, the area where the shadow will be formed but gives the wrong or no reasons	Cannot identify the area where the shadow will be formed and does not offer any explanation

Table 2. Children's correct responses are indicated with (√) and wrong or no responses with (–).

	Speech + deictic gesture analysis of the five children with no progress					
	Shadow formation area		Rectilinear propagation		Obstruction	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
S2	√	√	–	–	–	–
S6	√	–	–	–	√	–
S8	√	√	–	–	–	–
S14	√	√	√	–	√	–
S16	√	√	√	√	√	√

Child S14 also showed regression moving, however, from an adequate to a fair response. In the pretest, the child said 'here' + [pointing behind the brick]. She also used the phrases 'the light goes straight towards here' and 'the brick obstructs the light' to specify the trajectory of the light and the obstruction respectively. In the posttest, the child denoted only the shadow formation area using 'here' + [pointing behind the brick].

Current study

In the second analysis of the current study, the overall bodily activity of these five children was analyzed. The aim was to examine whether any bodily expression can alter our understanding of the children's reasoning. This was possible because both tests had been video recorded. The re-analysis compared the meanings expressed via the somatic actions of these five children with their verbal discourse. This comparison was performed on the pretest and the posttest, while the results of both were also compared to each other. Similarly, to the first analysis, the second analysis of this study assessed the children's reasoning based on its compatibility with scientific standards. In the current research, the reasoning was assessed in terms of the children's corporeal actions and their answers were not classified as adequate, fair, or inadequate.

Participants

The five (5) children, S2, S6, S8, S14, S16, who in the previous study showed either regression or no change, are now examined to discover whether a change in their bodily modalities reveals that they evinced changes in their reasoning during the posttest (Herakleioti & Pantidos, 2016).

Coding

The coding concerned the bodily modalities produced by the five children during the pre- and posttest. The codification and analysis of the data was carried out by the first two authors of the current paper. Each researcher watched the video recordings of both tests for all five children and then carried out the coding separately. Subsequently, the two researchers held meetings in which they compared the two tests (pre- and post) and came to an agreement regarding the codification. The agreement concerned both the categorisation of each bodily action and the meaning attributed to it. The researchers discussed their assumptions regarding how the children involve their body in their explanations (i.e. gestures, body posture) of shadow formation. For the categorisation of the deictic gestures in Table 3, the two researchers were in agreement regarding all the cases, while they disagreed on three cases related to the attribution of meaning to iconic gestures, which were then excluded from the process.

Table 3. Types of somatic modalities.

Ergotic gestures (eg)	Deictic gestures (dg)	Iconic gestures (ig)
eg_1: takes the brick and examines it or moves it	dg_1: points towards the brick	ig_1: depicts the rectilinear movement of light
	dg_2: points towards the flashlight	ig_2: depicts the flashlight
	dg_3: points towards a point around the brick	ig_3: depicts the obstacle
	dg_4: points towards the entire layout	ig_4: depicts the obstruction
	dg_5: points towards the sheet of the paper	ig_5: depicts the shadow
	dg_6: points behind him/herself	ig_6: depicts the movement of the object
	dg_7: points towards him/herself	ig_7: depicts the movement (not the rectilinear) of light

The video analysis process was conducted in the following stages: (a) the oral material was transcribed, (b) any statements consistent with the scientific mode were documented, (c) the video material was reviewed and each and every corporeal action was highlighted along with the time it took place, (d) bodily actions were categorised, depending on type and content (see Table 3), and (e) the ‘sentences’ that consist of the children’s bodily actions and corresponding verbal discourse were also documented (see Table 4). Table 3 presents the three types of gestures that were observed. Gestures regarding the manipulation of material objects by the students are referred to as ergotic; gestures pointing towards a direction, usually using the pointing finger or eye gestures, are referred to as deictic; while gestures, which describe morphological features are defined as iconic (McNeill, 1992; Roth, 2003). Pantidos, Valakas, Vitoratos, and Ravanis, (2008) adopted the broader term of *gestural signs* to describe movements of the entire body as opposed to *gestures* concerning movement of the hands. In the current study, the term gesture is

Table 4. (S) refers to any verbal discourse and/or deictic gestures dg_1, dg_3 evaluated as correct during speech analysis. (B) refers to all the bodily modalities (except for dg_1, dg_3), which may or may not be accompanied by verbal discourse.

	a (Shadow formation area)		b (Rectilinear propagation of light)		c (Obstruction of light)	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
S2	**S:** [dg_3(here)], [dg_3] **B:**	**S:** [dg_3(here)] **B:** [(dg_6/ig_3)(there)], [ig_6(to the sheet)]	**S:** **B:**	**S:** **B:**	**S:** [dg_1] **B:**	**S:** [dg_1] **B:** [I will put here (eg_1) the pen]
S6	**S:** [dg_3(here)] **B:**	**S:** **B:** [ig_6(to the sheet)], [ig_6(to the wall)], [(dg_6/ig_3)(there)], [ig_2(you have to take a flashlight) – ig_6 (and put it behind it)], [but if it has done-it will lay down here (dg_3)-ig_5]	**S:** **B:** [the torch will go like(ig_7) this]	**S:** **B:**	**S:** [I obstruct this], [dg_1(this)] **B:**	**S:** **B:** [dg_7(me)], [(ig_3)me and the sun … (ig_4)when I do this – it hides the shadow- (ig_4) and when I do this-it comes]
S8	**S:** [dg_3(here)] **B:**	**S:** [dg_3], [dg_3(here)] **B:** [(dg_4)-dg_6(to the paper)], [ig_6(there)], [dg_7(here)], [dg_6/ig_3]	**S:** **B:**[dg_5(here)], [ig_7(like this)]	**S:** **B:** [ig_7], [ig_7(it comes from here – and goes here)]	**S:** **B:** [ig_3(this)]	**S:** **B:**
S14	**S:** [dg_3 (here)] **B:**	**S:** [dg_3 (here)], [the shadow will be here (dg_3)] **B:**	**S:** [the light goes straight towards here] **B:** [dg_7 (table)], [the light goes straight towards here (dg_5)]	**S:** **B:** [from here (dg_2)(ig_1) – and it fall here (ig_3)], [ig_1 (this way … and – it goes up to here)]	**S:** [the brick (dg_1) obstructs the light] **B:** [dg_7 (table)]	**S:** [because I am in front of it], [dg_1 (this)] **B:**
S16	**S:** [the shadow will be here (dg_3)], [dg_3(a shadow)] **B:**	**S:** [dg_3(here)] **B:**	**S:** [the light goes forward] **B:** [dg_2 (the light goes forward)], [the torch will go (ig_1) here (dg_3)]	**S:** [light straight like this] **B:** [ig_1 (light straight like this)]	**S:** [this(dg_1) obstructs] **B:**	**S:** [the brick obstructs], [it stops at the brick(dg_1)-and it goes out(dg_3)] **B:**

used, although, in some few instances, the various types of gestures coincide with the movement of the child's entire body.

As far as the deictic and ergotic gestures are concerned, they apply explicitly to the children's acts of pointing at or moving something respectively. Thus, as presented in Table 3, ergotic and deictic gestures correspond to the physical acts the children perform. On the contrary, iconic gestures were codified based on the meaning they convey. For example, ig_1 is a 'movement of the hand in a straight line' but it actually means and depicts the rectilinear trajectory of the light. Therefore, as regards iconic gestures, the main difficulty the two researchers faced was what meaning to assign to specific actions, while, in the case of deictic and ergotic gestures, this was unnecessary, since they refer directly to specific human acts. For this reason, the concept of context was used. Thus, in the current analysis, for each iconic gesture that emerged, the two researchers examined both the question as formulated by the teacher and the content of the student's oral discourse. In that sense, each iconic gesture was perceived as a response to a specific question and was interpreted according to what it referred to (see Figure 9). In the case of the shadow formation phenomenon, the children's responses referred to: (a) the shadow formation area, (b) the rectilinear propagation of light and (c) the obstruction of light.

Table 4 contains both the speech and body analysis. The speech analysis only covers the utterances that express correct scientific meanings, which had been evaluated during the previous study (Herakleioti & Pantidos, 2016). Moreover, only gestures dg_1 and dg_3 had been taken into consideration during that analysis. Thus, the speech analysis in Table 4 contains the children's statements, e.g. (S16: 'light straight like this'), as well as constructions like [dg_3(here)], which indicate the coexistence of a deictic gesture along with the verbal element inside the parenthesis. The bodily analysis in Table 4 contains all the remaining bodily expression-verbal discourse constructions that appeared, without, however – in contrast to the speech analysis – an evaluation of whether they are correct or incorrect. This will be shown in the data analysis.

Table 4, apart from the elements dg_i, ig_i, eg_i, also contains the structure dg_6/ig_3, in which the two elements of deixis and iconicity appear simultaneously and have the same duration. In addition, whatever appears between two brackets, e.g. […], in Table 4 constitutes a sentence. Each sentence can consist of clauses separated by a hyphen '–' symbol. In clauses where the first element is a bodily modality, the verbal discourse inside the parenthesis has the same duration as the bodily modality. For example, in item '[ig_6 (to the sheet)]', child S6 makes the gesture ig_6 and, at the same time, says 'to the sheet'. In clauses where the first element is a verbal discourse, the bodily modality inside the parenthesis has the same duration as the part of the utterance that is underlined. For example, the sentence '[it stops at the <u>brick</u> (dg_1) – and it goes <u>out</u> (dg_3)]' consists of two clauses and the duration of gestures dg_1 and dg_3 is the same as that of the spoken words 'brick' and 'out' respectively.

Data analysis

After codification, three levels of analysis are applied to the data. In the first stage, we examine the meaning of all the gestures made during the pretest and compare it to the meaning of the verbal discourse of the pretest. In the second stage, we conduct the same comparison, this time using the gestures of the posttest. Finally, if certain gestures in the posttest have different meanings relative to the verbal discourse of the same test (see level 2), we examine whether the meaning of these gestures also differs from the verbal discourse of the pretest.

In every case where we identify a gesture whose meaning differs from that of the verbal discourse, we examine whether it contains within itself *new entities* and/or constitutes *new relationships between the entities* compatible with the scientific meaning related to: (a) the area of shadow formation, (b) the rectilinear propagation of light, and (c) the obstruction of light.

Results

The results arise from the application of the analysis criteria to the data in Table 4 and fall into two categories: (a) children (S6 and S14) who use their gestures to express a dimension of shadow formation, which is not expressed through verbal discourse in the corresponding framework (the test). In this case, these gestures are considered *critical elements*, since they are improvement (or even disclosure) indicators of the children's reasoning. For the gestures used as critical elements, first the child S6 and then the child S14 was analyzed. We first analyze gestures ig_2, ig_6, ig_3, ig_4, because child S6 performed these gestures, and then ig_1, since it was only used by child S14. And (b) children (S2 and S8) who carry out a transfer of knowledge by using their body (i.e. dg_6/ig_3) to define the shadow formation area.

a) *Gestures* ig_2, ig_6, ig_3, ig_4*and* ig_1*as critical elements in the children's reasoning*

Children S6 and S14 developed *new entities* in their explanations and/or established *new relationships between the entities.* As presented in Table 4, child S6 conceptualises the shadow formation area in the pretest using a deictic gesture and uttering the adverb 'here'. In contrast, the child generates the syntactical structure [ig_2 (you have to take a flashlight) – ig_6 (and put it behind it)] during the posttest. Gesture ig_2 depicts the flashlight and ig_6 depicts its movement. When the physical object, the flashlight, is placed in area A, the child, according to the speech analysis, gives an incorrect answer, saying that the shadow will form in area B (see Figure 3). In other words, to create the shadow, the child says 'here' and points to area B, which is located on a straight line perpendicular to the line where the flashlight is located (area A).

Subsequently, however, she states that 'you have to take a flashlight and put it behind it' gesturing with her hand at the flashlight (i.e. ig_2), which she 'places' (i.e. ig_6) in area C. Area C is opposite area B and the brick has been placed between them. In other words, [area C], [brick], and [area B] are on the same imaginary straight line. In that sense, the iconic gestures of depicting the 'flashlight' (ig_2) and moving it (ig_6) to area C construct the correct arrangement of the entities involved in the shadow formation. She actually produces the arrangement of her own initiative: depicted 'flashlight' (area C) – brick – shadow (area B). Simply put, when answering in the posttest, the child changes the spatial relationship between the 'flashlight' and the area of shadow formation through gestures ig_2 and ig_6, thus developing more complex reasoning. In this instance, the iconic gestures illustrate that this child constructs a mental image from what she performs through gestures ig_2 and ig_6 and not from what she expresses orally. It is worth

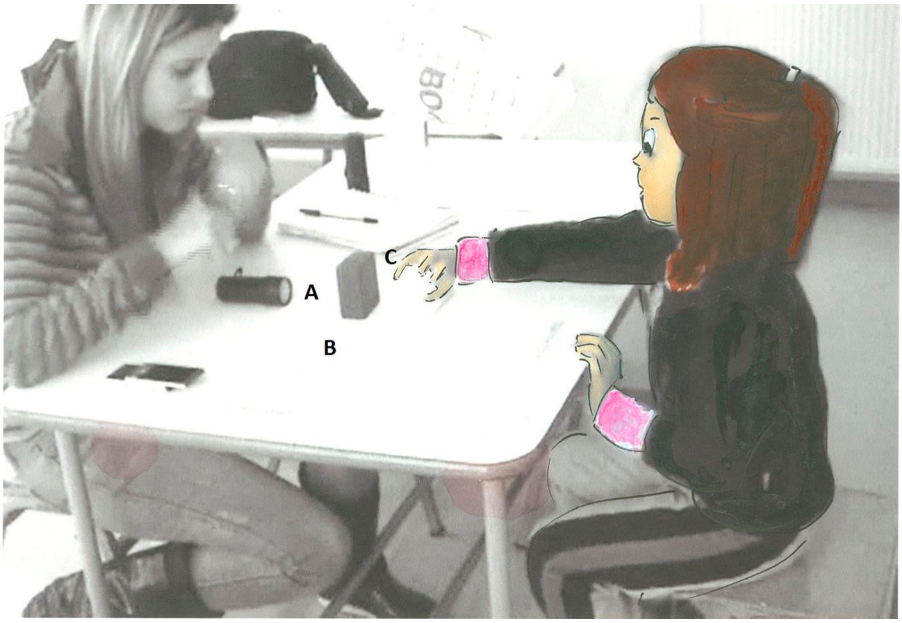

Figure 3. She makes with her right hand an imaginary flashlight placing it in the area C which is opposite to the area B.

noting that this corporeal reasoning is scientifically valid while the speech-based analysis had registered the child's performance as incorrect.

In another instance during the pretest, when the teacher asks 'what stops the light from passing?', child S6 refers to the brick using a deictic gesture and the word 'this' and saying 'it obstructs' (see Figure 4).

In the posttest, the child exhibits the multimodal structure [(ig_3) me and the sun … (ig_4) when I do this – it hides the shadow – (ig_4) and when I do this – it comes] (see Figure 5).

The meaning of this sentence is revealed only through a bodily based analysis. More specifically, in the posttest, when the teacher discusses the obstruction of the light with the child, the following dialogue takes place:

TEACHER:	Where is your shadow?
TEACHER:	What do we see on the wall?
CHILD:	Me and the sun … when I do <u>this</u> it hides … the shadow … and when I do <u>this</u> it comes.

The child, while trying to locate where her shadow will be appear, creates a narrative space that includes the entity 'sun'. Her bodily expression provides an embodied reasoning on obstruction: in this locus, as it appears in Figure 5, the student moves to-and-fro placing the imaginary 'sun' opposite to her. The imaginary sun is on the same side as the teacher with the flashlight, while the child stands opposite the 'sun' and sways from right to left. Therefore, we consider that the child's body is performing two functions: (a) it depicts the obstruction, placing itself in front of the 'sun' (ig_3), and (b) it depicts a process, the obstruction, as it sways from right to left in front of the sun (ig_4). The

Figure 4. Specifies the brick as an obstacle.

assumption that puts the 'sun' in front of her is ascertained by the verbal discourse. When she utters 'when I do this, it hides', she also stands erect in front of the imaginary sun. This probably denotes that her body hides the sun. Afterwards, when she says 'when I do this, it comes', the student starts oscillating from right to left as depicted in Figure 5, signifying that the sun (light) comes when 'I remove myself' (i.e. ig_4). If we only take verbal discourse into consideration, the child's speech in the posttest appears incoherent. However, since the analysis also focuses on the student's static gesture ig_3 and movement ig_4, the speech becomes meaningful. It is gestures ig_3 and ig_4 that collaborate with speech and construct the idea that the shadow results from the obstruction of light. Thus, if we only analyze the verbal discourse of the posttest, we conclude that the child does not address the obstruction of light (see Tables 2 and 4); however, if the analysis takes gestures ig_3 and ig_4 into account, it is evident that the child produced a meaning equivalent to that of the pretest. This had not been documented in the posttest speech analysis (see Table 2).

Furthermore, the body of child S6 enriches her reasoning creating functional interactive, though antithetical, relationships such as 'obstacle – absence of light (shadow)' and 'absence of obstacle – passing of light'. In this sense, she formulates two sentences based on the antithetical concepts of 'presence' and 'absence'. Taking into consideration both her speech and bodily expression, she is thinking as follows: A: [when I am standing in front of the sun then the light does not pass through and the shadow is formed], and B: [when I am not standing in front of the sun then the light passes]. These two conditionals are linked using the logical operation of disjunction (OR). All the above signify that the child managed to respond in terms of embodied reasoning, while also improving her multimodal syntax.

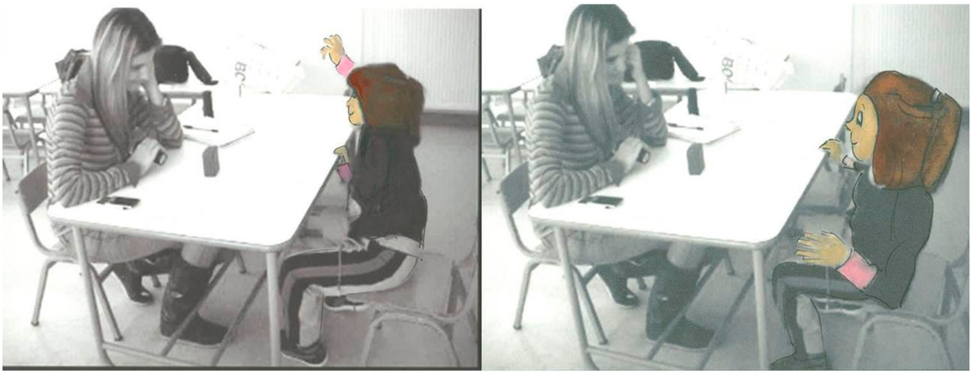

Figure 5. Child's body as an obstacle sways from right to the left in front of an imaginary 'sun'.

In a similar case, gesture ig_1, which the child S14 uses during the posttest is also a critical element. Gesture ig_1 is a hand movement along an imaginary straight line that depicts the rectilinear movement of light. In other words, in Figure 6, the child's hand moves in an imaginary straight line, beginning at a point above the flashlight, passing over the brick, and terminating at a point behind the brick. This gesture helps the child develop a more sophisticated reasoning compared to the reasoning she had formulated in the pretest; it also reveals that she uses her body to depict the rectilinear propagation of light in the posttest, something that is not stated through verbal discourse in the posttest.

In the pretest, the child depicted in Figure 7, answers a question concerning the light's direction, by indicating a point using a deictic gesture and stating that 'the light goes straight towards here'. Even though she uses the correct phrase 'straight towards' her right hand remains immobile and does not indicate any type of trajectory. In short, her right hand simply points to a spot and then makes no further movements.

On the contrary in the posttest, the child's use of the multimodal structure [ig_1 (this way … and it goes up to here)] demonstrates a more sophisticated thinking concerning the rectilinear propagation of light.

However, the meaningful value of gesture ig_1 (i.e. a hand movement along an imaginary straight line) appears in the posttest. Although the statement alone (i.e. 'this way … and it goes up to here') conveys the elements 'way' and 'goes up', it does not describe the direction of the light. This is made completely obvious by the child's iconic gesture (see Figure

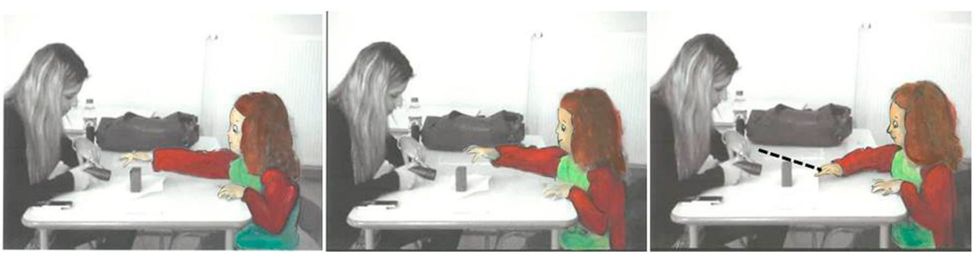

Figure 6. She illustrates the rectilinear propagation of light by moving her hand as the dashed line shows in the third snapshot.

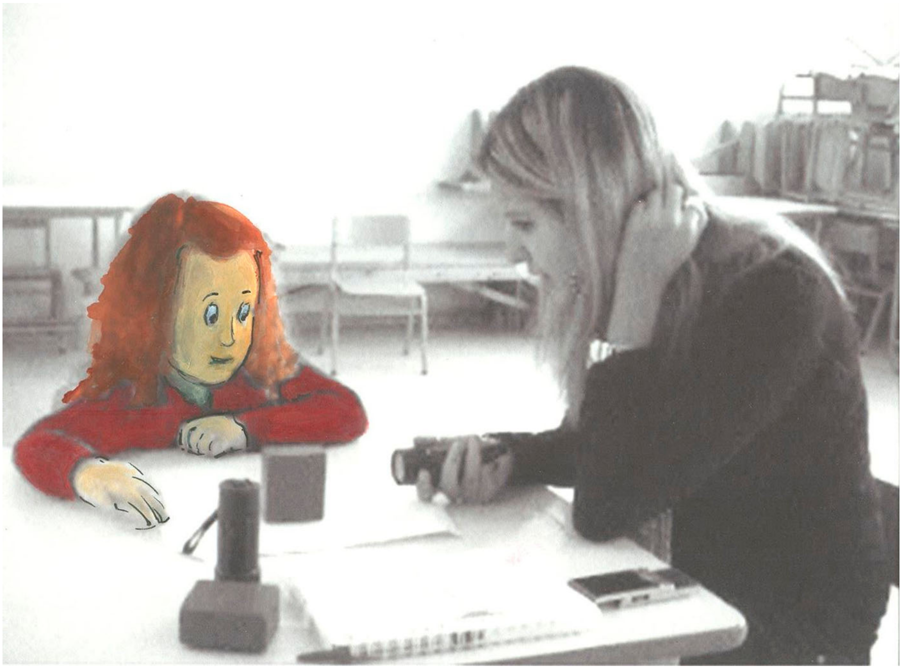

Figure 7. She indicates a point regarding the light's direction.

6). Indeed, the child depicted in Figure 6 uses her hand to demonstrate the light's rectilinear trajectory; this is correct insofar as it begins at the flashlight, but incorrect because it continues above and beyond the brick. Nevertheless, she depicts the rectilinear propagation of light, visualising the entity 'light beam'. Once again, it is worth noticing that this is not revealed by the speech-based analysis (posttest). This explains why, in the posttest, speech and body analysis generate different results; the first concludes that child S14 does not express the rectilinear trajectory of the light, while the body analysis concludes that it does.

b) Knowledge transfer through the children's bodies

During the pretest, children S2, S6, and S8 conceptualised the shadow formation area through deictic gestures and the vocalised elements 'here' or 'there'. In other words, they used one hand to point to a spot and made no other movement (see Figure 8).

In the posttest, they exhibited the syntactic structure dg_6/ig_3, which is only revealed through the body-based analysis. With this mode, they *point* towards the *area* where the shadow will form (dg_6), while *depicting* themselves as an *obstacle* (ig_3) at the same time (see Figure 9).

It must be noted that, in both the pretest and posttest, when the children initially responded to questions regarding the shadow formation area, regardless of whether their response was correct or incorrect, the teacher was putting the flashlight, which was switched off, towards them, and asking 'where will the shadow form now?' The idea was to give the children the chance to think and act using their bodies. Therefore,

Figure 8. During the pretest three children identify the formation area using a deictic gesture and the adverbs 'here' or 'there'.

two of these three children, i.e. children S2 and S8 responded thus during the posttest: (wrong answer) → (upon being assisted they produced dg_6/ig_3) → (correct answer). During the posttest, the researcher asked the children where the shadow would form, while aiming the flashlight at the brick. Children S2 and S8 initially gave the wrong answer; consequently, the researcher provided them with physical encouragement, turning the extinguished flashlight towards them and asking, 'Where will the shadow form now?' This way, the children activated the learning framework and looked behind themselves for the shadow (see Figure 9). Subsequently, the researcher asked the children once again where the brick's shadow would form and they correctly pointed behind it (see Figure 8). During the posttest, child S6 answered as follows: (wrong answer) → (after being helped it produced dg_6/ig_3) → (wrong answer), i.e. her bodily response was correct but, unlike children S2 and S8, she did not go on to give the correct verbal response in the framework with the brick. Thus, it appeared that children S2 and S8 'are solving the problem' set by the researcher within the framework they learned it, recognising and transferring visual correspondences between the arrangement flashlight-brick-shadow and flashlight-human body-shadow on the wall.

Overall, body-based analysis ascertained that these three children can signify the shadow formation area in a different learning situation. Indeed, analysis showed that, through the modality dg_6/ig_3 (i.e. dg_6: points behind itself and ig_3: depicts the obstacle), the children succeeded in attributing new properties to their bodies; those of the entity 'brick' (obstacle) by turning backwards and pointing to the wall. This indicates that the knowledge acquired through the embodied teaching intervention was transferred as an

Figure 9. Depicting himself as the obstacle, the child points toward the shadow formation area.

additional learning experience in the posttest. Speech analysis by itself, loses relevant information connected to the children's ability to include bodily reasoning in their responses. Actually, '*children think with (through) their bodies*' is the central point in the embodied cognition perspective, according to which human conceptualizations are formed through different kinds of experiences derived from specific bodily actions and interactions in the material world (Thelen, Schoner, Scheier, & Smith, 2001). In our case, when the children turn backwards searching for their 'shadows', it is not a new way to represent the same thing, but a new mode of reasoning which helps construct their future knowledge.

Discussion

In the present research, a body-based reanalysis was applied to five students, who had not exhibited any evolution in their reasoning in a previous speech-centered context. The results showed that bodily analysis and speech analysis produce different results. Specifically, gestures ig_2, ig_6, ig_3, ig_4, and ig_1 emerged, which convey elements of shadow formation that are not expressed through verbal discourse. The linear propagation of light, (i.e. ig_1: hand moving along an imaginary straight line), the ability to orient the flashlight-obstacle-shadow arrangement differently in a space (i.e. ig_2: depicting the flashlight, ig_6: depicting the movement of the flashlight) and the exploration of lit or unlit areas (i.e. ig_3: depicting themselves as obstacles, ig_4: placing their bodies in front of the source of light) constitute elements of the children's thinking that could be utilised during shadow formation activities.

By moving through space, learners can use their body to represent both the light and its trajectory. In that sense, students might come across an obstruction and thus investigate what happens to light when it encounters opaque objects. It is also useful for learners to investigate the different orientations in space of flashlight – obstacle – shadow arrangements. This might help some children whose mental images of spatial arrangements differ from the proposed instructional framework. In addition, it would be a good idea for the learners to investigate, using their entire body or their hand, whether or not light exists in the areas around the obstacle. This is the type of investigation child S6 carried out, replacing the flashlight (light source) with an 'imaginary' sun and the brick (obstacle) with her body (see Figure 5), stating where there was light and where there was no light. It is remarkable in this case, that this particular child constructs of her own accord a narrative space comprised of entities that are defined in relation to her own body: her own body stands before an imaginary sun. It would, therefore, make sense to give the children the chance to construct stories, to participate in narrating fairy-tales, and/or to describe incidents from everyday life, using their bodies to represent and explore aspects of the shadow formation phenomenon.

The basic element demonstrated by this particular research is the difference in the way speech and body analysis documented reasoning. It should be mentioned that the small sample and the nature of the shadow formation phenomenon constitute the main limitations of the current research. Our future plans include investigating how the reasoning of the remaining 11 children evolved through the bodily modalities they used. Regardless, this specific study confirmed that the body can be used to supplement verbal discourse, producing unique meanings (Hadzigeorgiou et al., 2009; Wagner-Cook & Goldin-Meadow, 2006). It also showed that children are able to use their bodies to construct narratives that serve as alternate aspects of the material environment. This plays a central role from an embodied learning perspective in which cognitive development lies in the human body's experiences embedded into actions from and actions on the mind, which gradually serve to construct various aspects of scientific conceptions (Kontra et al., 2012; Lindgren & Johnson-Glenberg, 2013). Therefore, tasks that give the subjects the opportunity to use their bodies in their explanations should be incorporated in research project design. In such a framework, the use of video is essential. Naturally, the development of more comprehensive coding and data analysis criteria is a prerequisite for collecting and analyzing the data (Chachlioutaki, Pantidos, & Kampeza, 2016).

The current research also demonstrated that to define the space where the shadow is formed, certain children used the modalities dg_6/ig_3 (i.e. dg_6: points behind itself and ig_3: depicts the obstacle) to transfer knowledge from the instructional framework to the posttest framework. A transfer of knowledge is the learner's ability to correctly apply to situation B, the knowledge acquired in situation A, which differs from situation B (Goldstone & Day, 2012). We should remember that the instructional intervention consisted of an activity that activated the children's bodies (see Figure 1). A great deal of attention has been devoted to the transfer of knowledge at all levels of education because it constitutes one of the main objectives of learning. For preschool-aged children especially, the metaphorical properties of the body are particularly valuable, if we take into consideration how difficult it is for them to express themselves verbally (Goldstone & Day, 2012; McNeil & Uttal, 2009).

Embodied teaching activities, apart from activating the children's bodies, also connect creativity and imaginative thinking with students' actions and assisting learning (e.g. Hadzigeorgiou, 2016; Konstantinidou, Gregoriadis, Grammatikopoulos, & Michalopoulou, 2014). The design of teaching and learning sequences could be more effective when embodied reasoning is activated. Within this framework, video recording data constitutes a basic tool even though such analysis is complicated. Otherwise, the analysis of teaching as well as learning will appear to be incomplete.

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